Pattern of organochlorine accumulation in the Antarctic minke whale based on JARPAII data

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ABSTRACT

Concentrations of persistent organochlorins were determined in the blubber of 5 mature male (21-25 years old) Antarctic minke whales from Antarctic Area V sampled by JARPAII in 2010/11. For comparison, blubber from 40 whales sampled by JARPA surveys in the period from 1988/1989 to 2004/2005, were used. In 2010/11 mean concentrations of HCB (140 ng/g fat wt.) were the highest followed by DDTs (100 ng/g fat wt.), PCBs (28 ng/g fat wt.), CHLs (25 ng/g fat wt.), and HCHs (0.8 ng/g fat wt.). Levels of DDTs, HCHs, HCB and CHLs in Area V decreased significantly with year, while the yearly trend of PCBs did not change significantly. HCHs levels in minke whales in 2010/2011 were similar to those in the JARPA period from 1996/1997 to 2004/2005 however they were lower than those in the JARPA period from 1988/89 to 1996/1997. These results suggested that levels of HCHs in the Antarctic Ocean have varied from slightly decreasing to a steady state in the middle 1990's.

KEYWORDS: ANTARCTIC MINKE WHALE; ORGANOCHLORINES; MONITORING; TREND

INTRODUCTION

In the 1995/96 research plan of Japan's Whale Research Program under Special Permit in the Antarctic (JARPA) the following objective was added, 'Elucidation of the effect of environmental change on cetaceans' (Government of Japan, 1995). This object was added in response to resolutions adopted by the Commission on research on the environmental and whale stocks and on the promotion of research on the conservation of large whales (IWC, 1995). Given this, the Scientific Committee held two specialized Workshops, one relating to chemical pollutants and cetaceans, and the other on the potential ecological effects on cetaceans of climate change and ozone depletion (IWC, 1999). Monitoring of pollutants in baleen whales and the ecosystem was then added as a part of first objective of JARPAII (Pastene *et al.*, 2014).

Organochlorines (OCs), such as polychlorinated biphenyls (PCBs), dichlorodiphenyl trichloroethanes and metabolites (DDTs), hexachlorocyclohexane isomers (HCHs), hexachlorobenzene (HCB) and chlordane compounds (CHLs), are man-made chemicals that are persistent in the environment. Particularly PCBs, DDTs and its metabolites concentrate in animal bodies through food webs. Whales are in a high position in the food web of the ocean thus they may be suitable as monitors of pollutant levels and their adverse effects (Tanabe *et al.*, 1986; O'Shea and Brownell, 1994). For this reason, we have been continuing to monitor OCs levels in blubber of Antarctic minke whale (*Balaenoptera bonaerensis*) since the beginning of the JARPA research.

Aono *et al.* (1996) reported that PCBs residue levels in Antarctic minke whales increased between the 1984/85 and 1992/93 seasons, implying continuous discharge of PCBs in the southern hemisphere. Furthermore, Yasunaga *et al.*, (2006) reported in the final JARPA review in 2006 that PCBs, DDTs, HCB and CHLs levels in minke whales in a period from 1988/89 to 2004/2005 extremely slowly decreased or maintained a steady state, while those of HCHs were drastically decrease in the period.

The objective of the pollution study in the JARPAII is to continuously monitor levels and behavior of OCs in minke whales. However, most of samples for this study since 2005/2006 were lost after the 2011 earthquake and tsunami (see IWC, 2012). Therefore, the limited number of samples that were not affected by the disaster in 2010/2011 were compared with the previous JARPA data during a period from

1988/1989 and 2004/2005, so that recent trend of OCs levels in minke whales could be examined.

MATERIALS AND METHODS

Materials

In this study, concentrations of PCBs, DDTs, HCHs, HCB and CHLs in the blubber samples of 5 minke whales (mature males: 21-25 years) taken from the Antarctic Area V in 2010/2011 were determined. The average body length was 8.58 m (range: 8.31 -8.78 m). In the field, blubber samples were collected, and stored at –20°C until analysis.

