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Temporal variation and biomagnification of organohalogen compounds in finless porpoises (*Neophocaena phocaenoides*) from the South China Sea

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Levels and temporal variations of organohalogen contaminants in the South China Sea.

Abstract

Polybrominated diphenyl ethers (PBDEs) and organochlorine compounds (OCs) were determined in the blubber of male finless porpoises (*Neophocaena phocaenoides*) collected in 1990 and 2000/01 from the South China Sea. Among the organohalogen compounds analyzed, DDTs and PCBs were the predominant contaminants in the porpoises, ranging from 26,000 to 260,000 and 1400 to 28,000 ng/g lipid wt., respectively. PBDEs ranged from a minimum of 84 ng/g lipid wt., in 1990 to a maximum of 980 ng/g lipid wt., in 2001, showing a significant increase during the time period investigated. Congener profiles in finless porpoises did not shift to higher BDE congeners during these years, implying a continuous discharge of lower BDE commercial mixtures, such as PentaBDE. For OCs, HCHs concentrations decreased significantly, while others did not exhibit any significant temporal variation. Biomagnification factors (BMFs) were found to be highest for CHLs and lowest for HCB. PBDEs and PCBs had comparable BMFs, indicating a similar potential for biomagnification through the food web.

Keywords: South China Sea; Finless porpoise; Organochlorines; Polybrominated diphenyl ethers; Temporal variation

1. Introduction

Polybrominated diphenyl ethers (PBDEs) are man-made chemicals used as flame retardants in a variety of consumer products such as electronic equipment, building materials, automobiles and textiles (Haglund et al., 1997). High binding affinity to particles, and their lipophilic nature made PBDEs ubiquitous environmental contaminants in both aquatic and terrestrial environments (de Wit, 2002). Concerns have been mounting over the increasing concentrations of PBDEs in aquatic biota, because of the evidence that they may exert toxic effects similar to those of polychlorinated biphenyls (PCBs), dibenzo-*p*-dioxins and furans (Darnerud et al., 2001). Although levels of organochlorine compounds (OCs) in various environmental matrices show declining trends due to the ban on their use and production, several temporal trend studies indicate the continuous increase of PBDE levels in the North American environment (Norstrom et al., 2002), Canadian Arctic (Ikonomou et al., 2002), Japan (Akutsu et al., 2003; Choi et al., 2003) and Sweden (Norén and Meironyté, 2000). These studies indicate that PBDE concentrations in the environment increased substantially since the large scale PBDE production began in the early 1970s.

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The global market demand for PBDEs (sum of penta-, octa-, and deca-BDE) in 2001 showed that Asian countries consumed about 40% of the total (BSEF, 2004). Despite the large quantities of PBDEs used in Asia, information on the environmental levels of these compounds is lacking in this region. In recent years, China has witnessed rapid industrial development and population growth along its coastal areas. Our previous studies on cetaceans from Hong Kong demonstrated high PBDE levels, when compared to cetaceans from other areas of the Asian region (Ramu et al., 2005; Kajiwara et al., in press). Results of our studies recommend that it is critical to examine the temporal variation of these emerging new contaminants in this region.

It is well known that organochlorine pesticides were widely used in China between the 1950s and the 1980s. The amount of hexachlorocyclohexanes (HCHs) and dichlorodiphenyltrichloroethane (DDT) produced in China before they were banned in 1983 was 4.9 and 0.4 million tons, respectively, accounting for 33% and 20% of the total world production (Zhang et al., 2002). Even after the ban on their usage in 1983, DDT concentrations in marine mussels collected from China are high, suggesting continuing usage of DDTs in the coastal areas of China (Nakata et al., 2002; Monirith et al., 2003). The use of PCBs in China was banned in 1980s; however even today a large proportion of PCB containing old transformers and capacitors still remain in use, which results in continuous environmental input to many environmental compartments (Fu et al., 2003). These results suggest the existence of significant sources of OCs in China and thus studies are needed to clarify their status of contamination.

