- Plastic debris constitutes a potential threat to marine mammals.
- Marine mammals can become physically entangled in loops or openings of drifting debris. Entangled animals may suffer impaired ability to catch food or avoid predators, incur wounds and infections from the abrasive or cutting action of attached debris.
- Plastic ingestion is a major risk to some cetacean species and could pose a threat to the dolphins.

Organochlorines

Organochlorine compounds are known to have detrimental effects on the reproductive success of some marine mammal species, in some instances resulting in sterility, and they may suppress the immune system in some species (Colburn & Smollen, 1996).

Hector's dolphin tissue has been found to contain high levels of organochlorines such as DDT (1.96-52.85 ppm), PCBs (0.95-10.21 ppm) and dioxins (TCDD TE 11-37 ppt) (Slooten & Dawson, 1994). The toxicity of a combination of different organochlorine compounds is commonly expressed by way of toxic equivalents (TEQs)[13]. Hector's dolphins show the highest TEQ levels of all southern ocean cetaceans (Table 3). On the global scale, however, Hector's dolphin organochlorine levels are generally within the lower range recorded for marine mammals in the highly industrialised Northern Hemisphere, except for DDTs (Tanabe *et al.*, 1994). DDT levels detected in Hector's dolphins are very high and second only to the highly contaminated Canadian beluga whales (*Delphinapterus leucas*) (Martineau *et al.*, 1987; De Guise *et al.*, 1995).

Table 1 Mean organochlorine TEQ levels of Southern Ocean cetaceans (adapted from Schröder, 1998).

Cetacean group	TEQ (pg/g) [a]
Baleen whales	1.7 [b]
Beaked whales	11.0 [b]
Pilot whales	12.2 [c]
Oceanic dolphins	12.5 [b]
Hector's dolphins	83.3 [b]

[a] Based on TEFs by van den Berg *et al.*, (1998); organochlorine concentrations reported by [b] Jones *et al.*, (1999) and [c] Schröder (1998).).

Metals

Essential metals (e.g. copper, iron, selenium and zinc), which are involved in biological and biochemical processes, generally pose less of a risk as organisms tend to be able to regulate them. Non-essential metals (e.g. mercury, lead and cadmium), which have little or no recorded biological function in an organism, can accumulate and are often toxic even at low concentrations (Bowles, 1999).

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[13] TEQs are computed based on the chemical residue data of the animal and so called 'Toxic Equivalency Factors' (TEFs), a measure of the relative toxicity of the compounds under investigation (Van den Berg *et al.*, 1998).

Table 1 Biometric data for the individual marine mammals analysed in this study.

Lab#	Doc#	Species	Sex	Age (y)	Location
MM8-HD2	9162	Hector's	Female	1	Waikouaiti
MM8-DD1		Dusky			Kaikoura
MM8-DD2		Dusky			Kaikoura
MM8-DD4		Dusky			Kaikoura
MM9-HD1	8730	Hector's	Female	3	Pegasus Bay
MM8-HD1	9363	Hector's	Female	1	North of Christchurch
MM9-HD2	8736	Hectors'	Female	10	Pegasus Bay
MM9-HD3	8737	Hector's	Female	19	Pegasus Bay
MM9-HD4	8739	Hector's	Male	18	South of Timaru
MM10-HD1	8844	Hector's	Female	2	Pegasus Bay
MM10-HD2	8845	Hector's	Male	1	Akaroa
MM10-HD3	8846	Hector's	Male	1	North of Timaru
MM11-HD1	W004	Hector's	Male	1	North of Westport
MM11-HD2	W005	Hector's	Male	1	Westport
MM11-HD3	W007	Hector's	Male	1	Granity

Table 3. Concentrations (pg/g) of individual PCDD and PCDF congeners in New Zealand marine mammals.

