Organochlorines and mercury in a sample of cetaceans from the N.E. Atlantic.

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This paper reports on mercury and pollution burdens in the tissues of a sample of cetaceans collected opportunistically from around the British Isles. High concentrations are confirmed in several species, particularly harbour porpoises and bottlenose dolphins. The data provide some support for the idea that the eastern Irish Sea constitutes a "hot spot" of contamination. For many of the animals, blubber, liver and kidney burdens are presented and, in most cases, these confirm that tissue concentrations of organochlorines correspond closely to lipid content. A few aberrant values may relate to rapid blubber lipid mobilisation. The high values reported and evidence of their mobilisation and potential impact on organ systems lend further weight to the idea that organochlorines have serious implications for cetacean health.

Introduction

There is growing concern about the status of some cetacean populations in the Northeast Atlantic (e.g. Evans; 1987; Reijnders, 1992; Simmonds, 1992 and 1997). Around the United Kingdom, the most obvious change in status is that of the harbour porpoise (*Phocoena phocoena*), with marked declines in the southern North Sea since the 1940s and, potentially, a more recent decline in the 1980s (Evans, 1990). Moreover, Tregenza (1992) has recently illustrated a significant decline in the sighting of dolphins from the Cornish coast. Evans (1990) has identified four factors that are adversely affecting cetaceans: depletion of food resources by over-fishing; incidental entanglement in fishing year; disturbance and pollutants. This paper considers this last factor presenting data from a range of species.

High levels of organochlorines and heavy metals have already been reported in some dolphins in British waters (Morris *et al.*, 1989, Law *et al.*, 1991 and Law *et al.*, 1992) and it can be suggested that they may be a significant source of increased mortality. Pollution in the eastern Irish Sea has been identified as particularly of concern (Law et al., 1991; Law et al., 1992).

This study reports the levels of organochlorines and mercury determined from several cetacean species and considers their significance. All of the animals sampled were found dead, either washed ashore or entangled in fishing nets. The primary source of contaminants for cetaceans would be expected to be their prey. All the species concerned have both fish and cephalopods in their diet, except for the minke whale (*Balaenoptera acutorostrata*), which preys on fish, Euphausiids and Pteropods (Evans, 1987). The relative importance of squid and fish to odontocetes varies from species to species. The diet of beaked whales is little known, although squid, octopus and deep-sea fish appear to be important (Evans, 1987). Pilot whales (*Globicephala melaena*) prey mainly on squid.

Materials and methods

Samples were obtained from one minke whale, six long-finned pilot whales, two bottlenose dolphins, sixteen harbour porpoises, fifteen Atlantic white-sided dolphins (*Lagenorhynchus acutus*), two common dolphins (*Delphinus delphis*), two striped dolphins (*Stenella coeruleoalba*), one white-beaked dolphin (*Lagenorhynchus albirostris*), one Cuvier's beaked whale (*Ziphius cavirostris*), one Northern bottlenose whale (*Hyperoodon ampullatus*), and a medium-sized female animal which could not be identified. Where possible, a sample of blubber was taken from the mid-dorsal region along with samples of liver and kidney. The state of decomposition of each carcass was noted and measurements made of total length and blubber depth for most animals. A few animals were weighed and, in some cases, cause of death could be determined (i.e. where either a full pathological examination was made of an animal or where it was otherwise apparent). Animals were sexed by visual inspection and, in a few cases (where teeth were available), growth layers in their teeth were counted to give an estimate of age, following the methods described by Lockyer and Calzada (1992). Otherwise, on the basis of their size, animals were divided into adult and juvenile categories. Information about the sampled animals, including where they were found and on what date, is presented in Table1.

Tissue samples were wrapped in pesticide residue analysis-grade-hexane washed aluminium foil, placed in similarly washed glass vials and transported frozen to the analytical laboratory at the Institute of Terrestrial Ecology at Monks Wood where they were stored at -20°C before analysis. Analytical methods were as described in Johnston *et al.* (1991). Organochlorine analyses were conducted on approximately 0.7g of tissue. This was homogenised using a grinding agent composed of acid-washed sand and anhydrous sulphate, both held at 700°C for 5 hours prior to use. The homogenates were repeatedly solvent extracted in a 1:1 pesticide analysis grade hexane/acetone mixture to give a final volume of 50ml. 25ml of this was then evaporated to dryness to give the lipid weight for the sample and redissolved in 5ml of hexane. 1ml of extract was then cleaned up by passing it through a column containing aluminium oxide previously held at 800°C for 4 hours and subsequently deactivated by tumbling with 5% distilled water added. The column was eluted to give 5ml of cleaned-up extract.