The primary objective of this study is to understand the changes in PBDE and OC concentrations during the latter 20th and early 21st centuries in finless porpoises (*Neophocaena phocaenoides*) collected from the South China Sea (SCS). The present study is the first attempt in this region to examine temporal variation of PBDE concentrations and congener patterns in the biotic environment. In this study, the stomach contents of some of the individuals were also analyzed to understand the biomagnification of these compounds.

2. Materials and methods

2.1. Samples

Seven adult male finless porpoises collected from Dongshan, SCS in 1990 by fishing nets and five adult male finless porpoises found stranded in several locations along the Hong Kong coast during 2000/01 were used in this study (Fig. 1). To understand the biomagnification of organohalogen compounds, stomach contents in semi-digested form in two finless porpoises from Hong Kong were also analyzed. Biological data of the animals analyzed are given in Table 1. Blubber samples were excised from the animals, and the stomach contents were wrapped in aluminum foil, and kept in a deep freezer at −20 °C until chemical analysis.

2.2. Chemical analysis

Analysis of PBDEs was performed following the procedure described by Ueno et al. (2004) with slight modification. Briefly, 2–3 g of the blubber sample or 15 g of stomach contents were ground with anhydrous sodium sulfate and extracted in a Soxhlet apparatus with a mixture of diethyl ether and hexane for 7–8 h. An aliquot of the extract, after adding 5 ng of internal standards ($^{13}C_{12}$-labeled BDE-3, BDE-15, BDE-28, BDE-47, BDE-99, BDE-153, BDE-154, BDE-183, and BDE-209), was added to a gel permeation chromatography (GPC; Bio-Beads S-X3, Bio-Rad Laboratories, CA, 2 cm i.d. and 50 cm length) column for lipid removal. The GPC fraction containing organohalogens was concentrated and passed through 1.5 g of activated silica gel (Wakogel S-1: Wako Pure Chemical Industries Ltd., Japan) column with 5% dichloromethane in hexane for clean up. $^{13}C_{12}$-labeled BDE-139 was added to the final solution prior to gas chromatograph equipped with a mass-selective detector (GC-MSD) analysis. Quantification was performed using a GC (Agilent 6890N) equipped with MSD (Agilent 5973N) for mono- to hepta-BDEs, and GC coupled with MS (JEOL GCmate II) for deca-BDE, using electron ionization with selective ion monitoring (EI-SIM) mode. GC columns used for quantification were DB-1 fused silica capillary (J&W Scientific Inc.) having 30 m × 0.25 mm i.d. × 0.25 μm film thickness for mono- to hepta-BDEs, and 15 m × 0.25 mm i.d. × 0.1 μm film thickness for deca-BDE. Ten major congeners of PBDEs (BDE-3, BDE-15, BDE-28, BDE-47, BDE-99, BDE-100, BDE-153, BDE-154, BDE-183 and BDE-209) were quantified in this study. All the congeners were quantified using the isotope dilution method to the corresponding $^{13}C_{12}$-labeled congener. Recovery of $^{13}C_{12}$-labeled BDE ranged between 60 and 120%.

OCs including PCBs, DDTs (DDT and its metabolites), HCHs, CHLs (chlordane related compounds), HCB (hexachlorobenzene), TCPMe [*tris*(4-chlorophenyl)methane] and TCPMOH [*tris*(4-chlorophenyl)methanol] were analyzed following the method described by Kajiwara et al. (2003). Another aliquot of the extract was subjected to GPC for lipid removal. The GPC fraction containing OCs was concentrated and passed through an activated Florisil column for clean-up and fractionation. Quantification of PCBs and most of the organochlorine pesticides was performed using a GC equipped with a micro-electron capture detector (micro-ECD) and an auto-injection system (Agilent 7683 Series Injector). The GC column used for OC analysis was a fused silica capillary (DB-1; 30 m × 0.25 mm i.d. × 0.25 μm film thickness, J&W Scientific Inc.). Identification and quantification of TCPMe and TCPMOH were performed using a GC-MSD (Agilent 5973N) in (EI-SIM) mode equipped with an autoinjection system (Agilent 7683 series injector). The concentration of individual OCs was quantified from the peak area of the sample to that of the corresponding external standard. The PCB standard used for quantification was a mixture of 62 PCB isomers and congeners (BP-MS) obtained from Wellington Laboratories Inc., Ontario, Canada. Concentrations of individually resolved peaks of PCB isomers and congeners were summed to obtain total PCB concentrations.

