

Baseline of organotin pollution in fishes, clams, shrimps, squids and crabs collected from the west coast of India.

Sangeeta Jadhav^{1*}, Darshana Bhosale² and Narayan Bhosle¹.

¹*National Institute of Oceanography, CSIR, Dona Paula, Goa- 403004, India*

²*Birla College of Arts, Commerce and Science, Murbad road, Kalyan (W), Thane, Maharashtra, India*

Abstract

Organotins, especially tributyltins (TBT) are highly toxic to many marine organisms. These compounds are introduced in marine waters by ship trafficking, ship scrapping activities, as antifouling compounds and sewage disposal. Marine fishes, crustaceans and molluscans are easily prone to organotins contamination. In View of this, a baseline monitoring study was conducted in order to establish the levels of organotins in edible marine fishes (n= 35), bivalves (n= 9), shrimps (n= 3), squids (n= 2) and crabs (n= 3) collected from Mumbai, Goa and Karwar on the west coast of India. At these locations average organotin concentration found in fishes, clams, shrimps, squids and crabs was 108 ng Sn g⁻¹ dw, 852 ng Sn g⁻¹ dw, 179 ng Sn g⁻¹ dw, 70 ng Sn g⁻¹ dw and 89 ng Sn g⁻¹ dw respectively. In all the samples butyltins dominated over phenyltins. The levels of organotins suggest that all the organisms were contaminated with organotins and their consumption may pose health problems to humans especially the clams.

Keywords: Butyltins; Phenyltins; Fishes; Butyltin degradation index; Phenyltin degradation index; Tolerable daily intake.

*Corresponding author. Tel.: + 91 832 2450 537 Fax: + 91 832 2450 615

Email address: sangeeta.jadhav@gmail.com or sjadhav@nio.org (S Jadhav)

Industrial use of organotins such as butyltins and phenyltins has increased several folds during the last two decades. Butyltins (BTs) and phenyltins (PTs) are synthetic, multipurpose chemicals, which have been extensively used as stabilizers in the manufacture of poly vinyl chloride (PVC) (Blunden et al., 1984; Hoch 2000), biocide in agriculture (Champ and Seligman, 1996) and as fungicide in wood preservatives (Bennett, 1996). Organotins, especially the TBT and TPT-containing paints are very effective antifouling agents and provides protection from fouling to ship hulls for almost 3-5 years (Hoch 2000). However, TBT is highly toxic and can cause high larval mortality, shell deformation, retardation of cell growth, imposex, etc. in oysters, gastropods and other invertebrates due to its endocrine disrupting properties (Fent, 1996). Organotins get bioaccumulated in higher organisms such as fishes, clams, oysters, etc. TBT at 100 ng L⁻¹ or even at lower concentration can cause lethal effects on the immune system of fish and can suppress the normal functioning of the immune system of mammals (Kannan et al., 1995). Irritation of skin and respiratory tract, vomiting and headache on inhalation are some of the observed effects of organotins in humans. Organotins especially the butyltins, are known to affect viability of thymocytes (lymphocytes produced by thymus, an endocrine gland) and natural killer cells (lymphocytes) in blood which play an important role in human immunity against tumor and virally-infected cells in human bodies (Kannan et al., 1999 and Hoch 2000). TBT and DBT have also known to disturb the functions of mitochondria (Antizaar., 2008) At present, scarce information on organotin contamination in biota, collected from Indian waters is available. The present study was planned to assess organotin contamination levels in edible marine organisms collected from the fish markets of Goa, Karwar and Mumbai, the west coast of India.

The sampling locations: Goa (15.5°N, 73.9°E), Karwar (14.8°N, 74.1°E) and Mumbai (18.97°N, 72.82°E) are located along west coast of India (Fig 1). Samples were collected during May 2007. Goa has an approximately 105 km long coastline and it produces about 90,000 tonnes of marine catch every year. It is one of the important centers on the west coast of India where intense fishing activities are carried out. Karwar has seven islands in its proximity. Fishing is done in near shore and offshore waters and as well as in the waters of the islands. The annual fish catch of Karwar is around 36,000 tonnes. Mumbai coast is about 140 km long. Mumbai is among busiest harbours on the west coast of India is known for industrial pollution. The fishes, clams, crabs and squids and shrimps were collected from local fish markets of Goa, Karwar and Mumbai, stored in ice boxes and immediately transported to the laboratory. In the laboratory samples were stored at -20 °C until analysis.

Organotins were extracted from the animal samples by using Grignard's reagent (Morabito et al., 1994; Jadhav et al., 2008). Animal tissue was ground in teflon mortar and pestle. A known quantity of the animal tissue sample (1 – 2 g) was transferred to a clean test tube to which 15 ml of 0.03%

tropolone in methanol, with tripropyltin chloride (TPrT) as an internal standard, vortexed for 10 min. After the mixture settles, the supernatant was taken in a separating funnel and liquid-liquid partitioning was performed twice with 15 ml of dichloromethane. Dichloromethane extracts were pooled and dried over anhydrous sodium sulphate. Iso-octane, extract was then evaporated almost to dryness and reacted with 1M pentyl magnesium bromide (Grignard reagent). The derivatives were purified on an activated silica gel column. Organotins were eluted using hexane: toluene (1:1) mixture and concentrated to 1ml using gentle stream of nitrogen and 1 µl of sample was analysed by GC-MS (Shimadzu QP 2010) with electron impact ionization mode (70 ev). The method was validated by using 08TBT4 mussel reference material (ENEA, Italy) under proficiency testing programme. The average recovery (n= 5) for TBT, DBT, MBT, MPT, DPT and TPT were $93.08 \pm 5.82\%$, $86.59 \pm 5.47\%$, $88.73 \pm 7.30\%$, $89.17 \pm 8.09\%$, $86.54 \pm 5.70\%$, $88.15 \pm 4.73\%$ respectively. The minimum detection concentration for butyltins and phenyltins were $0.2 \text{ ng Sn g}^{-1} \text{ dw}$. The average precision of the method for the butyltins and phenyltins were 89.46 ± 6.19 and 87.95 ± 6.17 respectively.

