Organochlorines in common dolphins caught in shark nets during the Natal 'sardine run'

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Received 17 July 1989; accepted 8 February 1990

The concentrations of organochlorines were determined in blubber and liver samples from common dolphins inhabiting the coastal waters of the south-east coast of southern Africa. Liver levels of PCBs and DDTs are far lower and do not appear directly associated with those in blubber. In males, blubber residue concentrations increased with age but in females a marked rapid decline in concentrations of PCBs and t-DDT was evident between the eighth and eleventh growth layer groups, approximately the age of sexual maturity and subsequent to their first or second ovulation. Lower levels in females are explained through transfer to the new-born calf during lactation and the consequences of this for the newborn calf are discussed.

Die konsentrasie van organochlore is bepaal in spek- en lewermonsters van gewone dolfyne wat die kuswaters van die suidoos-kus van Suider-Afrika bewoon. In die mannetjies het residu-konsentrasies in die spek met ouderdom vermeerder, maar in die wyfies is 'n opvallend vinnige afname in konsentrasies van PCBs en t-DDT duidelik te bespeur tussen die agtste en elfde groeilaag-groepe, wat min of meer ooreenstem met die ouderdom van geslagsvolwassenheid en die daaropvolgende eerste of tweede ovulasie. Laer vlakke in wyfies word verduidelik deur oordrag aan die pasgebore kalfie tydens laktasie en die gevolge hiervan op die pasgebore kalfie word bespreek.

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An ever-increasing literature documents the ubiquitous presence of chlorinated hydrocarbon residues in marine mammals from a wide variety of geographical areas (Risebrough 1978; Gaskin 1982; Wagemann & Muir 1984). The most frequently reported are the polychlorinated biphenyls (PCBs) as well as DDT and its metabolites DDE and DDD. The PCBs in particular, have high lipophilicity and it is this property that promotes their passive adsorption into the blood and tissue of the body (Matthews & Dedrick 1984). Marine mammals are long-lived, have large lipid reserves in proportion to their body size and mass and are therefore ideal repositories for high concentrations of these pollutants. Also, because they apparently lack certain enzymes for the metabolism of organochlorines, they may accumulate these compounds to a greater degree than other mammals and be more susceptible to their toxic effects (Tanabe 1988; Tanabe, Wantanabe, Kan & Tatsukawa 1988).

Although the toxic effects of organochlorines are difficult to assess, they have been implicated, particularly the PCBs, in reproductive abnormalities of female harbour seals from the Wadden Sea and may have also negatively influenced the survival potential of these animals (Duinker, Hillebrand, Th & Nolting 1979; Reijnders 1986). Similarly, high concentrations of PCBs in beluga whales from the St. Lawrence Estuary may be responsible for their decline in numbers (Martineau, Beland, Desjardins & Lagace 1987) and high levels of PCB and DDE have been negatively correlated with testosterone levels in Dall's porpoise (Subramanian, Tanabe, Tatsukawa, Saito & Miyazaki 1987). The accumulation of PCBs and DDTs may, therefore, be a significant and often critical factor in the survival of marine mammal populations, particularly those subject to other direct or indirect exploitation.

Information on the levels of organochlorines in marine mammals from the east coast of southern Africa is sparse, although their presence is indicated. The intense agricultural use of land along the coastal zone, particularly in southern Natal, could account for large quantities of DDT entering the marine ecosystem. Also, the continued use of DDT in state managed malaria control procedures in northern Natal (Van Dyk, Wiese & Mullen 1982) indicates that quantities of DDT are still entering the marine system. Although PCBs were never manufactured in South Africa, the dumping of products containing PCBs in industrialized areas, such as Richards Bay, Durban, East London and Port Elizabeth, suggests their accumulation in the marine environment.

Inshore dolphins and seals show higher residue levels than those inhabiting deeper offshore waters while, in general, residue levels for most species tested appear to be low and probably of little consequence (Cockcroft, Ross, Connell, Gardner & Butler, in press). In contrast, Indian Ocean humpback and bottlenose dolphins in Natal waters, contain organochlorine pollutants in concentrations which are of concern and may significantly affect their reproductive efficiency (Gardner, Connell, Eagle, Moldan, Oliff, Orren & Watling 1983; Ross 1984; Cockcroft, De Kock, Lord & Ross 1989).

The capture and death of substantial numbers of common dolphins in the Natal shark nets, during the annual sardine run, prompted this assessment of pollutant residue levels in the blubber and their relationship to biological characteristics of this species.

