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Organochlorine concentrations in resident bottlenose dolphins (*Tursiops truncatus*) in the Shannon estuary, Ireland

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Persistent pollutants are ubiquitous in the marine environment. Cetaceans are marine top predators and as such are particularly susceptible to persistent pollutants that may bio-accumulate through the food chain (Pauly et al., 1998; Strandberg et al., 1998). High concentrations of a wide range of pollutants including polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCP) have been recorded in cetaceans throughout the world (e.g. Aguilar and Borrell, 1995) but the impact of this contaminant burden is not known. High concentrations of PCBs have been associated with reproductive failure in common seals (*Phoca vitulina*) (Reijnders, 1986) and implicated in recent epizootics involving common seals in the North Sea, and striped dolphins (*Stenella coeruleoalba*) in the Mediterranean Sea (Aguilar and Borrell, 1994).

There have been few studies of persistent pollutants in mammals in Ireland (Nixon, 1991; Mason and O'Sullivan, 1992, 1993; Berrow et al., 1998; McKenzie et al., 1998; Smyth et al., 2000). All these studies have shown some level of contamination and Mason and O'Sullivan (1992, 1993) recorded concentrations in mink (*Mustela vison*) and otters (*Lutra lutra*) that could compromise some individuals. Contaminant levels recorded in by-caught harbour porpoise (*Phocoena phocoena*) and common dolphins (*Delphinus delphis*) in Ireland were similar to those reported from Scotland but lower than that reported from Scandinavia (Smyth et al., 2000). McKenzie et al. (1998) determined the concentrations of 19 PCB congeners (CB) and 14 OCP from a mass stranding of white-sided dolphins (*Lagenorhynchus acutus*) in Killala Bay, Co Mayo. Concentrations were similar to those reported in this species from Scotland and from the Western North Atlantic.

Bottlenose dolphins (*Tursiops truncatus*) are frequently observed in coastal waters throughout Europe and are thus thought to be more susceptible to anthropogenic influences such as pollution. This species is listed under Annex II of the European Habitats Directive, which requires member states to designate special areas of conservation (SAC) to protect their habitat. The Shannon estuary is a candidate marine SAC for bottlenose dolphins as it is home to the only known resident group in Ireland (Berrow et al., 1996). The Shannon river and estuary is the largest in the British Isles and is Ireland's busiest waterway with numerous industries along its banks. Limerick City is at the head of the estuary and the estuary itself is 100 km (11,700 km^2) from the tidal limits to the mouth at Loop Head

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(Boelens et al., 1999). As marine top predators, dolphins can act as a good indicator species of water quality and resident dolphins, feeding and calving in the estuary may reflect the status of the Shannon.

Tissue samples for pollution analyses can be obtained from stranded individuals; however, such samples are not considered ideal for pollution studies as the time and cause of death is not known and post-mortem changes in organochlorine concentrations have been documented (Aguilar and Borrell, 1995). In addition, bottlenose dolphins rarely strand in Ireland (Berrow and Rogan, 1997). Biopsy sampling of live individuals provides a much better tissue sample as the time and location of sampling is known and samples can often be linked to known life history and ranging patterns from identified individuals. Although frequently used in North America and Australia (Brown et al., 1991, 1994) biopsy sampling has not been used much in Europe due to concerns over the impact on the dolphins (e.g. Bearzi, 2000). In this study we have sampled known individuals, recognisable through photo-identification (Hammond et al., 1990), from a resident group of dolphins in the Shannon estuary. Sampling known, resident dolphins provides the opportunity to monitor the long term effect of biopsy sampling as well as the possibility of re-sampling individual dolphins to monitor temporal changes in pollutant burdens. The main objective of this study was to determine concentrations of organochlorines in resident bottlenose dolphins and compare the results with similar studies in other geographic regions to assess the potential impact of persistent pollutants on the habitat quality of the Shannon estuary for bottlenose dolphins.

