Organochlorine contaminants in northern royal albatross from Taiaroa Head, Otago Peninsula

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Summary

Northern royal albatross *(Diomedea sanfordi)* eggs and chicks were collected at Taiaroa Head from 1995 to 1998 by Department of Conservation staff.

Frozen whole eggs and chicks were submitted to ESR for chemical analysis. The analysis quantified the levels of polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs) and a range of persistent organochlorine pesticides, including dichlorodiphenyltrichloroethane (DDT) group compounds.

The total international dioxin equivalents (I-TEQ) ranged from 3.2 to 15.4 pg/g wet weight, while PCB concentrations (sum of 32 congeners) ranged from 15.7 to 89.2 ng/g wet weight. These values are very similar to the levels reported in northern royal albatross eggs collected from the Chatham Islands over the 1995 - 1996 period.

Certain organochlorine pesticide residues were detected in all samples. The most prevalent were p,p'-DDT, p,p'-DDE, hexachlorobenzene (HCB) and heptachlor epoxide, which had mean concentrations in eggs of 58 ng/g, 6.2 ng/g, 5.0 ng/g and 1.2 ng/g wet weight, respectively.

The profile of PCDD/F and PCB congeners was consistent with previous analysis conducted on northern royal albatross eggs from the Chatham Island. The profiles were also similar to those reported in albatross species from the North Pacific ocean.

There was no apparent effect on the measured levels of sampling season (95/96 versus 97/98) or whether analysis was on eggs or chicks. The mean (range) I-TEQ values for eggs 1995/96, eggs 1997/98 and chicks 1997/98 were 8.14 (4.79 - 12.88), 9.91 (6.57-13.79) and 9.91 (3.20-15.37) pg/g wet weight, respectively.

As all egg samples were from females of known age, the relationship between the age of females and the concentration of organochlorine residues in eggs was examined. No significant relationships were established. As an example, the regression between female age and egg concentration p,p'-DDE ($y = -1.98x + 112.57$) had a very weak r^2 value of 0.155.

The mean value and range for egg shell thickness was 0.57 min (0.53 - 0.63) indicating no egg shell thinning in the samples collected. The lack of egg shell effects and the similarity between residues in this study and samples previously collected from the Chatham Islands, suggests apparent reproductive impairment in Chatham Island albatross is not caused by the analysed organochlorine contaminants.

The similarity of the organochlorine levels between Taiaroa Head and Chatham Island albatross suggests that previous conclusions regarding risk still apply: namely, that while the greatest risk of adverse effects to albatross are attributable to the I-TEQ, the residues are below the exposure levels where adverse effects would be expected to occur.

1. Introduction

PCDD/Fs, PCBs and selected organochlorine pesticides are a group of chemicals that have attracted considerable attention due to their high toxicity, persistence in the environment, and ability to bioaccumulate. The combination of these properties means that organisms at the upper levels of the food chain can potentially be exposed to concentrations sufficient to cause adverse effects. In several regions including the relatively polluted North American Great Lakes system, the levels of some of these chemicals reached concentrations sufficient to cause reproductive impairment in animals, including predatory birds (SETAC 1998). In particular, DDE, a degradation product of DDT, has been shown to cause egg shell thinning in birds (Giesy et al. 1994).

Although 'remote' locations typically do not have the industry bases that result directly in nearby regions receiving high inputs of organochlorine pollutants, the threat of organochlorine compounds in these locations cannot be discounted, because of atmospheric redistribution from more polluted areas. This mechanism of long-range transport and deposition is demonstrated by the contamination occurring in polar and other remote regions (SETAC 1998).

Albatross are predatory birds which feed at the top of the marine food chains and therefore can be expected to accumulate relatively high concentrations of organochlorines (Walker 1990). In North Pacific albatrosses, high concentrations of PCBs and PCDDs have been recorded (Jones et al. 1996), levels that in at least one species have been suggested as sufficient to cause reproductive impairment (Auman et al. 1997). The observation of reproductive deficiencies, including egg shell thinning, in albatrosses at the Chatham Islands resulted in a study being undertaken examining the levels of organochlorine pollutants in these birds (Jones 1999). While the levels recorded were relatively low in comparison with those reported in Jones *et al.* (1996), the study did conclude that the levels of some compounds were approaching concern limits.