Analysis was performed on a Varian 3400 GC with electron capture detection using a 30m DB210 capillary column, at a programmed temperature of 190°C. Identification and quantitation were achieved by comparison with a standard pesticide mixture and a PCB standard of Aroclor 1254. Analyte recovery was tested on samples spiked at the extraction stage as part of the analytical quality control procedures. Pesticides and PCB recoveries were equal to or greater than 94% in all cases. Detection limits were as follows: 0.005ug g^{-1} for gamma-hexachlorocyclohexane (lindane) and hexachlorobenzene; 0.01ug g^{-1} for DDE, DDT, TDE and dieldrin and 0.05ug g^{-1} for PCBs.

Mercury analysis was conducted on approximately 2g of material dried to constant weight for 72 hours at 85°C. This was cold acid digested for 12 hours in 10ml of analytical grade nitric acid and brought to boiling for a final period of 1 hour. Digests were made up to 25ml volume and analyses conducted by cold vapour generation according to the method of Hatch & Ott (1968). Measurements were made on a Thermo-electron 151 background-corrected atomic absorption spectrophotometer. Detection limits were established at 4ppb wet weight. Recoveries of mercury from spiked samples were equal to or greater than 96% in all cases.

Results and discussion

Mercury

The most heavily contaminated porpoises (24 and 28) were a pregnant female and a juvenile female. The latter would not have lost any of its burden to offspring and was found on the Pembroke coast, possibly part of a population more heavily exposed to contaminants than the animals sampled from the Irish coasts. The precise effects of pregnancy on contaminant burdens are unknown. The lipid concentrations of the blubber of animal 24 (85%) do not indicate lipid depletion, but some mobilisation of reserves must occur during pregnancy and this could have affected tissue concentrations which in the kidney and liver of this animal are quite high.

White-sided dolphins

All males (except animal 13) were categorised as mature. Animal 6 had higher organochlorine values (with the exception of TDE) in its kidney tissues than its blubber. This animal stranded alive and, whilst its blubber thickness and lipid content were quite high, this distribution of contaminants could indicate a rapid mobilisation of lipids perhaps linked to its eventual reason for stranding. The animal was not subject to a post mortem examination. The only female sampled has one of the lower contaminant burdens of the group.

Common dolphins

Sexual maturity is reached at an average age of 6-7 years, and length of 1.6-1.9 metres in females. Thus both animals sampled appear to be adults and post mortem examination suggested that animal 33 was very old. Both are quite highly contaminated compared to adults from other species. Again, the higher kidney concentrations found in 33 might be indicative of blubber mobilisation prior to death, as also indicated by the low blubber lipid concentration recorded (63%).

Bottlenose dolphins

There is considerable variation in size between populations of bottlenose dolphins (Martin, 1990) but these two animals are large even compared to the range reported for bottlenose dolphins around Britain (c. 2.5-2.6m female; c. 2.7m male) (Evans, 1991) and are therefore categorised as adults. Both are quite highly contaminated, particularly the animal found at Newquay in Cornwall (34) - the second most contaminated of all the cetaceans reported here. This would seem to agree with their more inshore habits. This animal could have originated from the group which is now resident around the Cornish coasts or from the neighbouring Cardigan Bay population, or from elsewhere. The Cardigan Bay group appear to be relatively highly contaminated (see Morris *et al.*, 1989 and the discussion below) - although there are few data to compare them with - and this is supported here by the contaminants found in the female from this region. The state of preservation of the animal was poor but the lipid concentration (45%) could indicate some mobilisation of reserves prior to death, perhaps supported by the apparently slightly elevated kidney concentrations.

Striped, whitebeaked and unknown dolphins

Both striped dolphins are male and believed to be sub-adult, as they mature at a length of about 2.19 metres. The values reported are therefore probably consistent with their usually offshore habit and age.

Adult whitebeaked dolphins reach a length of around 2.5-2.7 metres (Evans, 1991). The adult female was fresh when sampled but had a significantly depleted blubber lipid concentration. This may indicate that she had been in a debilitated condition for some time prior to stranding, which may have caused an elevation of blubber and other tissue concentration of organochlorines. Liver concentrations of PCBs and DDE are the highest reported in this work and dieldrin, and TDE values are also high compared to the other animals.

It is tentatively suggested that the animal, which could not be identified, is another whitebeaked dolphin from the same population. Its contaminants profile (notably the high mercury values discussed above) is very similar to that of the whitebeaked dolphin.