Tissue samples for chemical analyses were obtained using biopsy darts. This involved firing a sampling tip into a dolphin from a standard crossbow. Each tip had three internal barbs, which hold the tissue sample after contact with the dolphin. A high-density foam collar causes the dart to bounce back off the dolphin after it has been struck. The foam collar also ensures the dart floats and can be recovered after delivery. A licence was obtained from Dúchas (No. C 8/2000), which permitted sampling of up to 10 individuals from the Shannon estuary candidate SAC.

After being located, the dolphins were tracked for a minimum of 10 min before a biopsy attempt was made. The dolphins' behaviour including dive duration, direction of travel, density or relative distances of group members, and the presence of adult-calf pairs was recorded. No calves, immature animals or adults accompanied by calves were sampled. Samples were to be taken from the flank region below the dorsal fin where the blubber layer, in bottlenose dolphins from European waters, is about 40 mm thick during the summer (Paul Jepson, personal communication). Video of the biopsy attempt was taken to document reaction and ensure the individual struck could be re-identified. The reaction of the dolphin to a biopsy attempt was defined following Weinrich et al. (1991):

(1) *No reaction:* Dolphin continued its pre-attempt behaviour.
(2) *Low-level reaction:* Dolphin modified its behaviour slightly, e.g. rapid dive or flinch.
(3) *Moderate reaction:* Dolphin modified its behaviour in a more forceful manner but gave no prolonged evidence of behavioural disturbance, e.g. tail slap, acceleration and rapid dive.
(4) *Strong reaction:* Dolphin modified its behaviour in a succession of forceful activities, e.g. successive percussive behaviours (breaches, tail slaps).

Following every biopsy attempt, the dolphin and group were tracked for up to 20 min, where possible, to observe any behavioural changes. During this post-biopsy period, the dolphins were approached within a distance of 10 m to solicit any reaction to the boat.

Prior to sampling, each tip was boiled for 10 min and cleaned with isopropyl alcohol together with all equipment that may be in contact with the sample. Eight tips were purchased for this study (25, 35 and 40 mm in length) and stored in aluminium foil after cleaning. After successfully obtaining a sample, biopsy tips with sample were stored on ice before sub-sampling. On return to port, the skin was removed from the sample and cut in half before storing in DMSO solution for sex determination at the Department of Zoology, University of Aberdeen. The blubber sample was wrapped in hexane washed aluminium foil and stored in a glass jar at −20° C. All samples were frozen within 4 h of sampling and sent to the Marine Institute for analyses. The gender of the bottlenose dolphins sampled was determined using a molecular genetic approach. Total genomic DNA was extracted from skin tissue samples using a standard proteinase K, phenol/chloroform extraction protocol (Sambrook et al., 1989). Gender was determined by the co-amplification of a 147 bp fragment of the sex-specific SRY gene (Richard et al., 1994) and a 211 bp microsatellite locus (EV37; Valsecchi and Amos, 1996). Multiplexed PCR reactions (10 μl) contained 1.5 mM $MgCl_2$, 1× NH_4 buffer, 0.2 mM of each nucleotide, 0.5 μM of the SRY primers, 0.25 μM of the EV37 microsatellite primers and 0.5 units of *Taq* polymerase (Bioline). Fragments were amplified using a constant 58 °C annealing temperature, and PCR products were separated on an ethidium bromide stained 2% agarose gel. Multiplexing the SRY marker with a microsatellite marker generates an internal positive control reaction, thereby avoiding erroneous female assignment due to general PCR failure. This multiplexed PCR protocol produces a sex-specific banding pattern that has proved highly reliable through validation

Table 1
Date, location and data recorded for each biopsy sample taken

Sample no.	Date	Location	Sample	Photo-ID	Video	Sex
#1	19/09/00	Clonderlaw	<1 cm	Yes	No	Male
#2	19/09/00	Killimer	2 cm	Yes	Yes	Male
#3	20/09/00	Kilcredaun	3 cm	Yes	Yes	Male
#4	20/09/00	Kilcredaun	<1 cm	Yes	No	Male
#5	22/09/00	Carrig	3 cm	Yes	Yes	Female
#6	22/09/00	Tarbert	3 cm	Yes	Yes	Male
#7	22/09/00	Glin	3 cm	Yes	Yes	Male
#8	22/09/00	Foynes	3 cm	Yes	Yes	Female

with samples from over 30 stranded dolphins of known sex.