Materials and Methods

Dolphins caught in shark nets were frozen as soon as possible after capture to await general dissection. Blubber samples (30 g) were removed from each animal, from the flank in the neck region anterodorsal to the flipper insertion where the greatest blubber thickness was consistently found. Liver samples (30 g) were cut from either lobe of the liver. All samples were wrapped in aluminium foil and immediately refrozen to await analysis. On all dolphins, all blubber from the neck to the caudal peduncle was removed to obtain blubber weights. Ovaries of females were sectioned serially and the number of corpora lutea and albicantia in both ovaries was counted and summed. Age is expressed as the number of dentinal growth layer groups (GLGs; *sensu* Perrin & Myrick 1980) counted in thin sections of teeth. For data interpretation dolphins were divided into immature animals (< 10 GLGs) and adults (> 10 GLGs).

Samples were analysed using the techniques and methodology outlined in Cockcroft *et al.* (1989).

Table 1 The mean concentrations (μg/g wet mass) of PCBs and t-DDT in the blubber of five common dolphin age categories (immatures < 10 GLGs of age, mature males, mature but resting females, pregnant females and lactating females). The *F* value obtained from two-way ANOVAs between age and reproductive categories and the relevant significance levels are shown ($p > 0{,}05^*$; $p < 0{,}05^{**}$ and $p < 0{,}01^{***}$)

			ANOVA *F* value			
			Mature	Females		
Age category	$\bar{x}$ Conc.	*n*	males	resting	lactating	pregnant
PCB concentrations						
Immatures	4,8	42	6,0**	0,7*	11,5***	8,8***
Mature males	7,9	17		3,1*	11,4***	6,9**
Resting females	3,9	11			2,1*	2,0*
Lactating females	1,9	18				0*
Pregnant females	1,7	9				
t-DDT concentrations						
Immatures	4,0	42	7,4***	0*	15,1***	5,1**
Mature males	6,4	17		3,9*	65,7***	27,1***
Resting females	3,8	11			6,9**	2,2*
Lactating females	0,9	18				1,0*
Pregnant females	1,5	9				

Results and Discussion

In both liver and blubber the major portion (approximately 70% overall) of DDT compounds was in the form of DDE with lower amounts of the DDT and DDD (overall 25% and 5% respectively). These three forms have been summed and referred to as total-DDT (t-DDT).

Blubber PCB and t-DDT levels were generally considerably greater than their corresponding liver levels. An analysis of PCB levels in the liver, using Kruskall Wallis rank analysis of variance and subsequently Dunn's Multiple Contrast method (Zar 1984), showed no age-related patterns and no significant differences between any of the five age and maturity groups of common dolphin. However, lactating females contained significantly lower mean liver t-DDT levels than their calves, resting females and mature males (Student's *t* test, $p < 0{,}05$) and although the number of pregnant females sampled was low (four), their mean liver t-DDT level was significantly lower than that found in mature males (Student's *t* test, $p < 0{,}05$).

Levels of t-DDT and PCBs in the blubber showed little correlation with those in the liver ($r = -0{,}367$ and 0,035, respectively) and is probably a result of the high lipid and carbohydrate turnover in the liver. The liver's importance in metabolic function suggests that liver lipids, with their associated residues, are highly labile, which may explain the lack of association between liver PCB levels in any of the sex/age groups. It is uncertain why lactating and pregnant females had lower liver concentrations of t-DDT than other sex/age classes, although it may be related to an increased metabolism during these reproductive stages (Cockcroft & Ross 1989). As the majority of a dolphin's residue load, greater than 90%, is stored in the blubber (Tanabe, Tanaka & Maruyama 1980), blubber pollutant concentrations are probably more physiologically important than those in liver.

Mature male common dolphins had significantly greater blubber PCB and t-DDT concentrations than all other sex and age categories except resting females (Table 1). In contrast, lactating and pregnant females had significantly lower blubber levels of both residues than immature and mature male dolphins (Table 1). Lactating and pregnant females also had significantly lower t-DDT levels than resting females ($p < 0{,}05$; ANOVA), although their PCB levels were not significantly different (Table 1). Resting females, as a category, contain both females that are truly resting i.e. between calves, and those that are mature but for some reason have not yet become pregnant and lactated. This and the low number of resting females in the sample would explain the similarity of their residue concentrations to all other categories.

Generally, the concentrations of both t-DDT and PCBs in the blubber of male common dolphins increase with age (Figures 1 & 2). Females, however, show a marked decline in concentrations of both residues between eight and eleven GLGs of age, approximating the time at which they attain sexual maturity (Figures 1 & 2). These patterns are particularly evident in the total blubber burdens (total blubber mass × blubber residue concentration) of the age and sex groups, where lactating and pregnant females contain considerably lower burdens than the other categories (Table 2).