Procedural blanks were analyzed simultaneously with every batch of five samples to check for interferences or contamination from solvents and glassware. Lipid contents were determined by measuring the total nonvolatile solvent extractable material on subsamples taken from the original extracts. The concentrations of organohalogens are expressed on lipid weight basis unless otherwise specified.

For quality assurance and control, our laboratory participated in the Intercomparison Exercise for Persistent Organochlorine Contaminants in Marine Mammals Blubber, organized by the National Institute of Standards and Technology (Gaithersburg, MD) and the Marine Mammal Health and Stranding Response Program of the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (Silver Spring, MD). Standard reference material (SRM 1945) was analyzed for selected PCB congeners and persistent OCs. Data from our laboratory were in good agreement with those for reference materials. The average percentage deviation from the certified values was 13% (range: 0.5–20%) for organochlorine pesticides and 28% (range: 1.3–57%) for PCB congeners.

Statistical treatment of the obtained results was performed with the SPSS software (SPSS for Windows, SPSS Inc., 2001). Probability values less than 0.05 obtained using Mann–Whitney *U*-test were considered as statistically significant.

3. Results and discussion

3.1. Temporal variation of PBDEs

Concentrations of PBDEs detected in the adult male finless porpoises from the SCS are shown in Table 1. Of the ten

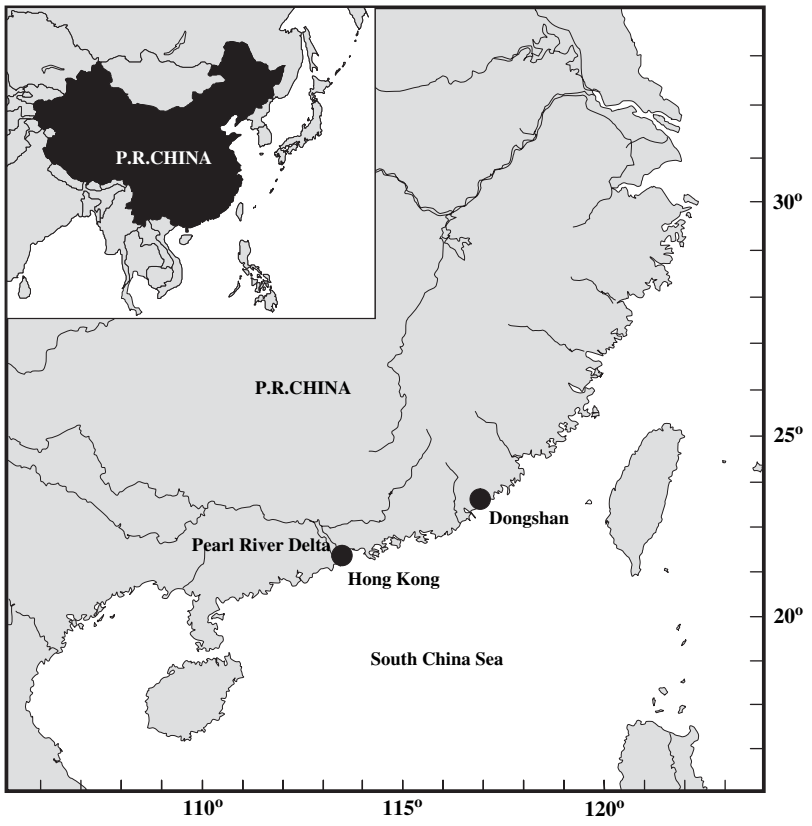

Fig. 1. Map showing the sampling locations of finless porpoises in the South China Sea.