This study was designed primarily to:

- quantify the levels of organochlorine contaminants in northern royal albatross *(Diomedea sanfordi)* from Taiaroa Head;
- enable comparison with the levels recorded in albatross from the Chatham Islands and thereby assist in deciding whether observed reproductive impairment was caused by organochlorine contaminants; and
- contribute information to the growing database describing the levels of organochlorine contaminants in avian species, both in New Zealand and internationally.

2. Methods

2.1 SAMPLING

Northern royal albatross eggs and chicks were collected in field seasons from 1995 to 1998 by Department of Conservation field staff. The collection was opportunistic, occurring when dead eggs or chicks were found. The samples were stored frozen at -20°C. For analysis, eggs were thawed and the embryos and embryo sac collected in pre-cleaned glass jars. Chicks were thawed, cut into small pieces with a cleaving knife and homogenised.

2.2 ANALYSIS

For analysis in the laboratory, embryos and chicks were thoroughly homogenised and a portion extracted to provide the total concentration of contaminants in the original sample. Samples were analysed by standard isotope dilution procedures (Jones et al. 1996). Analytes of interest were PCDD/Fs, PCBs and a range of organochlorine pesticides. Before extraction, a range of isotopically labelled internal standards were added to each sample. The samples were then subjected to a range of chemical and chromatography clean-up procedures to remove interfering substances.

After clean-up, analytes were determined by high resolution gas chromatography with high resolution mass spectrometry for identification and quantification of compounds of interest. Full analytical details are available on request, as are details of the quality assurance procedures used in the laboratory. All analyses were performed under the laboratory's ISO 9002/ISO Guide 25 - IANZ (formerly Telarc) accreditation.

3. Results & Discussion

The details for each sample, including collection data, maternal age, embryo or chick weight, lipid content and egg shell thickness are described in Table 1.

3.1 PCDD/F AND PCBS

While there are several hundred individual chemicals (congeners) referred to by the names 'PCDD', 'PCDF' and 'PCB', they vary widely in their toxic properties. To enable comparisons of the toxicity that these chemicals have in mixtures, toxic equivalency factors (TEFs) were developed. They relate the toxicity of each congener in comparison with 2,3,7,8-TCDD, widely regarded as the most toxic of the PCDD, PCDF and PCB congeners. By multiplying the

concentration of each congener with its TEF, and summing for all congeners, a value (I-TEQ) can be derived which gives a measure of the 'total' toxicity relative to 2,3,7,8-TCDD. The TEQ for a particular compound group, i.e. PCB-TEQ, can be derived by only summing the contribution of PCB congeners.

The I-TEQ, PCDD/F-TEQ and PCB-TEQ for each sample are described in Table 2. The total I-TEQ measured in northern royal albatross eggs from Taiaroa Head are very similar to levels reported in the same species from the Chatham Islands (Table 3). Also very similar is the percentage contribution of PCBs to the I-TEQ, 87% in Taiaroa Head albatross versus 83% in Chatham Island albatross. In albatross samples collected from Midway Island, the contribution of PCBs to the I-TEQ was lower, ranging from 30 to 40% (Jones et al. 1996). While there has been little other work examining the I-TEQs in New Zealand avian species, the total I-TEQ measured in this study are relatively low in comparison with levels recorded in albatross from Midway Atoll which were up to 10 fold higher depending on the species (Table 3). The I-TEQ in eggs from double-breasted cormorants and Caspian terns in the Great Lakes region were in the order of 350 to 2 800 pg/g wet weight (Yamashita et al. 1993). A level of contamination two orders of magnitude greater than found in this study.