Each blubber sample was analysed for a range of pesticides and PCBs. Lipid was extracted following the procedure of Smedes described in QUASH (1999). Seven organochlorines (HCB, α-HCH, β-HCH, *p*,*p*′-DDE, lindane, *trans*-chlordane, and *trans*-nonachlor) and 11 individual chlorobiphenyls and the sum of the seven congeners (CB 28, 52, 101, 118, 138, 153, 180) recommended by ICES for monitoring purposes were analysed by dual column gas chromatography with electron capture detection (Smyth et al., 2000). No reference material for the analysis of lipid content or for the quantification of organochlorines in marine mammals is currently available in Europe. A number of other QA/QC materials however were employed to ensure data quality. These included the extraction of mussel tissue from QUASIMEME inter-comparison exercises (QOR062BT) of known lipid content, and the analytical analysis of two certified fish oil reference materials BCR 598 having certified OC content and BCR 349 with certified levels of PCBs. Lipid content in the reference mussel tissue was measured at $2.25\% \pm 0.02\%$ ($n = 3$) compared to an expected value of 2.18%, all values falling with 95% confidence intervals for the analysis. The recovery for each of the OCs quantified in certified reference material BCR 598 ranged 88–100% and from 91% to 111% for each of the PCB's analysed in certified reference material 349. One of each of these materials and a procedural blank was analysed with the batch of samples in addition to a system suitability standard employed to ensure GC operation within set criteria. Limits of quantification for each analyte were in the order of 0.1–0.5 $\mu g\,kg^{-1}$. Analysis was carried out by dual column chromatography using Chrompack CPSIL 8 and 19CB columns on a Hewlett Packard 5890 Series II GC. All analyses were carried out in the Marine Institute facilities in Abbotstown, Dublin.

Between the 19 and 22 September 2000, tissue samples were obtained from eight individual dolphins, six males and two females. The location and sample details are described in Table 1. The strike rate was 100% and tissue samples (both skin and blubber tissue) were obtained from all biopsy attempts. Only two samples were obtained in the outer estuary, off Kilcredaun Head near Carrigaholt, with the remainder east of Scattery Island (Fig. 1). For five of the samples the length of blubber obtained was c. 3 cm, one 2 cm and only two samples <1 cm. Sample 4 was mainly of connective tissue and not blubber although it was still possible to extract lipid from this sample. High quality identification photographs were obtained for all eight sampled animals and video footage was obtained for six of the eight biopsies (#1 was not taken due to heavy rain and #4 missed as the film ran out just before the biopsy dart was delivered).

A reaction to a biopsy attempt may be described in two ways: (a) the intensity of the reaction and (b) the duration for which the reaction was recorded. A low-level reaction may be only a slight modification for a short period while a strong reaction could be a significant change in behaviour, which occurred for a long duration. The same reaction over a short period may still be described as strong but the assessment of the potential effect on the dolphin may be tempered by its limited duration. Reactions to each biopsy attempt are summarised in Table 2.