congeners analyzed, a total of eight congeners from di- to hepta-BDE were detected in the blubber of finless porpoises. BDE-3 (mono-BDE) and BDE-209 (deca-BDE) were below the limits of detection for analysis, which were 0.01 and 0.5 ng/g lipid wt., respectively. PBDE concentrations in finless porpoises ranged from a minimum of 84 ng/g lipid wt., in 1990, to a maximum of 980 ng/g lipid wt., in 2001 (Table 1). In 1990, PBDE levels were higher than TCPMe and TCPMOH levels, but were lower than other organohalogen compounds analyzed. In 2000/01, DDTs ranked first, followed by PCBs > CHLs > PBDEs > HCHs > HCB > TCPMe > TCPMOH. Total PBDE concentrations in finless porpoises increased significantly (sixfold) from 1990 to 2000/01 ($p < 0.01$). The significant increase of PBDE levels in finless

Table 1
Concentrations of organohalogens (ng/g lipid wt.) in the blubber of male finless porpoises and their stomach contents collected from the South China Sea

ID	Year	BL (cm)	Lipid (%)	PBDEs	PCBs	DDTs	CHLs	HCHs	HCB	TCPMe	TCPMOH
Finless Porpoise											
Dongshan											
9053	1990	121	87	170	5700	68,000	770	1100	140	90	61
9063	1990	126	73	120	6500	140,000	1200	3500	170	52	86
9067	1990	153	92	86	5500	140,000	1000	5500	140	72	84
9074	1990	158	78	100	5800	130,000	950	6600	160	83	73
9076	1990	160	83	140	11,000	280,000	1400	6100	160	140	150
9079	1990	160	91	91	5000	130,000	1200	15,000	230	18	42
9061	1990	167	71	84	9200	220,000	1500	11,000	180	87	230
Hong Kong											
NP00-28/12	2000	>123	40	740	4700	63,000	340	270	210	76	66
NP00-26/12	2000	152	34	780	7200	51,000	400	170	110	55	63
NP01-20/03	2001	121	63	230	1400	26,000	140	34	87	24	34
NP01-24/05	2001	159	65	980	28,000	260,000	1400	860	160	150	58
NP01-12/04	2001	163	32	840	22,000	260,000	1900	310	250	82	66
Stomach contents											
from NP00-26/12	2000		7.7	320	3000	38,000	160	130	130	25	39
from NP01-12/04	2001		4.2	480	10,000	140,000	520	170	300	59	28

BL, body length.

porpoises suggests that PBDEs have been used more extensively in recent years.

Economic development, coupled with agricultural and industrial activities has resulted in increased production and usage of chemicals in China (Fung et al., 2004). The study area, located in the Pearl River Delta (PRD), has numerous electronic and telecommunication industries, which have transformed this delta into one of the fastest growing industrial manufacturing areas in the world (Zheng et al., 2004). As PBDEs are commonly incorporated into polymers used in electronic components, the significant increase of PBDEs in finless porpoises over the last decade may be due to the discharge of effluents derived from materials used in the production or dismantling of electronic equipments. In China, the domestic production of brominated flame retardants (BFRs) was 10,000 tons in the year 2000 and the demand for BFRs increases at a rate of 8% per year (Mai et al., 2005). The escalating demand for BFRs in China is also evident, in the increasing PBDE concentrations in upper layers of sediment core samples from the PRD, China (Mai et al., 2005). The increase in PBDE levels in the present study is in agreement with the increasing demand for PBDEs worldwide (de Wit, 2002). Exponential increases in PBDE concentrations in marine mammals have also been reported in ringed seals (*Phoca hispida*) from the Canadian Arctic, from 1981 to 2000 (Ikonomou et al., 2002) and beluga whales (*Delphinapterus leucas*) from the St. Lawrence estuary, Canada, from 1988 to 1999 (Lebeuf et al., 2004). Northern fur seals (*Callorhinus ursinus*) collected during the 1972–1998 time period from the Pacific coast of Japan showed increasing PBDE levels between 1972 and 1994. However, a declining trend was noticed later, as a result of the restrictions on the usage of PBDEs in Japan (Kajiwara et al., 2004).

To our knowledge, this is the first study documenting the temporal variation of PBDEs in marine mammals from a developing country. The rising PBDE levels in various environmental matrices have been well documented in many developed countries. It is anticipated that, with the growing Chinese economy and the PRD becoming the world's largest manufacturing base for electronics and electrical products, the situation may deteriorate further in this region with regard to PBDE contamination. Results obtained in the present study suggest that the increasing levels of PBDEs are of concern and more monitoring studies are warranted in developing countries.