The organotin concentration in marine fishes collected from Goa, Karwar and Mumbai are summarised in Table 1. Butyltins ranged from 41 to $154 \text{ ng Sn g}^{-1} \text{ dw}$ and phenyltins were undetected in all the fish samples collected from the Panaji (Goa) fish market. The fishes *Cynoglossus* sp., *Synaptura* sp. and *Terapon* sp. had relatively higher concentration of butyltins compared to other fishes. The relatively higher abundance of DBT and MBT indicates abiotic and/or biotic degradation of TBT in these animals. For the Goan fishes, the geometric mean for BT was $88.34 \text{ ng Sn g}^{-1} \text{ dw}$. In Karwar fishes, the organotins range from 36 to $256 \text{ ng Sn g}^{-1} \text{ dw}$. Except the *gymnosarda* sp. all the fishes in Karwar were found to have higher organotin content. The geometric mean for butyltins was $88.92 \text{ ng Sn g}^{-1} \text{ dw}$ and for triphenyltins it was $40.84 \text{ ng Sn g}^{-1} \text{ dw}$. In Mumbai fishes, organotins ranged from 10 to $152 \text{ ng Sn g}^{-1} \text{ dw}$. *Sardinella* sp., *Argyrosomus* sp. *Trichurus* sp. and *Cleidogona mandeli* collected from Mumbai were comparatively more contaminated as compared to other fish samples (Table 1). For the Mumbai fishes, geometric mean for BT is $44.35 \text{ ng Sn g}^{-1} \text{ dw}$, for PT is $5.13 \text{ ng Sn g}^{-1} \text{ dw}$. The PT's were below detection level in the fishes collected from Goa. Fishes collected from Karwar and Mumbai were contaminated with phenyltins. The presence of phenyltins in fishes collected from Karwar can be attributed to agricultural wastes and untreated effluents released directly into river by industrial units, sand mining (in Supa dam) and chemical treatment plants in Kali River.

Comparing our present data with our earlier fish data collected from Goa (Bhosle et al., 2004), the TBT and DBT levels were almost comparable. Kannan et al. (1995) reported comparatively higher butyltin levels for fishes found on the coast of Australia. Fishes from European waters are having lower degree of organotin contamination in their biota (Gurein et al., 2007). The Perch fish in Baltic reported to have

organotin concentration as high as 200 ng g⁻¹ in organotin contaminated areas (Rantakokko et al., 2010). Concentration of organotins in fishes can vary with the type of sample, the geographical location, the seasonal variation and spawning period (Lee et al., 2005; Garg and Bhosle 2005).

It was interesting to note that the fishes collected from Mumbai were less contaminated than Goa and Karwar. The mackerel, sardine, croacker, orange fin pony fish and ribbon fish were collected from all the three fish markets (fig 2 a, b, c, d and e). The butyltin levels were almost similar for these five fishes except sardine and croacker which were collected from Karwar and Mumbai ports showed relatively higher butyltin concentration.

Mackerel, sardine and croacker are known to be having higher oil content in their body. As TBT is lipophilic in nature, probably due to this reason TBT can easily bind or bioaccumulate in these organisms. Although in our study seasonal variation and spawning period were not taken into account, higher organotins levels were observed near harbour areas and areas near intense shipping activities. The animals from Karwar were mostly collected from enclosed port area with poor flushing system and from nearby fish jetty. Probably due to this, organotin levels in the fishes were higher. Moreover, the demersal fishes (bottom dwelling fishes) were found to be more prone to bioaccumulation of organotins than pelagic fishes as sediments have capacity to trap organotins.

The organotin content in three different edible clams: *Donax cuneatus* (wedge clam), *Meretrix meretrix* (asiatic clam) and *Meretrix casta* (inflated clam) found on west coast of India, were assessed for organotin content (Fig 3). The organotins varied from 1208 to 1676 ng Sn g⁻¹ dw for the Goan clams, geometric mean for BT was 777 ng Sn g⁻¹ dw and for PT was 279 ng Sn g⁻¹ dw. For the clams collected from Karwar, the organotins ranged from 608 to 1062 ng Sn/g dw, geometric mean for BT was 801 ng Sn/g dw and for PT was 49 ng Sn/g dw. Organotins in clams collected from Mumbai ranged from 185 to 482 ng Sn g⁻¹ dw. For the Mumbai bivalves, geometric mean for BT was 207 ng Sn g⁻¹ dw and for PT was 62 ng Sn g⁻¹ dw. The Goa and Karwar bivalves were more heavily contaminated with organotins as compared to those collected from Mumbai Fish market (Fig 3). From our data it was evident that levels of PTs were lower than the levels of BTs recorded for these organisms. PTs in Goan clams were higher compared to Mumbai and Karwar. In Goa edible clams are usually harvested from rivers and estuaries, and they carry lot of agricultural and industrial waste which is major source of PT's in aquatic environment.