Five of the eight dolphins biopsied exhibited low-level reactions following dart impact. Two dolphins showed a moderate reaction (#2 and #5), and one animal (#4) a strong reaction. Low-level reactions in this study were all flinch and fast dive. A moderate reaction was observed after #2 was taken when a single dolphin was observed breaching up to 2 min after the biopsy had been taken but whether it was the biopsied animal could not be determined. Similarly a half-breach was observed 1 minute after #5 was taken. If these breaching dolphins were the ones that had been stuck then this would be considered a moderate reaction, as described by Weinrich et al. (1991), i.e. when behaviour was modified in a more forceful manner but gave no prolonged evidence of disturbance. The dolphin #4 reacted to the biopsy attempt by breaching 9 times within 4 min of being biopsied as well as carrying out one head slap and one tail fluke. Blood was observed coming from the biopsy wound in the animals' dorsal fin. Over the next 8 min breaching occurred less frequently as surfacing intervals became more frequent (c. 10 s) and regular. Photo-

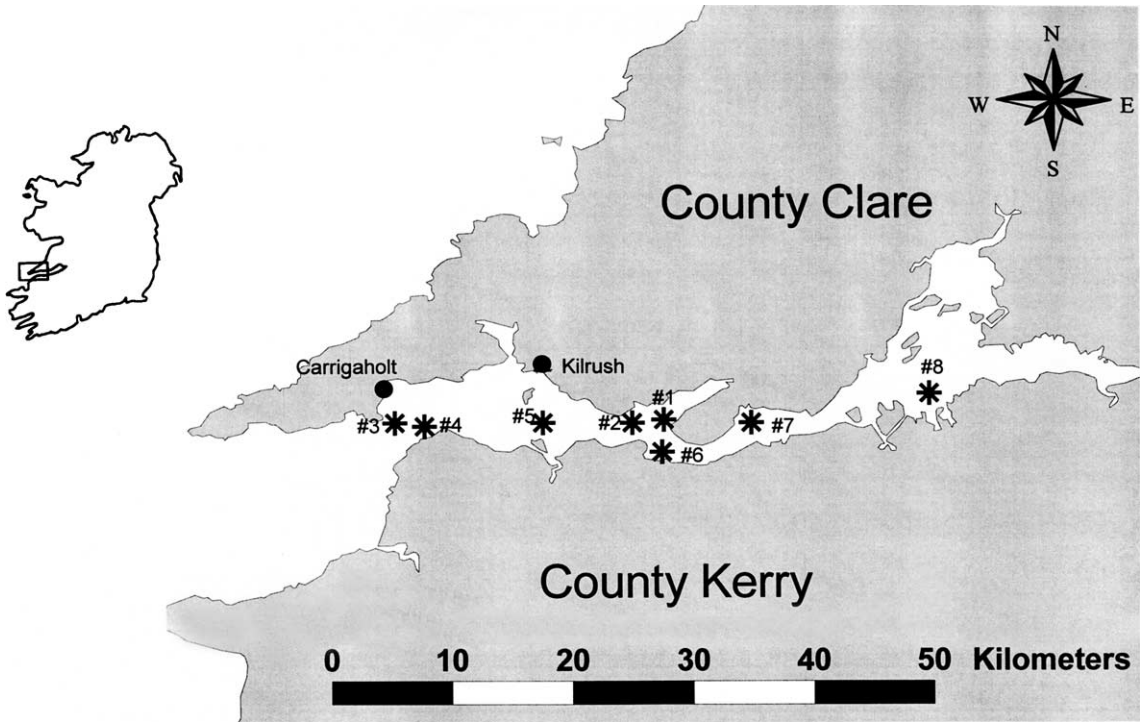

Fig. 1. Location of sampled dolphins in the Shannon estuary, Ireland.

Table 2
Individual and group reactions to biopsy sample

Dolphin ID	Reaction	Time taken to approach <10 m of the boat after biopsy (min)	No. of dolphins that reacted	Density of group	Direction of travel
#1	Low-level	17	Individual only (in group)	Tight group	Unchanged
#2	Moderate	16	Three fast-dived together	Individual	Unchanged
#3	Low-level	11	Group fast dived	No change	Unchanged
#4	Strong	16	Individual only (in group)	Left group	Changed
#5	Moderate?	11	Individual only (in group)	Together	Unchanged
#6	Low-level	–	On own	Individual	Opposite
#7	Low-level	2	Individual only (in group)	No change	Unchanged
#8	Low-level	6	On own	Individual	Unchanged

graphs taken of this dolphin showed it had been hit on the dorsal fin c. 10 cm up from the base. The dorsal fin comprises connective tissue and arteries, which are much closer to the skin.