3.2. Temporal variation of PBDE congener profiles

The percentage composition of each individual congener relative to total PBDEs in blubber of finless porpoises for the years 1990 and 2000/01 is shown in Fig. 2. BDE-47 was the most abundant congener in all the samples analyzed. The dominance of BDE-47 in PBDE congener profiles has been observed in terrestrial and marine animals, including humans and freshwater fish (Hites, 2004). The proportion of BDE-47 and -100 was smaller during 1990 than in 2000/01, and the opposite was true for BDE-153 and -154. PBDEs are

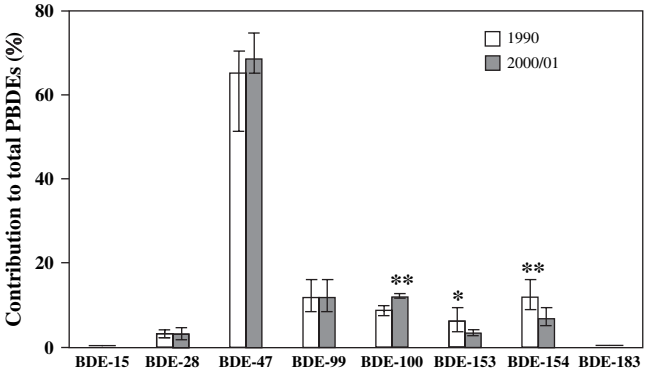

Fig. 2. Temporal trends of PBDE congener patterns in finless porpoises from the South China Sea. Vertical bars show the range and mean contribution of each congener to total PBDE concentration. Asterisks indicate significant differences between the two time periods (*$p < 0.05$; **$p < 0.01$, Mann–Whitney U-test).

commercially available as three products; the PentaBDE mixture contains primarily BDE-47 (37%), BDE-99 (35%) and BDE-100 (6.8%), with lesser amounts of other congeners (Sjödin et al., 1998), while the OctaBDE mixture contains several hexa- to nona-brominated congeners, and the DecaBDE mixture is almost entirely composed of BDE-209 (Alaee et al., 2003). To understand the change in PBDE congener patterns over the time period, the ratio defined by Zhu and Hites (2004) was used with the inclusion of BDE-183 in the equation:

$$R = \frac{[47] + [99] + [100]}{[153] + [154] + [183]}$$

where $[x]$ refers to the concentration of congener x in any unit. The numerator and denominator indicate major components of PentaBDE and OctaBDE, respectively. The calculated R values in finless porpoise in 1990 varied from 2.9 to 7, while in 2000/01 the values ranged from 6.6 to 11. There was a statistically significant difference in R values ($p < 0.01$) between these two periods, which may suggest the continuous or increasing usage of PentaBDE mixture in this region, when compared to OctaBDE mixture. Sediment analysis from the PRD and adjacent SCS also revealed that PentaBDE is one of the major commercial mixtures used in the PRD region in addition to DecaBDE mixture (Mai et al., 2005). Exponential increase of the lower brominated congener groups (PentaBDE) was also reported in ringed seals from the Canadian Arctic (Ikonomou et al., 2002). However, the congener pattern observed for northern fur seals from the Pacific coast of Japan was in contrast to the present study; in northern fur seals there was a shift towards the higher brominated congeners (Kajiwara et al., 2004).

Differences in production and use of commercial PBDE formulations may account for the differences in congener profiles from various locations. Since majority of the BDE congeners found in both humans and wildlife arise from PentaBDE commercial mixtures, globally there has been a shift towards the use of higher brominated congeners. Japanese industries