The fate of PCBs and t-DDT in the common dolphin is similar to that described for the harbour porpoise, *Phocoena phocoena* (Gaskin, Frank & Holdrinet 1983; Gaskin 1982), for the striped dolphin, *Stenella coeruleoalba* (Fukushima & Kawai 1980; Tanabe *et al.* 1980), for the beluga whale (Marineau *et al.* 1987) and for the bottlenose dolphin (Cockroft *et al.* 1989). In these species, increases in the concentration of both residues are closely correlated with age until animals reach sexual maturity. Thereafter, females experience a marked drop in concentrations while males continue to accumulate residues throughout their lives. The reduction in female load has been attributed to offloading during pregnancy and lactation (Tanabe *et al.* 1980; Gaskin *et al.* 1983; Martineau *et al.* 1987), the majority, some 90% in striped dolphins, occurring through lactation (Fukushima & Kawai 1980).

Male Dall's porpoises from the north-western north Pacific, with levels of PCBs and DDTs similar to those in male common dolphins, displayed decreased blood testosterone levels indicating decreased male reproductive efficiency (Subramanian *et al.* 1987). Although the latter study was based on few specimens, the results suggest that levels which were hitherto considered benign may well produce detrimental effects in adults.

Of particular interest is the significant difference in PCB and t-DDT levels shown by females before (6,6 µg/g and 6,7 µg/g, respectively) and subsequent to their first or second ovulation (0,96 µg/g and 2,1 µg/g, respectively) (in both instances $p < 0{,}05$; Student's t test) (Figure 3). This indicates that the primiparous female transfers 85 and 69% of her PCB and t-DDT residues, respectively, subsequent to the first or second ovulation and probably to the first-born calf. Cockcroft *et al.* (1989) found a similar pattern in bottlenose dolphin females. Subsequent calves probably receive a markedly lower load because of the initial drop in the female's residue concentrations. The variability of pollutant concentrations in young, just-weaned calves (1 GLG or less) is evidence that this may occur (Figures 1 & 2).

The effect of residue transfer on the first-born calf is unknown but probably depends on the load transferred

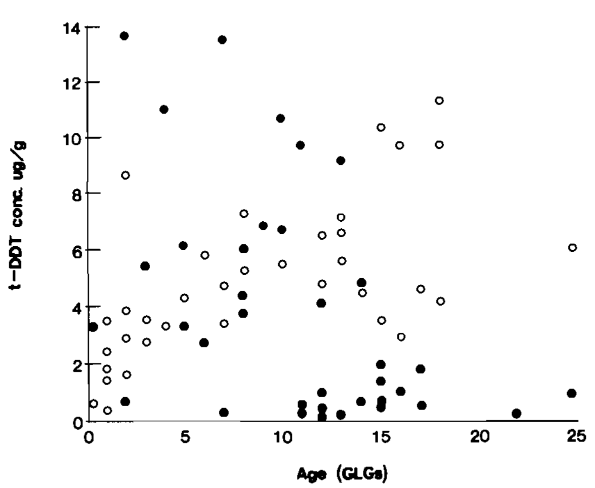

Figure 1 Relationship between age (GLGs) and blubber t-DDT concentration in male (open circles) and female (shaded circles) common dolphins captured in shark nets.

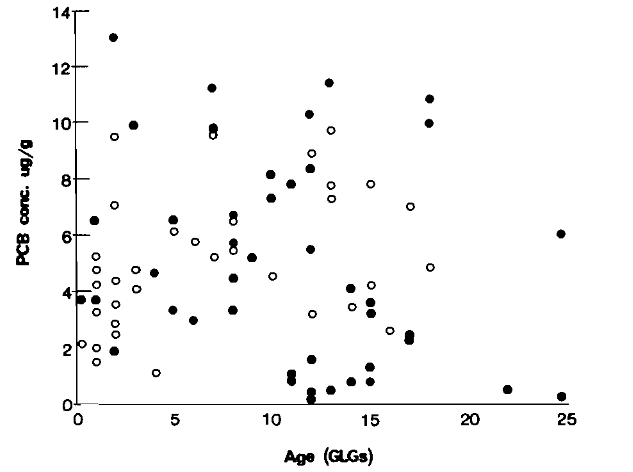

Figure 2 Relationship between age (GLGs) and blubber PCB concentration in male (open circles) and female (shaded circles) common dolphins captured in shark nets.