In the aquatic environment, BTs and PTs have low aqueous solubility, low mobility and they are easily adsorbed onto suspended particulate matter (SPM). Their deposition leads to organotin scavenging in sediments. TBT persists within the sedimentary column for years (Hoch, 2001). Organotins are rapidly bioaccumulated in tissues of organisms living in the water-sediment interface

(Cima et al., 2003). Bivalves are sedentary and are fairly resistant to chemical contamination. As a result they can be found living in areas where more sensitive species can not survive (O'Connor, 2002). Being filter feeders, organotins may enter bivalves via intake of food and water. These compounds are released in to water during excretion and depuration (O'Connor, 2002). The major source that could have contributed to the accumulation of organotins in bivalve species is desorption from sediments (Takahashi et al., 1999 and Chandrinou et al., 2007). Clams have been reported as being a significant accumulator of TBT, because TBT levels in clams correlate well with TBT in sediments (Garg and Bhosle 2005 and Yang et al., 2005). Clams could be used as valuable bioindicators of TBT contamination (Harino et al., 2005). It is observed that clams are more sensitive to organotin pollution than mussels (Bhosle et al., 2004 and Yang et al., 2005).

Surprisingly, as observed for the fish samples, it was interesting to note that the clams, shrimps and squids collected from Mumbai were less contaminated than those found in Goa and Karwar. Though Mumbai is one of the busiest ports in India and also has heavy ship traffic, the major fish supply to the city comes from several less contaminated small ports such as Malvan, Ratangiri, Devgad, etc. Probably due to this reason, concentration of organotins in the marine organisms collected from Mumbai is less as compared to organisms collected from Goa and Karwar area (Table 1 & 2).

The concentrations of organotins in clams from the west coast of India are considerably higher than those values reported for bivalves from European waters (Baroso et al., 2004; Diez et al., 2005 and Chandrinou et al., 2007). However, our values are almost comparable to those reported from South Asian countries including Korea, Indonesia, Philippines and Taiwan (Tanabe et al., 2000; Hong et al., 2002; Shim et al., 1998 & 2005). Yang et al. (2006) reported about 993 ng Sn g⁻¹ of dw of butyltins in a clam *Mya arenaria* and about 100 ng Sn g⁻¹ of dw in clam *Meretrix meretrix* from Dalian, China. These are developing economies with greater market for organotins.

The concentration of organotins in solar shrimp and squids found on west coast of India was assessed (Fig 4. a & b). Shrimps (379 ng Sn g⁻¹ dw) and Squids (737 ng Sn g⁻¹ dw) collected from Karwar (enclosed port) were having higher organotin concentrations than compared to Goan shrimp (123 ng Sn g⁻¹ dw) and squid (106 ng Sn g⁻¹ dw).

The organotin content in three different edible crabs *Scylla serrata* (Giant mud crab), *Portunus sanguinolentus* (Three spot crab) and *Portunus pelagicus* (Blue swimming crab) collected from the Mumbai fish market was assessed (Fig 5). The PTs could not be detected in Crabs. The concentration of BTs in *Scylla serrata* (112 ng Sn g⁻¹ dw) and in *Portunus sanguinolentus* (111 ng Sn g⁻¹ dw) was found to be higher than that recorded in *Portunus pelagicus* (42 ng Sn g⁻¹ dw). The inter-specieal variation was observed in crabs, the difference in butyltin levels may be due to their burrowing habitat

and food habits. Furthermore, intraspecies and seasonal variability could be more important than the stress induced by the exposure to different levels of pollutants (Cardwell et al., 1999; Gurien et al., 2007)

Gurein et al. (2007) has reported the total organotin content in shrimps, squids and crabs from France as 2.1 ng Sn g⁻¹ ww, 13.3 ng Sn g⁻¹ ww and 8.7 ng Sn/g ww, respectively. These values are quite low compared to the concentrations recorded in this study. France has banned the use of TBT since 1980's. This could be the reason for the low organotin levels in shrimps and squids from France.

The Butyltin degradation index (BDI) is ratio of degradation products (DBT + MBT) to the parent compound (TBT). BDI is useful to understand the efficiency of degradation in the organisms (Diez et al 2002 & Diez & Bayona 2009). If the ratio is < 1, organisms tend to bioaccumulate the TBT. If it is > 1 then individual organisms has better capability to degrade TBT. The BDI for most of fishes was > 1, indicating their mechanism to effectively debutylate TBT to lesser toxic DBT and MBT for example Tilapia fish can degrade TBT to less toxic DBT and a small amount to MBT (Antizar 2008) Likewise phenyltin degradation index (PhDI) was calculated. PhDI for most of the fishes was less than 1, except for mackerel, sardine, orange fin pony fish and shark probably these organisms have better mechanisms to degrade T (Table 1). BDI for clams was usually < 1 except for wedge clam collected from Karwar and Mumbai and for inflated clam collected from Karwar. This indicates that clams bioaccumulates butyltins. PhDI for clams was also <1, indicating bioaccumulation of phenyltins in clams. Shrimps were having BDI >1, squids did not show any particular pattern in their degradation index. Even crabs had similar BDI like clams, shrimps and squids suggesting their ability to bioaccumulate organotins (Table 2).

Extensive monitoring studies are required to estimate human dietary exposure to organotin compounds. As seafood consumption is the prime dietary source for human exposure to BTs. The tolerable average residual level (TARL) is calculated from existing TBT data available in the country. TARL depends on average consumer and its variation in consumer weight. For average Indian seafood consumer, TARL is 1.441 µg. g⁻¹.60 kg person.d⁻¹ (Belfroid et al ., 2000).