Congener	MM8-HD2	MM8-DD1	MM8-DD2	MM8-DD4	MM9-HD1	MM8-HD1	MM9-HD2	MM9-HD3	MM9-HD4	MM10-HD1	MM10-HD3
2,3,7,8-TeF	2.1	< 0.1	0.35	< 0.4	1.6	2.02	1.8	0.7	1.59	2.08	1.86
non-2,3,7,8-TeF	5.66	1.44	0.35	< 0.3	< 0.8	3.36	< 0.3	< 0.8	< 0.6	< 0.4	< 0.4
2,3,7,8-TeD	4.8	< 0.6	< 0.3	< 0.2	7.02	3.18	< 0.6	5.23	3.98	3.51	3.85
non-2,3,7,8-TeD	< 0.2	< 0.3	< 0.2	< 0.4	< 2	< 0.2	< 0.7	< 1	< 2	< 1	< 1
1,2,3,7,8-PeF	0.67	< 0.3	< 0.2	< 0.1	< 1	< 0.2	< 0.5	< 0.9	< 0.8	< 0.6	< 0.5
2,3,4,7,8-PeF	28.1	< 0.2	< 0.2	< 0.1	12.6	5.84	2.2	6.7	18.9	5.81	7.17
non-2,3,7,8-PeF	7.5	2.5	0.67	< 0.2	1.43	0.92	< 0.7	2.55	8.32	< 0.6	4.86
1,2,3,7,8-PeD	11.4	< 0.2	< 0.3	< 0.2	8.47	3.91	0.94	4.92	5.73	4.72	4.01
non-2,3,7,8-PeD	< 0.1	< 0.3	< 0.1	< 0.2	< 0.8	< 0.1	< 0.6	< 0.5	< 0.5	< 0.4	< 0.3
1,2,3,4,7,8-HxF	< 0.2	< 0.3	< 0.2	< 0.2	< 0.5	< 0.2	< 0.4	< 1	< 0.8	< 0.5	< 0.4
1,2,3,6,7,8-HxF	0.29	< 0.3	< 0.2	< 0.2	< 0.5	< 0.3	< 0.4	< 1	0.81	< 0.6	< 0.5
2,3,4,6,7,8-HxF	0.57	< 0.4	< 0.4	< 0.3	< 0.3	0.28	< 0.3	< 0.9	< 0.9	< 0.5	< 0.6
1,2,3,7,8,9-HxF	< 0.2	< 0.2	< 0.1	< 0.2	< 0.7	< 0.2	< 0.6	< 0.9	< 1	< 0.7	< 0.3
non-2,3,7,8-HxF	4.2	3.38	2.89	< 0.2	< 1	1.17	1.21	4.17	6.77	< 0.9	2.46
1,2,3,4,7,8-HxD	0.80	< 0.3	< 0.2	< 0.2	< 1	< 0.4	< 0.5	< 0.9	< 0.9	< 0.7	< 0.6
1,2,3,6,7,8-HxD	1.98	< 0.3	< 0.5	< 0.2	3.22	1.12	0.77	2.32	< 1	< 2.0	< 0.7
1,2,3,7,8,9-HxD	< 0.2	< 0.2	< 0.1	< 0.2	< 1	< 0.4	< 0.6	< 2	< 1	< 0.8	< 0.7
non-2,3,7,8-HxD	< 0.6	< 0.5	< 0.4	< 0.4	< 3	< 0.5	< 1	2.33	2.73	< 0.7	< 1
1,2,3,4,6,7,8-HpF	0.23	0.50	0.43	< 0.1	1.66	< 0.2	0.63	1.79	1.5	< 0.8	< 1
1,2,3,4,7,8,9-HpF	< 0.2	< 0.3	< 0.3	< 0.2	< 0.8	< 0.1	< 0.4	< 0.6	< 0.9	< 0.4	< 0.6
non-2,3,7,8-HpF	0.5	1.78	1.18	< 0.3	5.03	0.43	0.46	1.22	1.15	< 0.8	< 1
1,2,3,4,6,7,8-HpD	0.81	1.21	0.44	0.68	23.6	0.82	4.62	10.41	12.6	9.61	4.88
non-2,3,7,8-HpD	< 0.5	0.85	0.31	0.44	9.11	0.37	2.28	5.19	6.97	5.91	2.96
OCDF	< 0.7	1.3	< 0.7	< 0.6	15.3	< 0.6	< 2	< 3	< 3	< 4	< 3
OCDD	5.55	8.85	3.28	5.6	89.1	5.53	15.64	50.0	89.4	74.7	22.6
TE (pg/g)	25.2	0.5	0.4	0.3	18.7	8.50	2.32	11.9	17.1	9.42	9.91
Total TE (PCDDF+PCBs)	200	40.7	24.3	4.24	149.8	101	17.8	131.9	152.7	63.8	140
% TE from PCBs	87.4	98.7	98.2	92.9	87.5	91.6	87.0	91.0	88.8	85.2	92.9