After each biopsy attempt, the time taken for dolphins (including the biopsied animal) to re-approach within 10 m of the boat ranged from 2 to 17 min (mean = 11.3, SE = 2.1 min), but part of this time was involved in recovering the sample from the water. Two of the dolphins sampled were solitary when struck, and one of these individuals changed its direction of travel following sampling. This was the only dolphin or group whose direction of travel altered post-biopsy. Of the remaining 6 samples, on four occasions (67%) only the target dolphin exhibited a response, while in the other two cases, the entire group fast-dived together. Only one dolphin left the group it was with after it had been biopsied, and this was the dolphin #4, which showed a strong reaction to being hit. On one occasion (#1) the group was more tight post-biopsy, than before the attempt.

The concentrations of OCPs and PCBs are listed in Table 3 (expressed on a lipid weight basis) and Table 4 (expressed on a wet weight basis). Both are presented to allow comparison of concentrations with other published studies. Concentrations varied considerably with only PCB congener, CB126, occurring in small (<20 ppb) or undetectable concentrations. Mean concentrations were greater in males than females for all OC analysed. In the two females sampled, concentrations were consistently greater in #8 compared to #5. Although variation was greater in male dolphins, #4 generally had the highest concentrations, followed by #6, #7 and #1. The highest concentrations of individual

Table 3
Organochlorine concentrations in bottlenose dolphins *T. truncatus* from the Shannon estuary (mg kg^{-1} lipid weight)

	Dolphin ID (Sex)								Mean	Median	SD	%RSD
	1 (♂)	2 (♂)	3 (♂)	4 (♂)	6 (♂)	7 (♂)	5 (♀)	8 (♀)				
HCB	0.077	0.11	0.319	0.533	0.168	0.24	0.045	0.369	0.233	0.204	0.167	72
α-HCH	0.339	0.091	0.061	0.173	1.036	0.054	0.034	0.08	0.234	0.086	0.339	145
β-HCH	n.d.	0.025	0.022	0.267	0.493	0.037	0.009	0.028	0.126	0.028	0.186	148
Lindane (γ-HCH)	0.032	0.061	0.112	0.151	0.28	0.047	0.026	0.128	0.105	0.087	0.085	81
Trans-chlordane	0.042	0.008	0.020	0.050	0.018	0.028	0.004	0.026	0.025	0.023	0.016	64
Trans-nonachlor	2.09	1.18	1.31	12.0	3.52	5.21	0.17	2.51	3.49	2.30	3.75	107
p,p′-DDE	15.9	3.89	3.52	32.5	22.9	42.0	0.37	7.23	16.0	11.6	15.2	95
PCB 28	0.123	0.023	0.040	0.042	0.255	0.040	0.010	0.019	0.069	0.040	0.083	120
PCB 31	0.162	0.042	0.058	0.135	0.303	0.134	0.010	0.057	0.113	0.096	0.094	83
PCB 52	0.684	0.294	0.375	1.68	1.56	1.51	0.039	0.679	0.853	0.682	0.642	75
PCB 101	0.724	0.699	0.843	2.21	1.28	1.93	0.094	1.21	1.12	1.03	0.691	61
PCB 105	0.299	0.272	0.347	0.758	0.506	0.573	0.033	0.418	0.401	0.383	0.218	54
PCB 118	0.944	0.916	1.03	2.68	1.23	2.11	0.12	1.52	1.32	1.13	0.789	60
PCB 126	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	–	–	–	–
PCB 138	6.70	2.27	2.54	14.0	9.22	18.3	0.252	3.82	7.13	5.26	6.30	88
PCB 153	10.2	3.47	3.76	22.4	13.2	28.1	0.355	5.58	10.9	7.87	9.85	91
PCB 156	0.591	0.142	0.153	1.273	0.377	1.47	0.019	0.182	0.526	0.280	0.553	105
PCB 180	3.42	1.17	1.33	7.54	4.55	9.57	0.182	1.64	3.68	2.53	3.35	91
Sum ICES 7	21.9	8.14	9.08	48.4	30.1	59.6	0.958	13.3	23.9	17.6	20.8	87

n.d. = not detectable.