Penninks (1993) based on several immune function studies, recommended Tolerable daily intake (TDI) of 15 µg. 60 kg person⁻¹ d⁻¹ for TBT. Assuming that on an average an Indian consumes 9 g of sea food per day which accounts to 0.09 - 0.26 µg. 60 kg person⁻¹ d⁻¹, 1.7 - 15.1 µg. 60 kg person⁻¹ d⁻¹, 0.37-6.6 µg. 60 kg person⁻¹ d⁻¹ for fish, clams, shrimps, squids and crabs, respectively (Table 3). Garg and Bhosle (2005) reported daily intake of 1.45 µg. 60 kg person⁻¹ d⁻¹ for oysters in India, which is comparable to our present data. Though, estimated daily intake of butyltins by Indian population has

not exceeded the limits by consuming fish, shrimps, squids and crabs. But intake of clams from highly contaminated areas (Goan clams) may exceed proposed limit (TDI and TARD).

In conclusion, the concentration of organotins in marine fishes, clams, solar shrimp, squid and crabs are of concern. It is evident that marine fishes were comparatively less contaminated than the bivalves or all other organisms used. The organotin contamination levels in bivalves are high and can cause physical and metabolic damage to these organisms. Marine organisms collected from Goa and Karwar showed relatively higher degree of contamination compared to those recorded for the organisms collected from Mumbai. The widespread occurrence of BTs and PTs in the edible organisms used for this study, imply that the usage of organotins needs to be regulated. Furthermore, a regular monitoring of organotins in edible organisms and other environmental samples needs to be monitored on a regular basis to avoid catastrophic effects to these organisms and to the human health.

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References:

- Antizar-Ladislao, B., 2008. Environmental levels, toxicity and human exposure to tributyltin (TBT)-contaminated marine environment. A review. *Environment international*,34: 298-304.
- Barroso, C.M., Mendo, S., Moreira, M.H., 2004. Organotin contamination in the mussel *Mytilus galloprovincialis* from Portuguese coastal waters. *Mar Pollut Bull.* 8,1145–67.
- Bennett, R.F., Industrial manufacture and application of tributyltin compounds., 1996. In: de Mora SJ (Ed), *Tributyltin a case study of an environmental contaminant*, Cambridge environmental chemistry series. Cambridge Univ. Press, Cambridge. 21-61
- Belfroid, A.C., Purperhar, M., Ariese, F., 2000. Organotin Levels in Seafood, *Marine Pollution Bulletin* 40;3,226-232.
- Bhosle, N., Garg, A., Jadhav, S., Harji, R., Sawant, S., Venket, K, Anil, A.C., 2004. Butyltins in water, biofilm and sediments of the west coast of India. *Chemosphere.* 57, 897-907.

- Blunden, S. J., Hobbs, L.A., Smith, P.J., 1984. The environmental chemistry of organotin compounds., 1984
In: Bowen, I.J.M. (Ed.), Environmental chemistry. The Royal Society of Chemistry, London. 49-77
- Cardwell, R.D., Keithly, J.C., Simmonds, J., 1999. Tributyltin in U.S. market bought fish seafood and assessment of human health risk. *Hum Ecol Risk Assess.* 5(2), 317-335
- Champ, M. A., Seligman, P. F., 1996. An introduction to organotin compounds and their use in antifouling coatings., In: Champ MA., Seligman PF. (Ed), Organotin environmental fate and effects. Chapman and Hall, London.1-25
- Chandrinou, S., Stasinakis, A.S, Thomaidis, N.S., Nikolaou, A., Wegener, J.W., 2007. Distribution of organotins compounds in the bivalves of the Aegean Sea, Greece. *Environment International* 33, 226-232
- Cima, F., Craig, P.J., Harrington, C., 2003. Organotin compounds in the environment.,In: Craig PJ, editor. Organometallic compounds in the environment. Chichester: John Willey & Sons.101–49.
- Diez, S., Albalos, M., Bayona, J., 2002. Organotin contamination in sediments from the Western Mediterranean enclosures following 10 years of TBT regulation. *Water Research.* 36, 905–918.
- Diez, S., Bayona, J., 2009. Butyltin occurrence and risk assessment in the sediments of the Iberian Peninsula. *Journal of environmental management.* 90: S25 –S30
- Fent, K., 1996. Ecotoxicology of organotin compounds. *Critical Reviews in Toxicology.* 26, 1-117.
- Garg, A., Bhosle, N.B., 2005. Butyltin compounds in the oyster, *Saccostrea cucullata*, from the west coast of India. *Environ. Contam. And Toxicol.* 75:982-988.
- Gurein, T., Sirot, V., Volatier, J., Leblanc, J., 2007. Organotin levels in seafood and its implications for health risk in high seafood consumers. *Science of total environment.* 388, 66-67
- Harino, H., O'Hara, Burt GR, Chesman, B.S., Langston WJ., 2005. *Marine Pollution Bulletin.* accumulation of butyltin compounds in benthic biota of the Mersey Estuary. 50, 222-225
- Hoch, M., 2001. Organotin compounds in the environment—an overview. *Applied geochemistry.* 16, 719– 43.
- Hong, H., Takahashi, S., Yoon Min, B., Tanabe S., 2002. Butyltin residues in blue mussels (*Mytilus edulis*) and arkshells (*Scapharca broughtonii*) collected from Korean coastal waters. *Environ Pollut.* 117, 475-486
- Kan-Atireklap, S., Yen, N., Tanabe, S., Subramanian, A.N., 1998 Butyltin compounds and organochlorine residues in green mussel (*Perna viridis* L.) from India. *Toxicol. Environ. Chem.*67, 409.
- Kannan K., Tanabe S., Iwata H., Tatsukawa R., 1995. Butyltins in muscle and liver of fish collected from certain asian and oceanic countries 90, 279-290
- Lee C., Wang T., Hsieh C., Tien CJ., 2005. Organotin contamination in fishes with different living pattern and its implications for human health risk in Taiwan. *Env. Pollut* 137, 198-208.
- Morabito, R., Chiavarini, S., Cremisini, C., 1995. GC–MS for the speciation of organotin compounds in environmental samples. In: Quevauviller, Ph., Maier, E.A., Griepink, B. (Eds.), Quality Assurance for Environmental analysis. Elsevier Science, Amsterdam. 435–464.