phased out the use of TetraBDE products in 1990, the isomeric composition of which was found to be almost similar to the commercial PentaBDE mixture produced in Europe and USA (Watanabe and Sakai, 2003). Out of the total global market demand of 67,400 tons of PBDEs in 2001, PentaBDE mixture accounted for 7500 tons, out of which about 150 tons was used in Asia (BSEF, 2004). The precise place of use of the PentaBDE mixture in Asia is not clear, but the intensity of manufacturing operations in China suggests that it could be one of the major consumers of PentaBDE mixture in Asia. The primary usage of PentaBDE mixture is as an additive flame retardant in polyurethane foams (PUF) used in furnishings and textiles (Alaee et al., 2003). It has been envisaged that the possible sources of these PentaBDE contaminants to the environment are the discarded PentaBDE impregnated materials, such as PUF as well as direct vapor emission and wastewater from related industries (Hale et al., 2002). The daily discharge of enormous quantities of untreated sewage into the coastal waters of Hong Kong, and the large scale dismantling and processing of used electric products (computers, televisions and other electric household equipment) that come from developed nations, along the coastal areas of China (Hileman, 2002) may be the reasons for the increase in PentaBDE congeners over the time period in SCS. Air samples from the city of Guangzhou in Southern China, which has numerous industries as well as electronic waste processing units, had PBDE pattern similar to the technical PentaBDE mixture (Bromkal 70-5DE) (Mai et al., 2005); this may further explain the increase in PentaBDE congeners in SCS. Although DecaBDE is one of the most produced BFRs in China (Mai et al., 2005), it was not detected in any of the samples analyzed in this study; this may due to its low bioaccumulation potential. The photolytic debromination or the enzymatic debromination of DecaBDE to lower brominated congeners, as reported in fish, could also explain that BDE-209 was not detected in our samples (Söderström et al., 2004; Stapleton et al., 2004a).

3.3. Temporal variation of OCs

OC contaminants were detected in all the samples of finless porpoises collected from SCS (Table 1). DDTs, followed by PCBs, were the predominant contaminants during both time periods. With the exception of HCHs, concentrations of other OCs did not change significantly during the last decade. Concentrations of HCHs in finless porpoises collected in 2000/01 were significantly less, when compared to the porpoises in 1990 ($p < 0.001$). Differences in isomer composition of HCHs could also be seen over the same period (Fig. 3). β-HCH, the persistent isomer was predominant during both time periods. For finless porpoises collected in 1990, α-HCH was detected in all the samples, while porpoises in 2000/01 had α-HCH below detection limits, which may suggest that the usage of technical HCH has declined in China. Earlier studies reported China as one of the largest producers/consumers of technical HCHs in the world. The total amount of HCH production in China during 1952 to 1983 was estimated

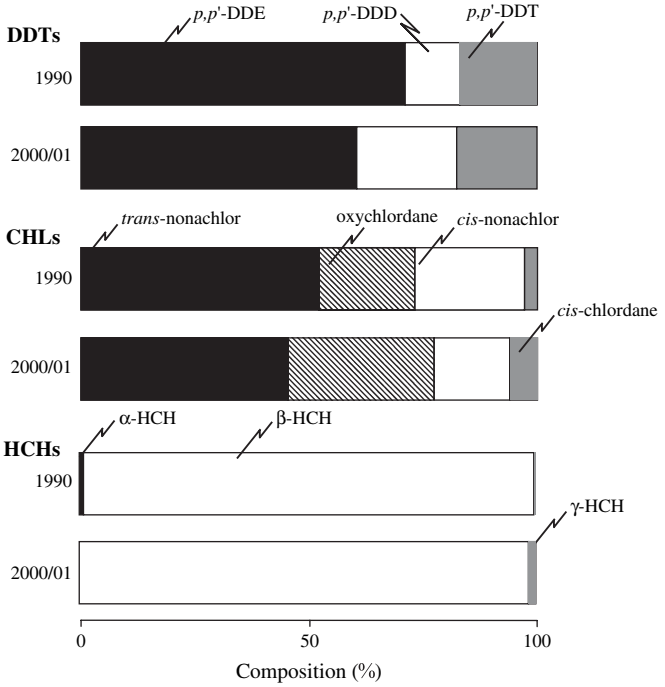

Fig. 3. Temporal change in the percentage compositions of DDT and its metabolites, CHL compounds and HCH isomers in finless porpoises from the South China Sea.

to be 4.46 million tons (Li et al., 1998). Technical HCHs were replaced in China by the purified active isomer γ-HCH in 1991, also known as lindane (Li et al., 2001). Thus, the observed isomer profile for HCHs in finless porpoises may be due to change in usage of HCH mixtures. Residue levels of HCHs in Chinese foodstuff during 2000/01 also decreased drastically since the 1980s, after the ban on the usage of HCHs in 1983 (Nakata et al., 2002). Thus, the lowered levels of HCHs in finless porpoises in 2000/01 may be due to the ban on use of HCH in agriculture in China.