Table 4
Organochlorine concentrations of bottlenose dolphin *T. truncatus* from the Shannon estuary (mg kg^{-1} wet weight)

	1 (♂)	2 (♂)	3 (♂)	4 (♂)	6 (♂)	7 (♂)	5 (♀)	8 (♀)	Mean	Median	SD	%RSD
HCB	0.010	0.019	0.103	0.036	0.004	0.071	0.006	0.025	0.034	0.022	0.035	103
α-HCH	0.042	0.016	0.019	0.012	0.026	0.016	0.014	0.005	0.019	0.016	0.011	59
β-HCH	n.d.	0.004	0.007	0.018	0.012	0.011	0.004	0.002	0.008	0.007	5.678	69
Lindane (γ-HCH)	0.004	0.011	0.035	0.01	0.007	0.014	0.01	0.009	0.013	0.010	0.010	76
Trans-chlordane	0.005	0.001	0.006	0.003	n.d.	0.008	0.002	0.002	0.003	0.003	0.003	81
Trans-nonachlor	0.26	0.205	0.408	0.812	0.087	1.553	0.069	0.169	0.445	0.233	0.507	114
p,p′-DDE	1.96	0.67	1.13	2.20	0.565	12.5	0.050	0.485	2.45	0.903	4.13	169
PCB 28	0.015	0.004	0.013	0.003	0.006	0.012	0.001	0.001	0.007	0.005	0.006	82
PCB 31	0.020	0.007	0.018	0.009	0.007	0.04	0.001	0.004	0.013	0.008	0.013	95
PCB 52	0.084	0.051	0.120	0.114	0.039	0.450	0.005	0.046	0.114	0.068	0.141	124
PCB 101	0.089	0.121	0.271	0.15	0.032	0.573	0.013	0.081	0.166	0.105	0.183	110
PCB 105	0.037	0.047	0.112	0.051	0.013	0.171	0.004	0.028	0.058	0.042	0.056	97
PCB 118	0.116	0.159	0.332	0.182	0.03	0.628	0.016	0.102	0.196	0.138	0.201	103
PCB 126	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	–	–	–	–
PCB 138	0.826	0.393	0.815	0.952	0.228	5.432	0.034	0.256	1.12	0.604	1.78	159
PCB 153	1.25	0.601	1.21	1.52	0.327	8.36	0.048	0.374	1.71	0.905	2.74	160
PCB 156	0.073	0.025	0.049	0.086	0.009	0.438	0.003	0.012	0.087	0.037	0.145	167
PCB 180	0.422	0.203	0.429	0.512	0.113	2.85	0.025	0.11	0.583	0.313	0.932	160
ICES 7 PCB	2.81	1.53	3.19	3.46	0.775	18.3	0.142	0.97	3.90	2.17	5.94	153

n.d. = not detectable.

OCs were for *p,p′*-DDE (42.0 and 32.5 mg kg^{-1} lipid) followed by the PCB congeners CB153 (28.1 and 22.4 mg kg^{1} lipid weight) and CB138 (18.3 and 14.0 mg kg^{-1} lipid weight). Concentrations of *trans*-nonachlor and CB180 were elevated in #4 and #7. A maximum concentration of 59.6 mg kg^{-1} lipid was recorded in #6 and 48.4 mg kg^{-1} lipid in #4, both male dolphins. The highest concentration recorded in a female was 13.3 mg kg^{-1} lipid in #8. The same overall pattern occurs when expressed as wet weight (Table 4) with CB153 and CB138 occurring in greatest concentrations with maximum concentrations recorded in #7, #4, #3 and #1.