- O'Connor, T.P., 2002. National distribution of chemical concentrations in mussels and oysters in the USA. *Mar Environ Res.* 53, 117–43
- Rantakokko, P., Hallikainen, A., Airaksinen, R., Vuorinen, P., Lappalainen, A., Mannio, J., Vartiainen, T., 2010. Concentrations of organotin compounds in various fish species in the Finnish lake waters and Finnish coast of the Baltic Sea. *Science of The Total Environment*, 408;122474-248
- Shim, W.J., Oh, J.R., Kahng, S.H., Shim, J.H., Lee, S.H., 1998. Accumulation of tributyl- and triphenyltin compounds in Pacific oyster, *Crassostrea gigas*, from the Chinhae Bay System, Korea. *Arch Environ Contam Toxicol.* 35, 41–7.
- Shim, W.J., Yim, U.H., Kim, N.S., Hong, S.H., Oh, J.R., Jeon J.K., 2005. Accumulation of butyl- and phenyltin compounds in starfish and bivalves from the coastal environment of Korea. *Environ Pollut.* 133, 489–99.
- Sudaryanto, A., Takahashi, S., Iwata, H., Tanabe, S., Ismail, A., 2004. Contamination of butyltin compounds in Malaysian marine environments. *Env Pollut.* 130, 347-358.
- Takahashi, S., Mukai, H., Tanabe, S., Sakayama, K., Miyazaki, N., Masuno, H., 1999. Butyltins residue in livers of humans and wild terrestrial mammals and in plastic products. *Environ. Pollut.* 106, 213-218.
- Tanabe, S., Maricar, S., Prudente, Kan-Atireklap, S., Subramanian, A., 2000. Mussel watch: marine pollution monitoring of butyltins and organochlorines in coastal waters of Thailand, Philippines and India. *Ocean & Coastal Management.* 43, 819-839
- Yang, R., Zhou, Q., Jiang G., 2005. Butyltins in the marine clam *Mya arenaria*: An evaluation of its suitability for monitoring butyltin pollution. *Chemosphere.* 63, 1-8

Table 1

Organotin concentration in commercial marine fishes found on west coast of India

	Common name	Scientific name	ng Sn g ⁻¹ dw								BDI	PhDI
			TBT	DBT	MBT	BT	MPhT	DPhT	TPhT	PT		
Goa:	Mackerel	<i>Rastrelliger kanagurta</i>	10.12	27.82	10.18	48.12	Nd	Nd	Nd	Nd	3.75	*
	Sardine	<i>Sardinella longiceps</i>	46.34	14.15	8.24	68.73	Nd	Nd	Nd	Nd	0.48	*
	Croaker	<i>Argyrosomus amoensis</i>	8.45	12.82	27.65	40.47	Nd	Nd	Nd	Nd	4.79	*
	Orange fin pony fish	<i>Leiognathus bindus</i>	12.32	24.7	56.78	93.8	Nd	Nd	Nd	Nd	6.61	*
	Ribbon fish	<i>Trichiurus gangeticus</i>	35.52	41.56	27.32	104.4	Nd	Nd	Nd	Nd	1.94	*
	Toungue sole	<i>Cyanoglossus macrostomus</i>	34.12	74.82	46.45	155.39	Nd	Nd	Nd	Nd	3.55	*
	Mud sole	<i>Synaptura pectoralis</i>	3.25	47.23	83.14	133.62	Nd	Nd	Nd	Nd	40.11	*
	Corporo	<i>Terapon jarbua</i>	2.90	70.28	99.5	172.68	Nd	Nd	Nd	Nd	58.54	*
	Highfin pony fish	<i>Leiognathus leuciscus</i>	5.25	45.5	2.15	52.9	Nd	Nd	Nd	Nd	9.08	*
	Anchovy	<i>Engraulis eurystole</i>	18.15	50.65	26.8	95.6	Nd	Nd	Nd	Nd	4.27	*
Karwar:	Mackerel	<i>Rastrelliger kanagurta</i>	25.12	31.50	28.75	85.37	4.75	8.75	1.80	15.30	2.40	7.50
	Sardine	<i>Sardinella longiceps</i>	29.25	63.15	30.15	93.3	13.50	85.75	35.25	134.50	3.19	2.82
	Croaker	<i>Argyrosomus amoensis</i>	16.50	78.65	70.25	165.4	6.05	17.10	50.25	73.40	9.02	0.46
	Orange fin pony fish	<i>Leiognathus bindus</i>	27.50	22.15	76.45	126.1	14.68	43.25	37.50	57.93	3.59	1.54
	Ribbon fish	<i>Trichiurus gangeticus</i>	42.00	35.50	29.85	107.35	0.65	Nd	12.13	12.78	1.56	0.05
	Toungue sole	<i>Cyanoglossus macrostomus</i>	8.50	36.05	4.00	48.55	4.65	Nd	19.25	23.90	4.71	0.24
	Mud sole	<i>Synaptura pectoralis</i>	52.15	6.25	2.00	60.4	1.50	8.00	11.00	20.50	0.16	0.86
	Dogtooth tuna	<i>Gymnosarda nuda</i>	38.25	37.50	5.50	81.25	3.85	25.12	70.25	99.22	1.12	0.41
	Frigate tuna	<i>Auxis thazard thazard</i>	4.25	14.50	9.75	28.5	2.50	Nd	5.55	8.05	5.71	0.45
	Anchovy	<i>Engraulis eurystole</i>	15.75	65.12	54.50	135.37	18.35	20.32	52.75	91.42	7.59	0.73
Lesser sardine	<i>Sardinella sp.</i>	12.05	70.50	62.50	145.05	19.45	20.75	61.00	101.20	11.04	0.66	
Mumbai:	Mackerel	<i>Rastrelliger kanagurta</i>	29.56	19.75	13.85	63.16	Nd	Nd	Nd	Nd	1.14	*
	Sardine	<i>Sardinella longiceps</i>	45.12	35.50	41.56	122.18	5.80	8.15	12.08	26.03	1.71	1.15
	Croaker	<i>Argyrosomus amoensis</i>	39.5	65.58	40.62	145.7	Nd	0.78	6.35	7.13	2.69	0.12
	Orange fin pony fish	<i>Leiognathus bindus</i>	32.05	49.55	24.75	106.35	5.95	Nd	Nd	5.95	2.32	*
	Ribbon fish	<i>Trichiurus gangeticus</i>	52.2	30.05	62.15	144.4	3.86	Nd	34.50	38.36	1.77	0.11
	Black promfret	<i>Apolectic niger</i>	23.38	29.12	9.80	62.3	1.65	3.48	15.69	20.82	1.66	0.33
	Lizard fish	<i>Saurida tumbil</i>	0.98	13.15	Nd	14.13	3.25	Nd	Nd	3.25	13.42	*
	Bombay duck	<i>Harpodon nehereus</i>	1.8	18.25	13.15	33.2	0.75	Nd	6.18	6.93	17.44	0.12
	White promfret	<i>Pampus argenteus</i>	1.2	23.15	8.05	32.4	3.30	Nd	Nd	3.30	26.00	*
	Shark	<i>Carcharhinus albimarginatus</i>	2.15	7.95	5.68	15.78	1.05	0.76	0.95	2.76	6.34	1.91
	Dori	<i>Otolithoides biauritus</i>	16.85	29.12	22.20	68.17	Nd	0.79	7.25	8.04	3.05	0.11
	Lady fish	<i>Mugil sp.</i>	Nd	4.87	23.35	28.22	Nd	2.05	18.25	20.30	*	0.11
	Indian salmon	<i>Eleutheronema tetradactylum</i>	9.85	Nd	Nd	9.85	Nd	Nd	Nd	0.00	*	*
Mandeli	<i>Cleidogona mandeli</i>	30.23	46.12	28.05	104.4	2.95	Nd	12.25	15.20	2.45	0.24	