* Highest levels in 1 year-old female

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calculated for the different cetacean groups (Table 2). TEQs were lowest in the baleen whales, higher in the open ocean odontocetes and highest in the inshore Hector's dolphin. By calculating the TEQ contributed by specific compounds analysed it is possible to assess their relative toxicological significance (Fig. 2). The contribution of PCDD and PCDF to the TEQ

Table 2

Mean chlorinated hydrocarbon congener concentrations in blubber of different groups of southern ocean cetaceans (PCBs in ng/g wet weight; PCDD and PCDF in pg/g wet weight). Where values less than the detection limit occurred, one half of that detection limit was used to calculate the mean. TEFs from Ahlborg *et al.*, 1988; Ahlborg *et al.*, 1994.

na = not analysed. nd = not detected. * PCDD and PCDF data from Buckland *et al.*, 1990.

Analyte	TEF	Pygmy right	Baleen whales	Oceanic dolphins	Beaked whales	Hector's dolphin*
PCB #28	0	0.25	0.03	0.93	0.95	3.78
PCB #52	0	0.34	1.30	14.5	4.90	9.93
PCB #77	0.0005	0.005	0.002	0.08	0.06	0.09
PCB #101	0	0.42	1.87	60.1	19.7	32.5
PCB #99	0	0.23	1.41	44.0	23.3	56.9
PCB #118	0.0001	0.20	0.79	37.5	14.7	56.1
PCB #105	0.0001	0.11	0.23	10.9	4.25	28.7
PCB #126	0.1	0.003	0.01	0.06	0.08	0.43
PCB #153	0	0.58	2.89	267	64.5	330
PCB #138	0	0.85	2.64	232	48.7	240
PCB #169	0.01	0.002	0.02	0.14	0.07	0.09
PCB #187	0	0.28	0.80	46.8	24.8	77.7
PCB #183	0	0.02	0.23	16.3	6.97	29.4
PCB #180	0.00001	0.14	0.77	68.1	21.1	86.2
PCB #170	0.0001	0.17	0.34	22.6	13.7	64.3
PCB #202	0	0.001	0.03	5.46	1.43	1.6
PCB #194	0	0.001	0.02	8.50	1.64	na
Congener sum (ng/g)		3.61	12.9	833	251	1,018
2,3,7,8-TeF	0.1	0.06	0.10	0.10	0.15	9.12
non-2,3,7,8-TeF	0	0.11	0.18	3.70	1.30	nd
2,3,7,8-TeD	1.0	0.10	0.08	0.10	0.06	7.83
non-2,3,7,8-TeD	0	0.18	0.08	0.10	0.10	nd
1,2,3,7,8-PeF	0.05	0.06	0.05	0.10	0.12	0.77
2,3,4,7,8-PeF	0.5	0.13	0.10	0.02	0.22	24.6
non-2,3,7,8-PeF	0	0.18	0.20	6.44	1.79	nd
1,2,3,7,8-PeD	0.5	0.13	0.10	0.10	0.09	9.08
non-2,3,7,8-PeD	0	0.23	0.13	0.15	0.09	nd
1,2,3,4,7,8-HxF	0.1	0.13	0.08	0.10	0.10	nd
1,2,3,6,7,8-HxF	0.1	0.10	0.12	0.10	0.09	0.56
2,3,4,6,7,8-HxF	0.1	0.13	0.12	0.10	0.17	0.51
1,2,3,7,8,9-HxF	0.1	0.18	0.15	0.10	0.06	0.27
non-2,3,7,8-HXF	0	0.20	0.20	2.96	0.82	nd
1,2,3,4,7,8-HpD	0.1	0.15	0.12	0.04	0.07	nd
1,2,3,6,7,8-HpD	0.1	0.15	0.17	0.04	0.15	2.83
1,2,3,7,8,9-HpD	0.1	0.18	0.12	0.04	0.08	0.23
non-2,3,7,8-HpD	0	0.30	0.20	0.10	0.15	nd
1,2,3,4,6,7,8-HpF	0.01	0.28	0.43	0.05	0.19	0.30
1,2,3,4,7,8,9-HpF	0.01	0.18	0.15	0.04	0.05	0.08
non-2,3,7,8-HpF	0	0.43	0.85	0.20	0.10	nd
1,2,3,4,6,7,8-HpD	0.01	0.65	0.98	0.15	0.53	3.15
non-2,3,7,8-HpD	0	0.68	0.76	0.50	0.27	nd
OCDF	0.001	0.52	2.33	0.15	0.26	1.54
OCDD	0.001	2.75	10.2	0.50	3.91	12.5
TEQ (pg/g)		0.77	1.9	15.7	12.5	81.4