Pilot whales

These can be regarded as medium-sized whales; females reaching sexual maturity at a length of 3.8 metres and males at about 5 metres. Of the six sampled, 41 and 43 appeared to be juveniles. The blubber reserves of 38 may have been depleted, although its state of preservation was poor. The biggest animal (40), a male of 5.7 metres, is also the most highly contaminated (PCBs in blubber: 129.6ppm). This value is high compared to most other reported values for long-finned pilot whales (reviewed in Simmonds *et al.*, 1994), except for some reported from the French coasts (mean PCB concentration 189ppm). The mean concentration of PCBs in blubber from a sample of 50 pilot whales killed in the Faroes was 19.51 ppm (Simmonds *et al.*, 1994).

The beaked whales

The biology of these deep water animals is little known. Female Sowerby's beaked whales can reach 5.05 metres in length, so the specimen sampled was probably not an adult. Similarly, the bottlenose whale can be mature at 6 metres and the individual reported here is, therefore, probably also sub-adult. Unfortunately, we lack information about the Cuvier's beaked whale (although its standing near to the Sowerby's may indicate that they were schooling together). All the beaked whales had quite high lipid blubber values, and the bottlenose whale had one of the highest liver concentrations of DDE (58.6ppm).

Minke whales

The only mysticete sampled was a small minke whale which, though mutilated when found, was certainly a very young animal. The blubber lipids were very low (22%) and HCH and DDT could not be detected. It also had the lowest PCB values reported (other than the mother and foetus harbour porpoise pair) and all other contaminants were at, or towards, the lowest end of the scale reported for other species.

Minke whales might be expected to have lower contaminant values than toothed species because invertebrate species may generally make up a greater part of their diet than those of the other essentially piscivores and cephalopod-eating odontocetes. However, the data reported here are difficult to interpret. The low lipid value and the animal's size may indicate that this was a calf separated from its mother. Transfer of organochlorines from the mother may, therefore, only have been limited and it is unlikely to be representative of minke whales in this region.

Partitioning of organochlorines between organs

Aguilar (1985) has shown that although absolute amounts of lipophilic compounds are higher in the blubber, they usually maintain a certain proportionality with other organs. Martineau *et al.* (1987) examined organochlorines in the blubber, liver and kidney of beluga whales (*Delphinapterus leucas*) from the St. Lawrence Estuary, Canada. They noted that, in terms of wet weight, concentrations were invariably

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Species	Date Sampled	Location	Sex	Age	Length (m)	Weight (kg)	Blubber Depth (mm)	Condition
29. "	27/11/'89	Newport, Dyfed	F	A	1.73	46	8	Fresh 8,9
30. "	30/7/'89	Hartlepool Cleveland	M	A	1.70	-	-	Good 10.
31. "	28/8/'89	Wells-Holkam, Norfolk	F	J	1.04	13.5	25	Fresh 10.
32. Common dolphin	5/5/'89	Sand Bay, Bristol Channel	F	A	1.69	-	-	Very poor
33. "	5/3/'90	Cefn Sidan Sands Carmarthen Bay	F	A	1.62	88	17	Fresh 11.
34. Bottlenose dolphin	24/6/'89	Penbryn Beach, Newquay, Cornwall	M	A	2.77	-	-	Fair
35. "	27/6/'89	South Cardigan Bay	F	A	2.75	195	-	Very poor
36. Striped dolphin	22/1/'90	Pendino Sands, Carmarthen Bay	M	J	1.86	74	13	Fresh
37. "	14/2/'90	South Beach, Aberystwyth	M	J	1.77	65	15	Fresh 6.
38. Pilot Whale	13/1/'89	Allihies Co. Cork	M	A	5.57	-	-	Poor
39. "	29/4/'89	Ballyferriter Co. Kerry	F	A	4.63	-	-	Very poor
40. "	9/2/'90	Toormure, Co. Cork	M	A	5.70	-	-	Fresh
41. "	20/2/'90	Barley Cove, Co. Cork	-	J	1.73	-	-	Very poor
42. "	3/3/'90	Sherkin Island, Co. Cork	F	A	3.80	-	-	Poor
43. "	3/3/'90	Fanore Beach, Co. Clare	M	5-6	4.50	-	-	Poor
44. Sowerby's Beaked Whale	17/8/'90	Templeboy, Co. Sligo	F	J	4.55	-	-	-
45. Cuvier's Beaked Whale	18/8/'90	Arlands, Co. Donegal	F	-	-	-	-	-
46. Bottlenose Whale	27/12/'88	Long Strand Co. Cork	F?	J	app.5	-	-	?
47. Whitebeaked dolphin	28/6/'89	West Kirby	F	A	2.55	171	15	Fresh
48. Unknown	26/6/'89	Hoylake, Wirral	F	-	1.71	87	15	Very Poor
50. Minke Whale	4/7/'89	Tragumna, Co. Cork	F	J	3.5?	-	-	- 12*.