Nd: not detected; *: no ratio

Table 2

Organotins in clams, squids, shrimps and crabs collected from the west coast of India.

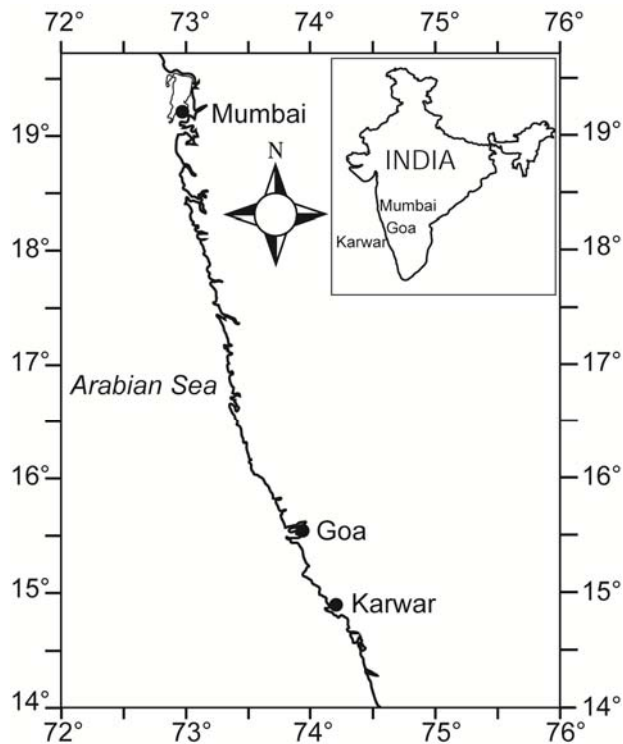
Site	Common name	Scientific name	ng Sn g ⁻¹ dw									BDI	PhDI
			TBT	DBT	MBT	BT	MPhT	DPHT	TPhT	PT			
Goa	Wedge clam	<i>Donax cuneatus</i>	520.46	161.34	90.29	772.09	12.24	95.97	202.18	310.39	0.48	0.53	
	Asiatic clam	<i>Meretrix meretrix</i>	679.23	180.56	122.45	982.24	56.13	52.25	128.87	237.25	0.44	0.84	
	Inflated clam	<i>Meretrix casta</i>	839.12	274.85	170.56	1284.5	32.34	75.15	190.20	297.69	0.53	0.56	
	Squid	<i>Loligo sp.</i>	25.25	47.34	27.65	100.24	Nd	Nd	Nd	Nd	2.96	Nd	
	Solar shrimp	<i>Penaeus indicus</i>	48.05	28.16	10.20	86.41	Nd	Nd	27.32	27.32	0.79	Nd	
Karwar	Wedge clam	<i>Donax cuneatus</i>	278.45	454.08	183.55	916.08	36.89	52.55	56.50	145.94	2.28	1.58	
	Asiatic hard clam	<i>Meretrix meretrix</i>	321.32	233.50	42.50	597.32	0.96	Nd	9.98	10.94	0.86	0.09	
	Inflated clam	<i>Meretrix casta</i>	336.26	439.14	164.35	939.75	10.52	18.21	47.54	76.27	1.79	0.60	
	Squids	<i>Loligo sp.</i>	518.04	58.12	36.57	612.73	6.56	19.52	98.23	124.31	0.18	0.26	
	Solar shrimp	<i>Penaeus indicus</i>	128.47	145.12	97.78	371.37	0.55	2.11	4.85	7.50	1.89	0.54	
Mumbai	Wedge clam	<i>Donax cuneatus</i>	114.45	95.84	88.12	298.41	79.75	25.24	79.47	79.47	1.61	1.30	
	Asiatic clam	<i>Meretrix meretrix</i>	126.13	14.23	30.62	170.98	19.00	Nd	2.10	2.10	0.36	Nd	
	Inflated clams	<i>Meretrix casta</i>	128.08	12.15	35.18	175.41	Nd	Nd	9.25	9.25	0.37	1.00	
	Solar shrimp	<i>Penaeus indicus</i>	1.62	14.28	4.85	20.75	0.14	2.5	23.93	23.93	11.84	0.10	
	Giant mud crab	<i>Scylla serrata</i>	79.10	8.26	25.30	112.66	Nd	Nd	Nd	Nd	0.42	Nd	
	Three Spot swimming crab	<i>N. suguinolentus</i>	85.23	10.03	16.12	111.38	Nd	Nd	Nd	Nd	0.31	Nd	
	Blue swimming crab	<i>N. pelagicus</i>	15.18	8.90	18.20	42.28	Nd	Nd	Nd	Nd	1.78	Nd	