The Shannon estuary is Irelands' only site (SAC) designated for the conservation of cetaceans and their habitat. In order to manage such a site it is essential to quantify any potential threats, including the levels of persistent pollutants and assess their impact on the health of the animals. This was also the first attempt in Ireland to obtain tissue samples from wild cetaceans using biopsy darts. The technique was very successful in obtaining tissue samples and has provided an opportu-

Table 5
Comparison of organochlorine concentrations ± standard deviations (mg kg^{-1} lipid weight) recorded in male dolphins from the Shannon estuary compared to similar studies on males of other odontocete species elsewhere in Irish waters

Location	Shannon estuary	South and west coast	Southwest coast	Killala Bay, Co Mayo
Species	Bottlenose dolphin	Harbour porpoise	Common dolphin	White-sided dolphin
References	This study	Smyth et al. (2000)	Smyth et al. (2000)	McKenzie et al. (1998)
Sample size (n)	♂ $n = 6$	♂ $n = 6$	♂ $n = 5$	♂ $n = 8$
Age range (years)	?	2–6	1–11	1–17
HCB	0.241 ± 0.168	–	–	0.310 ± 0.140
α-HCH	0.292 ± 0.380	–	–	–
β-HCH	0.019 ± 0.209	–	–	–
Lindane (γ-HCH)	0.114 ± 0.093	0.12 ± 0.17	0.045 ± 0.047	–
Trans-nonachlor	4.21 ± 4.09	0.90 ± 0.46	1.54 ± 1.24	3.54 ± 1.94
p,p′-DDE	20.1 ± 15.5	1.94 ± 0.72	7.67 ± 5.27	14.8 ± 11.0
CB153	13.5 ± 10.0	2.58 ± 1.28	3.03 ± 2.76	13.1 ± 10.2
ICES 7	29.5 ± 20.9	6.15 ± 2.80	8.95 ± 5.95	–

nity to assess the long-term impact of this sampling technique.

Reaction to biopsy attempts by Odontocetes is generally greater than that reported for Mysticetes (Brown et al., 1991; Weinrich et al., 1991; Hooker et al., 2001). Most reactions to biopsy in the present study were low-level or moderate; only one dolphin showed a strong reaction. Most reactions were similar to the short-term behavioural changes reported by Weller et al. (1997); mainly flinch and fast-dive by the individual sampled, with little observed effect on group dynamics or direction of travel. The one individual in the Shannon that exhibited a strong reaction was hit in the dorsal fin and behaved in a similar manner to bottlenose dolphins tagged with a crossbow or pole with a VHF radio transmitter attached to a suction-cup (Schneider et al., 1998) when dolphins breached many times in quick succession. Similar devices have been successfully deployed on other dolphin species, some smaller in size than bottlenose dolphins e.g. Dall's porpoise (*Phocoenides dalli*). This suggests that bottlenose dolphins, as a species, react very strongly to interference, which could include poor biopsy attempts. All dolphins sampled remained within 10 m of the boat for between 2 and 17 min after the biopsy attempt, suggesting that although dolphins react to the biopsy, they do not associate this with the vessel.

The use/deployment of non-tethered projectiles (i.e. darts and tags) provides a very powerful tool for improving our understanding of the movements and diving behaviour of cetaceans, as well as providing tissue samples for a wide range of analyses. These techniques can provide important data for the management and conservation of cetacean populations and their habitat. There is, however, a cost to using this technique, usually involving some degree of behavioural disturbance and this must be taken into account before initiating a study of this kind.

Due to their high trophic level, high lipid content and longevity, dolphins can accumulate relatively high burdens of contaminants such as organochlorines. Concentrations of organochlorines tend to increase with age in males, and decrease in the blubber of mature females, due to reproductive transfer to offspring during both gestation and lactation (Borrell et al., 1995). The results from this study are consistent with that reported elsewhere, although the age of the sampled animals is not known.