Notes:

1. A live stranding - sampled one day after death.
2. Part of a group which stranded over a period of a few days but the bodies recovered were in varying states of decomposition and are believed to be the result of a bycatch.
3. Probable cause of death - pneumonia (numerous lesions).
4. Bycatch: all caught off Galley head, no. 16 on 18/12/'88 and numbers 17-19 on 30/1/'89.
5. Foetus of Harbour porpoise No. 17. The umbilical cord was also analysed but no contaminants were detected expect for 0.090 ppm total PCBs.
6. Bycatch
7. Found with rope around head, probably bycatch.
8. Pregnant.
9. Cause of death - parasitic bronchiopneumonia.
10. Cause of death - injury to head.
11. Old animal - no specific cause of death.
12. Carcass found (and length measured) without head or tail.

Age categories (i.e. A = Adult and J = Juvenile) are based on the size of the animal - see text for details, except where numbers are given (e.g. "5-6") which refer to growth rings measured in teeth.

	DDE			Dieldrin			TDE			DDT		
	B	K	L	B	K	L	B	K	L	B	K	L
1.	32.096	-	0.845	0.244	-	0.080	2.453	-	0.102	2.898	-	0
2.	48.740	0.627	0.234	0.129	0.091	0	1.421	0	0	1.688	0	0
3.	31.115	5.742	1.176	0.304	0.373	0.123	2.025	0.211	0	2.763	0.245	0
4.	23.340	-	0.670	0.085	-	0.128	1.100	-	0	1.212	-	0
5.	25.007	-	0.502	0.165	-	0.095	1.224	-	0	1.447	-	0
6.	31.933	37.420	0.617	0.029	0.030	0.114	4.369	0	0	0	3.058	0
7.	12.603	0.495	-	0.038	0.105	-	2.073	0.124	-	1.507	0.017	-
8.	13.707	4.650	-	0.030	0.021	-	1.533	0.460	-	1.229	0.259	-
9.	26.049	-	-	0.182	-	-	2.376	-	-	2.667	-	-
10	0.529	1.057	0.371	0.090	0.203	0.060	0.062	0	0.042	0	0	0
11	31.045	1.128	0.314	0.049	0.169	0.128	2.599	0.147	0.055	0	0	0
12	17.920	1.302	0.534	0.026	0.193	0.108	1.528	0.196	0.124	0.624	0	0
13	16.846	1.309	0.856	0.099	0.141	0.077	1.012	0.112	0.095	1.247	0	0
14	14.054	-	1.133	0.242	-	0.445	2.54	-	0.286	1.813	-	0
15	4.550	0.198	0.285	0.014	0.139	0.146	0.955	0	0.095	0	0	0
16	1.705	-	-	0.067	-	-	0.632	-	-	0.582	-	-
17	0	0	0	0	0	0	0	0	0	0	0	0
18	1.12	0	0.347	0	0	0.075	0.307	0	0	0	0	0
19	0.048	0.085	1.402	0.067	0	0.072	0	0	0.243	0	0	0.185
20	-	-	0	-	-	0	-	-	0	-	-	0
21	2.137	-	-	0.149	-	-	0.409	-	-	0.334	-	-
22	3.955	-	-	0.307	-	-	1.860	-	-	1.071	-	-
23	15.154	0.184	0.713	0.438	0.142	0.244	3.431	0	0.215	5.823	0	0
24	5.326	0.203	0.163	0.158	0.050	0.326	4.847	0.034	0.558	2.448	0	0
25	2.508	-	-	0.043	-	-	0.622	-	-	1.248	-	-
26	-	-	0.174	-	-	0.061	-	-	0.107	-	-	0.076
27	0.586	-	-	0.166	-	-	0.915	-	-	0.235	-	-
28	45.707	-	-	17.604	-	-	10.161	-	-	4.479	-	-
29	-	0.036	0.026	-	0	0	-	0	0	-	0	0
30	2.534	0	0.065	0.070	0.022	0.061	0.548	0	0	1.183	0	0
31	7.490	0.359	0.554	0.144	0.365	0.543	2.071	0	0.217	1.513	0	0
32	22.517	0	0.522	8.478	0	0.170	2.040	0	0.132	1.618	0	0
33	12.994	0.269	0.145	0.323	0.108	0.119	1.703	0	0	1.479	0	0
34	58.613	0.473	0.677	1.108	0.087	0.162	12.128	0	0.102	4.088	0	0
35	18.532	0.533	0.116	0.371	0.139	0.050	3.414	0.108	0	1.162	0	0
36	6.006	0.127	0.471	0.050	0.031	0.048	0.562	0	0.146	0.877	0	0.102
37	5.502	0.061	0.196	0.036	0.024	0.027	0.521	0	0.111	0.744	0	-
38	0	-	-	0.148	-	-	1.726	-	-	0.480	-	-
39	6.993	-	-	0.080	-	-	0.602	-	-	0.980	-	-
40	19.040	-	-	0.029	-	-	2.095	-	-	6.248	-	-
41	15.198	-	-	0.071	-	-	1.415	-	-	0.547	-	-
42	1.160	-	-	0.018	-	-	0.913	-	-	0.832	-	-
43	3.691	-	-	0.044	-	-	0.423	-	-	0.497	-	-
44	3.374	-	-	0.043	-	-	0.734	-	-	0	-	-
45	1.002	-	-	0.021	-	-	0.326	-	-	0.457	-	-
46	39.946	-	-	0.204	-	-	2.374	-	-	4.331	-	-
47	33.937	0.850	4.456	0.709	0.108	0.434	3.376	0.062	0.331	3.258	0	0
48	4.996	0.162	0.251	0.158	0.087	0.128	4.679	0.136	0.186	0	0	0
49	0.195	-	-	0.053	-	-	0.149	-	-	0	-	-