Nd: not detected

Table 3

Estimated daily intake of organotins for humans by consumption of sea food in India

Animals	Min- Max organotins in organisms $\mu\text{g Sn g}^{-1} \text{ dw}$	Min-Max estimated daily intake by humans $9\text{g}^{-1} \mu\text{g Sn}^{-1} 60\text{kg}^{-1} \text{person}^{-1} \text{day}^{-1}$
Fish	0.01-0.256	0.09 - 2.3
clams	0.18 - 1.676	1.65 - 15.08
Shrimps	0.05 - 0.38	0.43 - 3.41
Squids	0.106 - 0.74	0.95 - 6.63
Crabs	0.04 - 0.112	0.38 - 1.01

**Fig 1.** Map of the west coast of the India showing sampling locations.

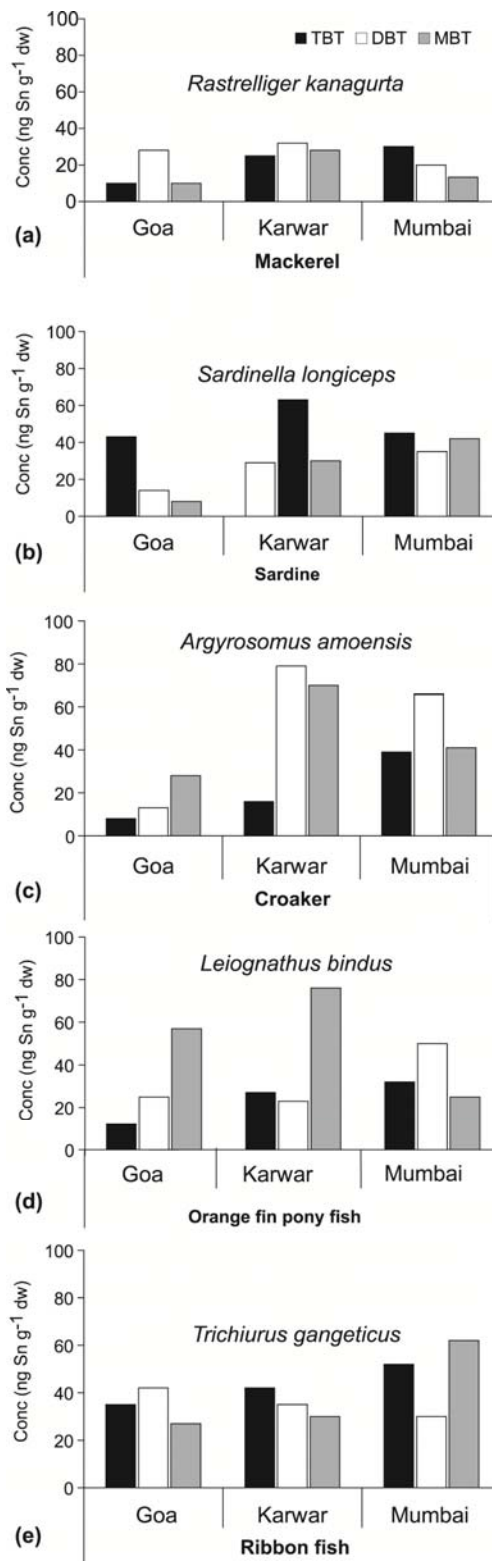


Fig. 2. Regional variation in butyltin concentration in five different fishes (a) Mackerel, (b) Sardines (c) Croaker, (d) Orange fin pony fish and (e) Ribbon fish found on west coast of India.