Laboratory analysis

OCs were determined by a GC-ECD (Hewlett Packard 5890 Series) and by GC-MS (JEOL Ltd., JMS-700; JMS-SX102A). Chemical analysis of the OCs was carried out using the standard method described by the Environmental Agency of Japan, with some modifications (Japan Environmental Agency, 1998). Concentrations of OCs were expressed on a fat weight basis. Accuracy and precision of the methods were confirmed using 'Organics in cod liver oil' (NIST 1588a). Chemical analyses were performed by the Miura Institute of Environmental Science.

Statistical analysis

Temporal trends of OCs levels in blubber of minke whales were assessed by simple linear regression analysis (Zar, 1999). In the regression analysis, OCs levels in minke whales were logarithmically converted, because distribution of persistent OCs levels in biota is skewed to a higher order. A p value of less than 0.05 was used as the criterion for statistical significance. These statistical analyses were executed by PASW Statics 17.0 for Windows (SPSS Co. Ltd.).

RESULTS

Table 1 shows the concentrations of OCs in blubber in minke whales from Area V in 2010/2011. The ranges of concentrations for each compound were, in ng/g fat wt.: PCBs, 21-43; DDTs, 81-160; HCHs, <0.2-0.8; HCB, 110-190; CHLs, 19-40. The patterns were in the order of HCB> DDTs> PCBs> CHLs > HCHs.

For comparing those in this study, organoclorines levels in minke whales in the JARPA period from 1988/1989 to 2004/2005 are shown in Table 1. Fig. 2 shows plots of OCs levels in blubber of minke whales from Area V from 1988/89 to 2010/11. Table 2 shows a simple linear correlation coefficients and probability between year and log OCs concentrations in blubber from Area V ($p<0.05$). Levels of DDTs, HCHs, HCB and CHLs in Area V significantly decreased with year, while PCBs did not show a significant yearly trend. Fig. 3 shows OCs standardized with respect to PCBs, which are stable in the environment as well as animal body. In addition, PCBs have declined extremely slowly in the open ocean and the Antarctic (Tanabe *et al.*, 2003) and the influence of changes in the body fat is nullified by standardization with PCBs. HCHs/PCBs ratio decreased by a factor of about ten in a span of 22 years in Area V, while temporal trends of DDTs/PCBs, HCB/PCBs and CHLs/PCB were stable.

DISCUSSION

The OCs levels of minke whales in this study are first compared to those of the common minke whales taken from the northern hemisphere in the 1990's. Mean PCBs level of Antarctic minke whales (28 ng/g) was two orders of magnitude lower than those of common minke whales in the western North Pacific (Aono *et al.*, 1997: 3,168 ng/g). Mean DDTs, HCHs and CHLs levels of Antarctic minke whales (100 ng/g, 0.8 ng/g, 25 ng/g, respectively) were one order of magnitude lower than those of common minke whales in the western North Pacific (Aono *et al.*, 1997: 2,297 ng/g, 446 ng/g, 595 ng/g, respectively). On the other hand, mean HCB level of Antarctic minke whales (140 ng/g) was comparable to those of common minke whales in the western North Pacific (Aono *et al.*, 1997: 189 ng/g). Therefore the present study confirms that the accumulation of PCB and most organochlorine pesticides in Antarctic minke whales from the Antarctic Ocean are lower than those in common minke whales from the western North Pacific.

All simple linear analyses (Table 2) for temporal trend of OCs in the Antarctic minke whales during the period from 1988/1989 to 2010/11 show OCs, except for PCBs, slightly decreased in the period. Yasunaga *et al.* (2006) reported PCB levels in minke whales during the period from 1988/1989 to 2004/05 significantly decreased. Aono *et al.* (1997) reported that DDTs, CHLs, HCHs and HCB levels in blubber of the Antarctic minke whales taken from area V were comparable or slightly decreasing during