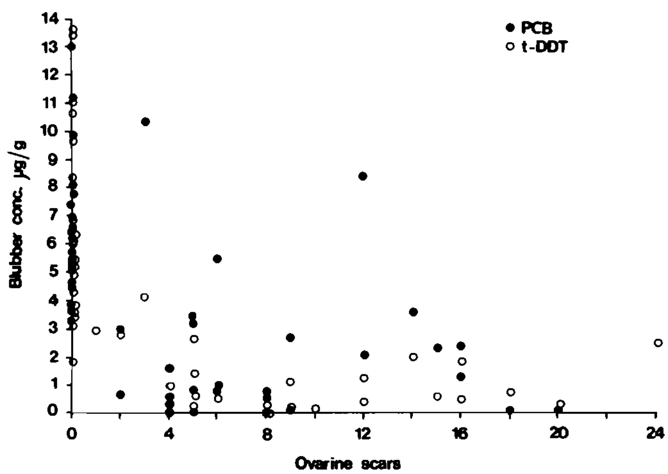

Figure 3 Relationship between the number of ovarine scars and concentration of PCBs and t-DDT in the blubber of common dolphin females.

Table 2 Total blubber burden (total blubber mass × residue concentration = TBB mg) of t-DDT and PCBs for immature (< 10 GLGs), mature males and resting, lactating, and pregnant female common dolphins captured in shark nets

		Mature	Females		
	Immatures	males	resting	lactating	pregnant
TBB PCB	62,9	107,5	69,6	48,4	36,9
TBB t-DDT	46,3	104,3	67,3	15,5	21,6

and the rapidity of transfer. Cockcroft *et al.* (1989) have proposed that initial transfer is rapid and that calves of primiparous bottlenose dolphin females ingest some 4% of the mothers residue load per day, resulting in the mother imparting 80% of her load within seven weeks *post partem*. Similar calculations for common dolphins (assuming a primiparous female initial blubber load of

6,6 μg/g of PCBs and t-DDT), indicate that about 84 mg of each pollutant would be transferred within seven weeks of the initiation of lactation. This would result in weaning calves with residue concentrations exceeding 24 μg/g, although, interestingly, none were found with levels as high as this. Although this anomaly has also been noted for striped dolphin calves (Kawai & Fukushima 1980), Cockcroft *et al.* (1989) found a few neonatal bottlenose dolphin calves with values almost as high as might be predicted.

These calculations imply that first-born calves may receive a large, rapid dose of toxic substances soon after birth. The consequences of this are unknown, although the toxic effects of high doses of PCBs and DDTs on monkey infants (Carstens, Barsotti & Allen 1979; Allen, Barsotti & Carstens 1980), the apparent inability of cetaceans to metabolize organochlorines (Tanabe 1988; Tanabe *et al.* 1988) and the evidence for the immunosuppressive effect of PCBs (Safe 1984) imply that the lives of first-born calves may be at risk.

Common dolphin blubber Chlordane and Lindane levels were low and Lindane levels, particularly, were highly variable. The few data available precluded analyses for age-related patterns. Immature dolphins, however, had generally higher mean Chlordane levels than mature males, suggesting that neonates receive an initial high dose, probably through lactation. Although the toxic effects, if any, of Chlordane are not understood, a high initial dose of this, in addition to PCBs and DDTs, may further stress new-born calves.

Bottlenose and humpback dolphins off the Natal coast have mean residue levels considerably higher than those in common dolphins (Gardner *et al.* 1983; Cockcroft *et al.*, in press; Cockcroft *et al.* 1989). This almost certainly reflects the inshore habitat of the former two species and therefore their proximity to the sources of these pollutants. In contrast, common dolphins feed primarily on pelagic schooling fish and are probably only seasonal visitors to Natal, their presence associated with the annual 'sardine run' (Cockcroft, in press).

Bottlenose dolphins captured on the Natal north and south coasts show significantly different levels of both PCBs and DDTs, indicating a long-term separation of animals in the two areas (Cockcroft *et al.* 1989). In contrast, this is not reflected in the residue levels of common dolphins from Natal which implies that common dolphins are part of a homogeneous population.

An examination of the ratio of blubber DDE to total DDT allows an assessment of the level of recent DDT input (Aguilar 1984; Addison, Brodie, Zinck & Sergeant 1984; Borrell & Aguilar 1987) into the coastal zone on the east coast of southern Africa. For the years 1980–1982 and 1983–1986 this ratio is 0,83 and 0,95, respectively, for mature females and 0,77 and 0,94, respectively, for mature males. This indicates a reduction of DDT input between the two periods even though DDT is still being used on land to combat malaria. Evidence from DDTs in bottlenose dolphins also indicates no recent addition of DDT into the Natal system (Cockcroft *et al.* 1989). However, the continued monitoring of the occurrence of PCBs and DDTs in common dolphins is necessary to determine long-term changes in pollutant input into the marine environment.

Acknowledgements

This study was financed by the Port Elizabeth Museum and a grant from the CSIR (SANCOR). Their support is gratefully acknowledged. A special thanks to the Director and staff of the Natal Sharks Board who made the collection of samples possible. We are grateful to Mrs C. Saunders for her technical assistance.

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