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Table 1. Mean TEQ and PCB concentrations and Biomagnification Factors (BMFs) for contaminants in New Zealand marine sediments and biota.

	2,3,7,8 TCDD (pg/g)	OCDD (pg/g)	PCDD/F TEQ (pg/g)	ΣPCB (ng/g)	PCB TEQ (pg/g)	ΣTEQ (pg/g)	ΣTEQ/ ΣPCB
Hector's Dolphin	2.77	26.8	8.83	1770	72.3	81.1	0.05
Fish	0.03	0.13	0.1	1.42	0.31	0.41	0.29
Sediment	0.33	44.9	1.31	1.87	0.24	1.55	0.83
BMF(Dolphin/Fish)	8.4	0.6	6.8	948	300	52.4	
BMF(Fish/Sediment)	0.08	0.003	0.08	0.76	1.3	0.27	
* BMF(Dolphin/Sediment)	102	209	89.8	1247	230	197	

4) Discussion

The higher concentration of contaminants in the dolphin samples is clear evidence of the biomagnification of these contaminants in this aquatic food chain. Biomagnification Factors (BMFs) from fish to dolphins were higher for PCBs than for PCDD and PCDF congeners. This can be attributed to the high number of non-detect values for PCDD and PCDF in the fish analysed.

While BMFs for the biomagnification of PCDD and PCDF congeners are within previously reported ranges, the BMF for the transfer of PCBs between the dolphins and fish (BMF=948) is higher than those previously reported for other open ocean[5] (BMF=54.4) or freshwater dolphin species[4] (BMF=22.7). This difference is largely due to lower concentrations of PCHs in food species in New Zealand compared with those found in these other studies. In contrast, PCH concentrations in the marine mammal samples from New Zealand are generally within one order of magnitude of concentrations found in similar species in the northern hemisphere. Similar observations have been made concerning the biomagnification of organochlorines in the New Zealand fur seal[13].

It therefore seems that a fugacity type model may be useful in explaining the accumulation of PCHs in marine mammals. This model suggests that all marine mammals are approaching a similar PCH concentration and that the key factor determining an individuals tissue PCH concentration is the kinetics of the uptake process. In areas with relatively low environmental PCH concentrations, such as New Zealand, the kinetics of uptake are relatively slow. Therefore, tissue PCH concentrations are lower than those reported in northern hemisphere marine mammals. This model explains why New Zealand marine mammals have similar organochlorine concentrations to northern hemisphere species while ambient environmental concentrations are usually several orders of magnitude lower.

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