the period from 1984/85 to 1992/93, while those of PCBs were likely to increase during a period of 1984/85 and 1990/92 and showed slightly decrease in the 1992/93 samples. Tanabe *et al.* (1999) analyzed those samples up to the 1994/95 season, and reported that DDTs, CHLs, HCHs and HCB levels in Antarctic minke whales in 1994/95 samples were generally within the same range as previous results, while PCBs levels in 1994/95 samples were higher than those of samples during the period from 1984/85 to 1992/93. Our results of DDTs, CHLs, HCHs and HCB in the Area V were consistent with those of Aono *et al.* (1997) and Tanabe *et al.* (1999), while our results for PCBs in the Area V were inconsistent with their results. Aono *et al.* (1997) and Tanabe *et al.* (1999) used pooled data for the male minke whales less than 25 years old, while the present study used the 20-25 year old males to avoid sex and aging effects. The present study provides more accurate estimations for the temporal trend of OCs in the Antarctic minke whales than those of Aono *et al.* (1997) and Tanabe *et al.* (1999).

Figure 3 shows organochlorine pesticides standardized with respect to PCBs, which are stable in the environment as well as animal bodies. In addition, PCBs have declined slowly in the open ocean and the Antarctic (Aono *et al.*, 1997; Tanabe *et al.*, 2003) and the influence of changes in the body fat is nullified by standardization with PCBs. HCHs/PCBs ratio decreased by a factor of about ten in a span of 16 years in both Areas IV and V, while temporal trends of DDTs/PCBs, HCB/PCBs and CHLs/PCB were stable. These results indicated that PCBs, DDTs, HCB and CHLs levels in the Antarctic minke whales were unchanged or slightly decreased in Area V during the research period. However, only HCHs levels clearly decreased. The increase of OCs in the Antarctic environment and Antarctic minke whales observed in the 1980s appears to have ended in the 1990s. Organochlorine levels in ocean are affected by historical usage and their physicochemical properties. About 10 Mt of HCHs have been released in the environment, especially in the northern hemisphere (Li, 1999). Emission of HCHs increased steadily after their introduction in the 1940s until they reached a peak in the early 1970s in northern hemisphere (Li and Macdonald, 2005). However, the usage history is similar to other OCs, because organochlorine levels generally declined in the 1970s and leveled off in the 1980s as several bans were enforced in developed countries (Weber and Goerke, 2003).

HCHs/PCB ratios of Antarctic minke whales in Area V for 22 years decreased by about 15 %, while ratios of DDTs, HCB and CHLs to PCB concentrations of were stable. The decreasing ratios correspond to 6 years as the half-life of HCHs/PCB in the whales. However, HCHs levels in minke whales in 2010/2011 were similar those in later stage of JARPA (1996/1997-2004/2005). This could suggest a tendency for background levels of HCHs in Antarctic Ocean to have varied from slightly decreasing to a steady state since middle 1990's.

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Table 1. Organochlorine concentrations (ng/g fat wt.) in the blubber of mature male (21-25 years) of Antarctic minke whales in Area V in JARPA during a period from 1988/89 to 2004/05 and JARPAII in 2010/2011