	PCBsM			PCBsA		
	B	K	L	B	K	L
1.	23.801	-	0.482	46.101	-	0.699
2.	12.437	0.335	0.047	18.746	0.554	0.047
3.	20.580	2.848	0.432	44.485	4.936	0.836
4.	5.883	-	0.218	10.227	-	0.218
5.	9.064	-	0.725	18.971	-	0.736
6.	163.474	172.602	3.862	237.132	260.522	4.380
7.	33.351	2.224	-	86.388	3.839	-
8.	33.965	8.572	-	88.074	16.328	-
9.	11.614	-	-	27.191	-	-
10	1.517	6.559	1.001	2.147	7.821	1.514
11	72.709	3.390	0.599	115.905	4.523	0.918
12	41.575	5.110	4.070	68.689	8.483	4.671
13	8.108	0.956	0.397	19.458	1.678	0.786
14	14.328	-	1.908	24.614	-	2.589
15	18.248	1.402	1.935	30.192	1.931	2.798
16	5.042	-	-	7.168	-	-
17	0.125	0	0	0.55	0	0.172
18	2.236	0	0.362	3.215	0	0.393
19	0.136	0	1.975	0.136	0	2.498
20	-	-	0	-	-	0
21	2.317	-	-	5.551	-	-
22	20.980	-	-	27.318	-	-
23	39.069	0.641	1.386	59.859	0.641	1.783
24	72.458	0.544	5.611	100.947	1.172	6.353
25	27.419	-	-	40.144	-	-
26	-	-	1.800	-	-	2.886
27	8.517	-	-	12.272	-	-
28	149.297	-	-	174.740	-	-
29	-	0.138	0.598	-	0.290	0.608
30	3.301	0	0.147	6.179	0	0.19

	PCBsM			PCBsA		
	B	K	L	B	K	L
31	8.237	0.606	0.774	20.099	1.015	1.185
32	57.354	0.198	2.225	68.124	0.198	2.286
33	36.110	1.396	1.430	44.407	1.676	1.430
34	142.088	0.546	0.871	165.501	0.570	1.021
35	43.228	0.965	0.156	50.689	0.991	0.156
36	4.472	0.221	0.399	8.289	0.252	1.017
37	5.806	0.108	0.209	8.664	0.131	0.551
38	11.078	-	-	35.842	-	-
39	6.329	-	-	8.860	-	-
40	87.655	-	-	129.645	-	-
41	19.698	-	-	32.147	-	-
42	16.644	-	-	25.791	-	-
43	14.590	-	-	20.362	-	-
44	7.607	-	-	11.512	-	-
45	5.771	-	-	8.666	-	-
46	7.955	-	-	9.920	-	-
47	107.442	1.193	6.631	117.251	1.251	7.491
48	16.079	0.744	1.950	21.044	0.912	2.269
49	0.888	-	-	1.278	-	-