China had been a major producer and user of DDT since the 1950s. The use of DDT in agriculture in China was legally banned in 1983 (Chen et al., 2002). In spite of the ban on usage, DDTs were the predominant organohalogen contaminants in finless porpoises, and no declining trend was seen for DDT compounds in the present study (Table 1). DDTs levels as high as 260,000 ng/g lipid wt., were found in some of the individuals collected in 2000/01. It is interesting to note that finless porpoises, inhabiting more open waters as compared with Indo-Pacific humpback dolphins (*Sousa chinensis*), also have high DDT levels. This may indicate the widespread DDT contamination in Chinese waters (i.e. not restricted to estuaries). The elevated concentrations of DDTs and high proportions of the parent compound *p,p′*-DDT in finless porpoises collected in 2000/01 suggest a continuous input of this compound in this region (Fig. 3). Zheng et al. (2000) also reported that there is little sign of any declining trend in concentrations of DDT following its ban in China in 1983. Considering these observations and the results of this study, it is probable that DDT is still in use around the coastal waters of China.

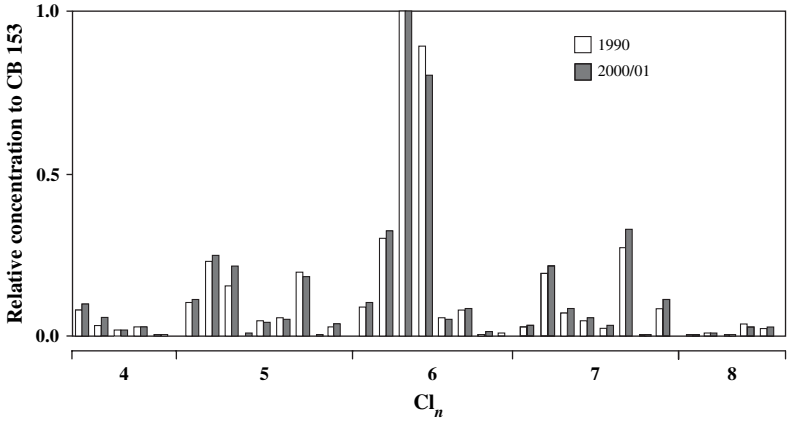

Fig. 4. Temporal variation of PCB congener profiles in finless porpoises collected in 1990 and 2000/01 from the South China Sea. Vertical bars represent concentrations of PCB congeners relative to the most abundant congener, CB-153, which was treated as 1.0.

Next to DDTs, PCBs were the major contaminants in the samples analyzed. The use of PCBs was banned in China in the 1980s, but no declining trend in PCB levels in finless porpoises was seen during the last decade (Table 1). Slower decline of PCB concentrations in marine mammals have also been reported in striped dolphins (*Stenella coeruleoalba*) from the western north Pacific (Loganathan et al., 1990), northern fur seals from north Pacific coast of Japan (Tanabe et al., 1994) and minke whales (*Balaenoptera acutorostrata*) from the Antarctic (Aono et al., 1997). During both the time periods, CB-153 and -138 dominated the PCB profiles and no significant differences in the pattern of the profiles could be seen during the last decade (Fig. 4). The steady state of PCB contamination in the aquatic environment has also been reported in a number of previous investigations dealing with temporal trends of OC contamination using higher trophic mammals as bioindicators (e.g. Tanabe et al., 2003). In China, a large proportion of PCB containing old transformers and capacitors still remain in use (Fu et al., 2003); and the continuous discharge of PCBs from these equipments may be one of the contributing factors for the steady state of PCBs observed in this study. In a spatial and temporal assessment of PCB pollution in China, Xing et al. (2005) observed that concentrations of PCBs in many areas of China increased during the 1980s and 1990s and concluded that China will continue to experience increases in PCB levels. The low rate of decrease in the levels of PCBs in the marine environment suggests a possible prolonged exposure of these compounds to the marine biota in the coming years especially top predators like finless porpoises.