Area	Year	*n*	Fat (%)	PCBs	DDTs	HCHs	HCB	CHLs
JARPA	1988/89	5	82.0	30	110	1.8	230	37
			(77.7 - 87.9)	(23 - 40)	(71 - 150)	(0.6 - 3.2)	(130 - 340)	(27 - 51)
	1990/91	5	70.5	33	120	1.8	220	39
			(61.7 - 80.3)	(20 - 70)	(57 - 260)	(0.6 - 4.1)	(160 - 380)	(19 - 84)
	1992/93	5	62.4	50	180	1.6	260	56
			(44.8 - 78.2)	(22 - 78)	(74 - 300)	(0.4 - 3.8)	(130 - 400)	(25 - 91)
	1994/95	5	69.7	38	140	1.4	280	58
			(55.4 - 77.2)	(26 - 49)	(80 - 180)	(0.4 - 3.0)	(180 - 380)	(34 - 73)
	1996/97	5	69.4	31	130	0.5	210	45
			(45.2 - 83.1)	(18 - 60)	(44 - 300)	(<0.2 - 1.0)	(120 - 370)	(17 - 89)
	1998/99	5	72.0	27	110	0.4	160	44
			(62.6 - 86.2)	(18 - 35)	(50 - 150)	(0.2 - 0.6)	(140 - 190)	(27 - 57)
	2000/01	5	73.3	17	69	0.4	110	28
			(54.6 - 83.8)	(10 - 27)	(30 - 130)	(<0.1 - 0.4)	(75 - 210)	(10 - 60)
	2002/03	5	75.9	24	66	0.8	150	28
			(63.4 - 84.3)	(21 - 26)	(51 - 74)	(0.7 - 0.9)	(110 - 190)	(23 - 32)
	2004/05	5	67.9	28	100	0.8	140	25
			(61.9 - 75.0)	(21 - 43)	(81 - 160)	(<0.2 - 0.8)	(110 - 190)	(19 - 40)
	Total	40	71.5	31	110	1.2	200	40
			(44.8 - 87.9)	(10 - 78)	(30 - 300)	(<0.2 - 4.1)	(75 - 400)	(10 - 91)
JARPA II	**2010/11**	**5**	**67.9**	**28**	**100**	**0.8**	**140**	**25**
			(61.9 - 75.0)	**(21 - 43)**	**(81 - 160)**	**(<0.2 - 0.8)**	**(110 - 190)**	**(19 - 40)**

Table 2. Simple linear correlation coefficients and probability between research years (1988/1989-2010/2011) and organochlorine contaminant concentrations (ng/g fat wt.) in the blubber of Antarctic minke whales

		LN (PCBs conc.)	LN (DDTs conc.)	LN (HCHs conc.)	LN (HCB conc.)	LN (CHLs conc.)
Constant	B±SE		70.4±21.9	165±41	74.4±16.7	53.2±21.4
Reserch year	B±SE		-0.033±0.011	-0.083±0.021	-0.035±0.008	-0.025±0.011
	p value		0.004**	<0.001***	<0.001***	0.025*