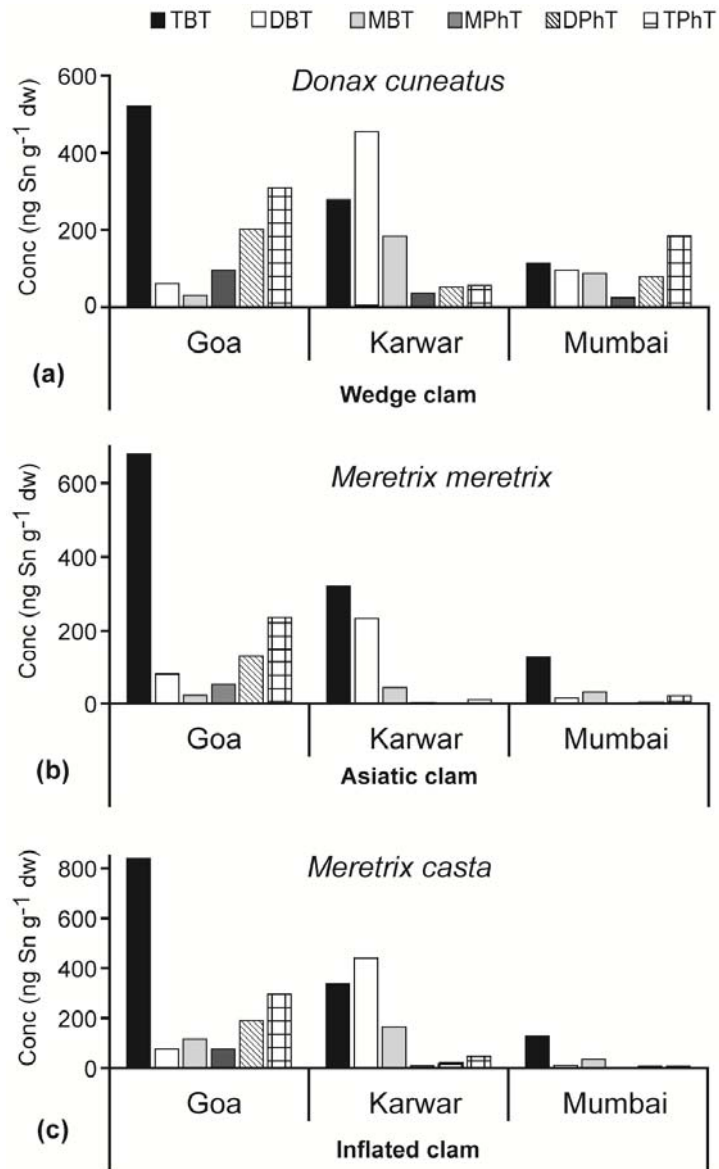


Fig 3. Regional variation in organotin concentrations in three clams: (a) Wedge clam (b) Asiatic clam and (c) Inflated clam found on west coast of India.

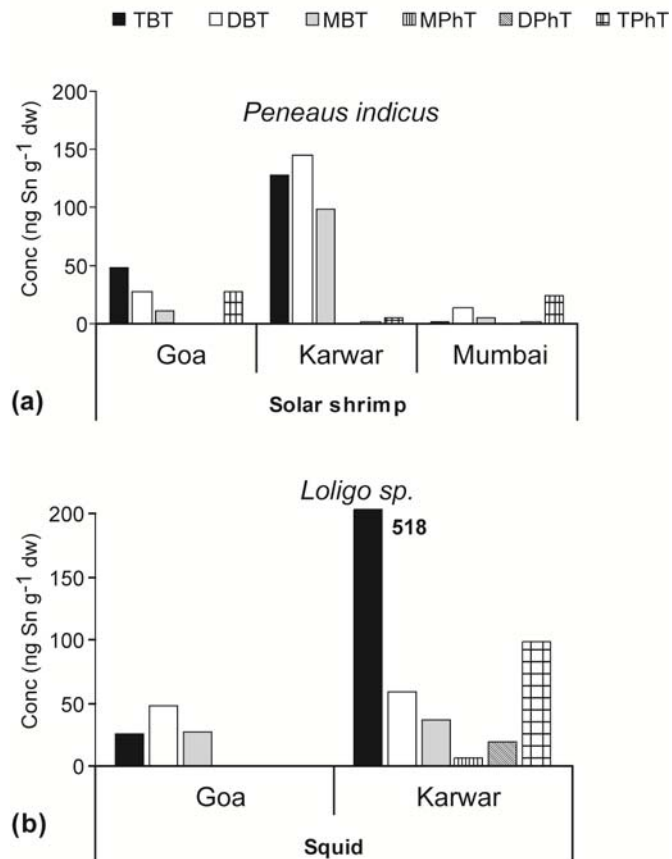


Fig 4. Regional variation in organotin content in (a) shrimps and (b) squids found on west coast of India

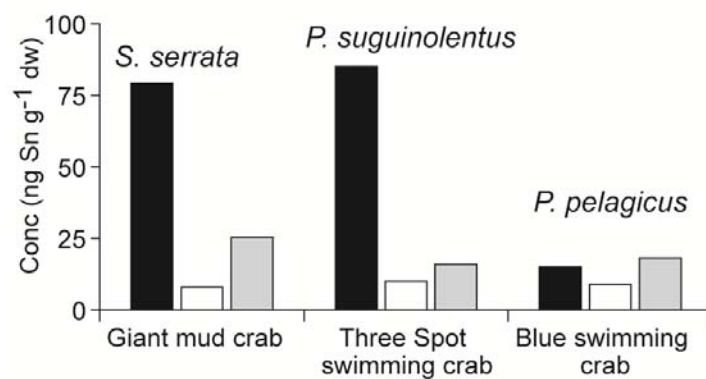


Fig. 5. Interspecific variation in butyltin content in three crabs found in Mumbai, west coast of India.