There are no data on concentrations of OCP in bottlenose dolphins from Irish waters with which to compare the results from this study. Table 5 compares our data with recent data on organochlorine levels in other Odontocete species sampled in Ireland. Age may strongly influence accumulation of OCP and PCB and this is not known from the Shannon study thus we may not be comparing similar age profiles. Comparison of levels of contaminants in cetaceans is further confounded by the lack of standardisation of both methodology and formats for reporting results. Furthermore, analytical comparability is undermined by the lack of quality assurance tools available to laboratories engaged in testing for contaminants in cetaceans. There is no proficiency testing schemes or certified reference materials for marine mammal matrices available in Europe (de Boer and McGovern, 2001). However the samples from the Shannon were analysed in the same laboratory as those by Smyth et al. (2000), which provides some consistency.

The results from this study suggest that the mean levels of OCP and PCB contaminants are higher in bottlenose dolphins from the Shannon estuary compared to results reported by Smyth et al. (2000) for harbour porpoise and common dolphin incidentally caught in fishing nets in Irish waters, but are similar to those from a mass stranding of white-sided dolphins from Killala Bay, on the west coast of Ireland (McKenzie et al., 1998). There are two resident or semi-resident populations of bottlenose dolphins in the United Kingdom. One is in northeast Scotland, known to range throughout NE Scotland, from the Moray

Firth to the Firth of Forth, and the other around Cardigan Bay, in on the Welsh Coast. The Moray Firth is a relatively non-industrialised area. The levels reported in this study are similar to those reported for bottlenose dolphins from Moray Firth for both PCBs (ICES 7 PCB 0.8–15 mg kg^{-1} wet weight) and OCPs (Law and Allchin, 1994). Much higher levels of PCBs (ICES 7 PCB 77–92 mg kg^{-1}) have been reported for bottlenose dolphins from Cardigan Bay (Law et al., 1995). More recently, similar results have been reported for a range of cetaceans including six dolphins (5 species) stranded on the coasts of England and Wales (Law et al., 2001). The levels of organochlorines are much lower than those for bottlenose dolphins from Italian coastal waters where a mean of 584 ± 456 mg kg^{-1} (lipid weight) has been reported (Corsolini et al., 1995).

McKenzie et al. (1998) demonstrated the difficulties in interpreting results of pollution studies as the similarity of contaminant patterns in white-sided dolphins from Irish and Scottish waters suggested these dolphins were not exposed to local point sources of contamination but to a ubiquitous source in the marine environment. The congener distribution pattern is similar in all individual dolphins sampled suggesting uniformity in physiological response to the contaminant burden.

Wagemann and Muir (1984) considered PCB concentrations of between 50 and 200 mg kg^{-1} wet weight in blubber may put the health of cetaceans at risk. Levels in this study were much less than these (maximum 18.3 mg kg^{-1} wet weight) and are not thought to pose a risk to health. Routine monitoring of shellfish from the Shannon estuary indicates low-level organochlorine contamination, typical of the Irish west coast (McGovern et al., 2001). This study suggests that persistent pollutants are not a significant threat to bottlenose dolphins in the Shannon estuary but water quality and contaminant burden should continue to be monitored in order to ensure water quality is maintained at a favourable status for bottlenose dolphins.

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Concentrations of selected trace metals (Cu, Pb, Zn), organochlorines (PCBs, HCB) and total PAHs in mangrove oysters from the Pacific Coast of Mexico: an overview

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The biomonitoring of trace contaminants provides information on the geographical and temporal variation in the concentrations of those substances which are bioavailable in coastal waters. Biomonitors have been defined as species which accumulate trace contaminants in their tissues, revealing essentially that fraction in the environment which may be of direct ecotoxicological relevance, i.e. the bioavailable chemical forms (Rainbow and Phillips, 1993; Blackmore et al., 1998). Various organisms potentially useful as biomonitors occur along the Pacific coast of Mexico, including oysters, mussels,

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