*: $p<0.05$, **: $p<0.01$, ***: $p<0.001$

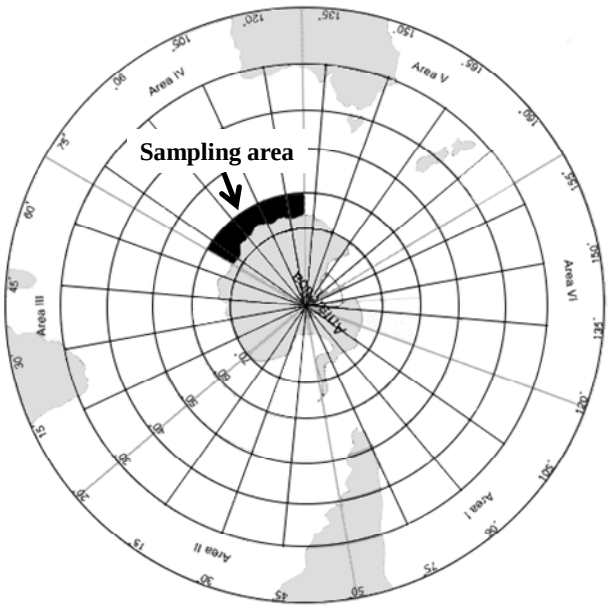

Figure 1. Sampling area of Antarctic minke whales in Area V

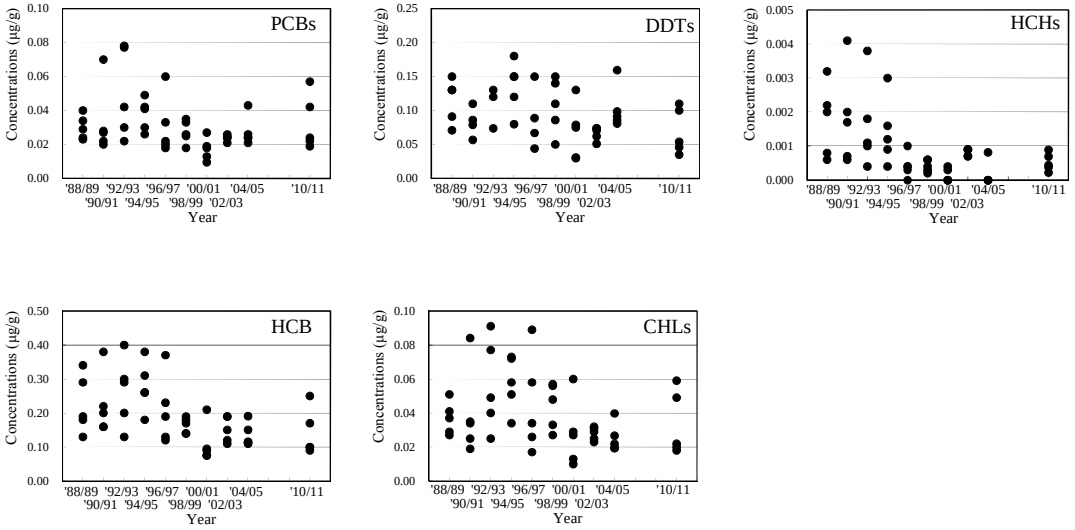

Figure 2. Temporal trend of organochlorine concentrations (ng/g fat wt.) in the blubber of Antarctic minke whales from Area V during a period from 1988/89 to 2010/11

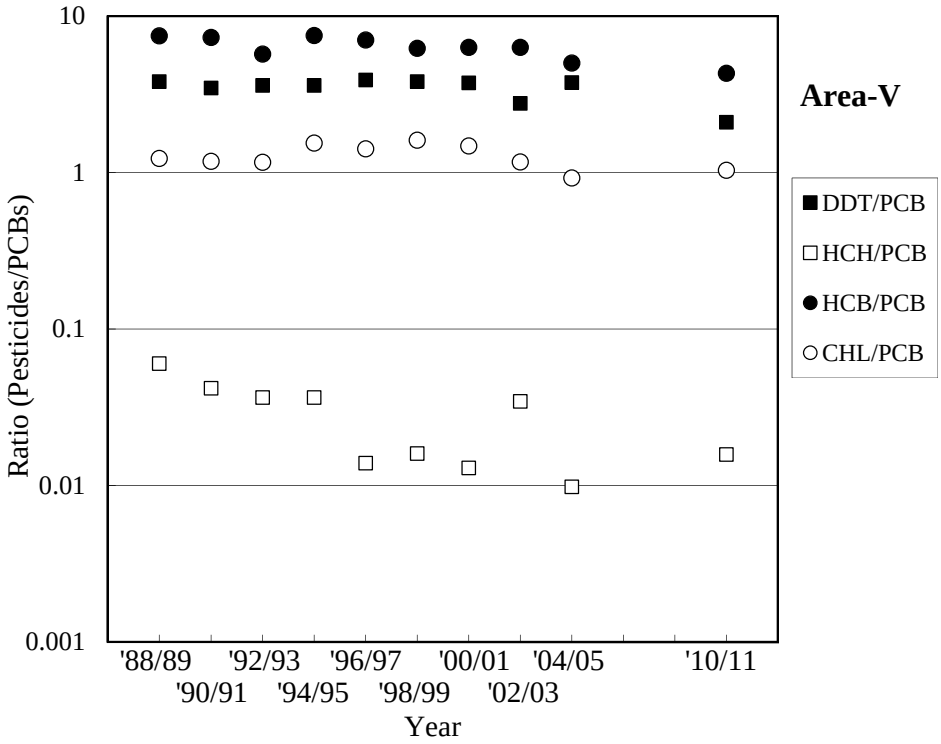

Figure 3. Ratios of organochlorine pesticides and PCBs in the blubber of Antarctic minke whales from Area V during 1988/89 and 2010/11 seasons