In contrast to the PCB-TEQ, the PCB sum is derived by summing the concentrations of PCB congeners present without correction for relative toxicity. In this study, 32 PCB congeners were quantified in the determination of the PCB sum, an increase in 7 over the 25 congeners measured in the previous study examining northern royal albatross. However, the additional congeners only increased the total PCB sum by 2-3%, and therefore the two methods for deriving total PCBs can be considered comparable. (The additional PCB congeners also did not alter the derivation of PCB-TEQ values.) The comparison between total PCB levels in eggs from the Taiaroa Head, Chatham Islands, and other sea birds are given in Table 3. In a study examining the levels of total PCBs in New Zealand collected seabirds, Solly & Shanks (1976) reported values that were typically in the range 0.1-1 mg/g muscle wet weight, although values closer to 7 mg/mg muscle and liver wet weight were reported in a gannet and petrel species. Although differences in analytical methodology and sample need to be remembered, the total PCB levels of approximately 0.05 mg/g wet weight in Northern Royal albatross eggs appear comparatively low (Table 1).

The congener profiles for PCDD/Fs and PCBs in Taiaroa Head northern royal albatross were compared to the profiles reported in the Chatham Islands, and with other albatross species on Midway Atoll (Figs 1 and 2). The congener data for individual samples is described in Tables 4 and 5. As would be expected given the relative geographical proximity, the eggs from Taiaroa Head and Chatham Islands had very similar profiles. The PCB profiles were also comparable to those in albatross from Midway Atoll, however, the royal northern albatross samples typically had reduced levels of the lower chlorinated congeners and increased levels of the higher chlorinated congeners. In Jones (1999), the PCB profile for New Zealand albatross was attributed to local or inshore sources of PCBs, since an abundance of lower chlorinated PCBs would have suggest atmospheric deposition as a major source.

The PCB congener profile was also comparable to levels reported in cormorant samples collected from Japan. In this later study the International Union of Pure and Applied Chemistry (IUPAC) congener number 153 was the most abundant, followed by IUPAC Numbers 138, 118, 180, 99, 105 and 132. Together these congeners accounted for nearly 70% of the total PCB load (Guruge &Tanabe 1997). In northern royal albatross eggs these congeners accounted for approximately 77% of the PCB load.

The PCDD/F profiles in northern royal albatross were also similar to those reported in Midway Atoll samples, albeit that the latter had relatively higher levels of the hexa-CDF congeners and tended to have lower concentrations of octachloro-dibenzodioxin (OCDD). Interestingly, there was also an apparent difference between levels of OCDD in chicks and eggs from Taiaroa Head, although the range of values and limited number of chick samples means some caution is required in attributing significance to the difference. Further, the OCDD profile in chicks is similar to the mean value reported for albatross samples (not limited to northern royals) from the Chatham Islands (Jones 1999).

3.2 ORGANOCHLORINE PESTICIDES

In this study, p,p'-DDE constituted 87% of the total DDT compounds, while the mean percentage ratio of p,p'-DDT to p,p'-DDE in eggs was 11%. This compares with mean percentage ratios of 19.5% in northern royal albatross eggs recently collected from the Chatham Islands, 35% in wandering albatross eggs from the Auckland Islands (Bennington et al. 1975), and the 1974 finding that p,p'-DDE constituted 78% of the total DDT compounds in Taiaroa Head and Stewart Island mutton birds (Dacre 1974). Relatively lower percentage ratios of p,p'-DDT to p,p'-DDE were reported in black-footed and Laysan albatross from Midway Atoll. The values were 2.3 and 9.5%, respectively.

The actual levels of DDT compounds in northern royal eggs from Taiaroa Head (Table 6) are similar to the levels reported in eggs from the same species in the Chatham Islands, and for wandering albatross from the Auckland Islands (Bennington et al. 1975) (Table 3). The levels reported for other marine birds collected from New Zealand are highly variable, with historic levels of DDT compounds reported up to 10-fold higher and lower depending on the species involved (Dacre, 1974; Bennington et al. 1975). In a study examining a wide variety of marine predatory birds Lock & Solly (1976) reported a total DDT of 0.31 mg/mg muscle wet weight, a level approximately 5-fold higher than we have found. Nevertheless, given the potential differences in analytical methods, locations and species involved, there are insufficient historical data to confidently interpret trends in the concentrations of organochlorine pesticides in New Zealand albatross.