3.4. Biomagnification of organohalogen compounds

Organohalogen compounds in the semi-digested stomach contents of two finless porpoises were analyzed to calculate biomagnification factors (BMFs), which were defined as the ratio of the chemicals concentration in the blubber of porpoise to those in its stomach contents on a lipid weight basis (Table 1). BMFs for all the organohalogen compounds were generally greater than one, implying that organohalogen compounds magnify in the aquatic food chain (Table 2). The bioaccumulation of these compounds depends on the uptake and elimination ability of the organism, as well as the physicochemical properties of the chemicals (octanol–water partition coefficient, effective cross section, molecular weight, etc.). In general, CHLs had somewhat higher BMF than other compounds and HCB had the least BMF. The octanol-water partition coefficient (log K_{ow}) values for tetra- to hexa-PCB and PBDE congeners ranged from 5.84 to 6.92, and 5.87 to 7.92, respectively (Burreau et al., 1997). The comparable BMFs observed for PCBs and PBDEs in the present study could be attributed to the similar log K_{ow} values, which further suggest that they have analogous potential to bioaccumulate in biological systems. For all PBDE congeners, BMFs were comparable and no relationship could be seen between BMF and

Table 2
Biomagnification factors for organohalogens compounds in finless porpoises from Hong Kong

Compounds	NP00-26/12	NP01-12/04
PBDEs	**2.4**	**1.8**
BDE-15	2.4	1.6
BDE-28	2.4	1.6
BDE-47	1.5	1.8
BDE-99	2.4	1.8
BDE-100	2.4	1.7
BDE-153	2.2	1.6
BDE-154	2.2	1.4
BDE-183	2.2	0.80
PCBs	**2.4**	**2.2**
DDTs	**1.3**	**1.9**
p,p′-DDE	1.4	2.2
p,p′-DDD	0.93	0.96
p,p′-DDT	71	170
CHLs	**2.5**	**3.7**
Oxychlordane	9.5	8.8
trans-Nonachlor	0.68	2.5
cis-Nonachlor	2.8	4.7
cis-Chlordane	1.1	1.5
HCHs	**1.3**	**1.8**
HCB	**0.85**	**0.83**

degree of bromination in the present study. There are a few studies on BMFs of PBDE congeners in the natural environment. By feeding carp (*Cyprinus carpio*) a diet spiked with a cocktail of PBDE congeners under laboratory conditions, Stapleton et al. (2004b) found BMFs of 0.028 and 1.36 for BDE-153 and -47, respectively. Bioaccumulation of organohalogen compounds also depends on the metabolic capacity of the organisms, thus there is a possibility of BMFs being underestimated due to biotransformation or overestimated due to bioformation kinetics (Tomy et al., 2004). Finless porpoises inhabiting Hong Kong waters have a diverse diet that includes several species of fish, squid and shrimp (Barros et al., 2002); this may partly explain the differences in BMFs for the organohalogen compounds among the two finless porpoises analyzed. Another factor is that stomach contents do not always fully represent the diet and they might just happen to be present at the time of sampling. More work needs to be done to assess the efficiency by which these compounds are biotransformed and whether the resulting metabolites present a greater hazard than their parent compounds.

4. Conclusions

This is the first study on the temporal variation of organohalogen contaminants in finless porpoises from SCS. Lack of regulation on the use of PBDEs and the dumping of *e*-waste from the developed nations along the South China coast for recycling suggest that the situation may continue to deteriorate in this region. Continuous monitoring studies on organohalogen contaminants in finless porpoises and other marine mammals from SCS are recommended to ascertain the trends observed in this study and also to determine the toxic effects on cetaceans. The present study underlines the utility of long-term archival specimen banks in scooping out historical loading of environmental contaminants and in forecasting their future trends.

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