HCB residues were recorded at levels of between 3.2 and 9.5 ng/g wet weight in all Taiaroa Head samples (Table 6). In contrast, HCB was not detected in mutton bird samples (Dacre 1974) and was only detected in 6 of 25 southern black-backed gulls with a range of <0.01-0.11 mg/mg muscle wet weight (Lock

& Solly 1976). The later study could not detect lindane in any samples, while residues were found in all Taiaroa Head samples. These differences do not mean residues are increasing, as they are most likely the result of improvements in analytical limits of detection. In the Lock & Solly study of 1976, the limit of detection was 0.01 mg/mg muscle wet weight, meaning that the mean values in this study of 0.005 mg HCB/g and 0.018 ng lindane/g could not have been quantified.

Inter-annual variations and eggs versus chicks

The data presented in Tables 1 and 6 show that there is a great deal of similarity between the levels of organochlorine compounds in eggs from the 1995/96 and 1997/98 seasons and also between the levels in chicks and eggs. As an example, the mean (range) I-TEQ pg/g values for eggs 1995/96, eggs 1997/98 and chicks 1997/98 were 8.14 (4.79 - 12.88), 9.91 (6.57-13.79) and 9.91 (3.20-15.37), respectively. Although the environmental levels of the organochlorine compounds examined are typically reported to be declining (SETAC 1998), the lack of a difference between 1995/96 and 1997/98 levels is not surprising, given the relatively small number of samples analysed, short time period involved, and the high environmental stability of the compounds measured. As noted earlier, the temporal trends for contaminant concentrations in New Zealand albatross eggs cannot be confidently assessed due to differences with historical data in terms of analytical protocols, the species examined, and collection locations.

The data from this study support the conclusions of Jones (1999) that the findings of apparent inter-annual variation in albatross eggs between 1995/96 and 1996/97, and between northern royal albatross and mollymawk eggs, were due to differences in sample preservation and ecological niches.

Relationship between residues and maternal age

The albatross colony at Taiaroa Head is well suited to scientific investigations, as many of the breeding females are of known age, thus enabling the relationship between female age and egg residues to be examined. However, the regressions for organochlorine residues versus female age were all very weak, indicating there were no significant relationships. As an example, the regression for p,p'-DDE was described by the equation $y = -1.98x + 112.57$, $r2 = 0.155$ (Fig. 3).

Hazard index

In a previous study commissioned by the Department of Conservation, Jones (1999) conducted a risk assessment comparing organochlorine residue levels in northern royal albatross eggs with reference doses derived from avian no-observable-adverse-effect concentrations (Giesy et al. 1994; Auman *et al.* 1997). It is generally accepted when using this approach that until the ratio of residue to reference dose exceeds 10, adverse effects are unlikely to be seen. Once the ratio exceeds 20, there is an expectation that adverse effects will become apparent at the population level. The ratios derived by Jones (1999) for residues in albatross eggs were all less than one, with the I-TEQ ratio being the highest at 0.86, and the ratios for total PCBs and DDE being 0.08 and

0.01, respectively. Given the similarity between the residue levels reported by Jones (1999) and this study, his conclusions can be transferred to Taiaroa Head albatross: namely, that while there appears to be a 5- to 10-fold 'margin of safety' between current residues and the levels expected to cause adverse effects, there remains little global assimilative capacity for TEQ.

4. Conclusions

Although a variety of persistent chlorinated organic compounds were found in northern royal albatross eggs from Taiaroa Heads, it is not expected that the residues are sufficiently high to result in adverse effects on bird health.

The levels recorded were very similar to concentrations in northern royal albatross eggs from the Chatham Islands, but were substantially lower than the residues recorded in marine birds from the Great Lakes and Midway Atoll. While there are difficulties in comparing levels with some historical reports for New Zealand marine birds, the values in this study also appear at the lower end of historical levels in New Zealand.

The similarity between residues in eggs from Taiaroa Head and the Chatham Islands, coupled with the absence of egg shell thinning in Taiaroa Head eggs, suggests that apparent reproductive impairment in the northern royal albatross from the Chatham Islands is not caused by the measured pollutants.

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Table 1. Outline of Taiaroa Head Northern Royal albatross sample identification, collection details, maternal age, lipid content, egg shell thickness and embryo or chick weight.

ESR sample identification	DoC code - females	Sample details	Maternal age (years)	Lipid content w/w	Egg shell thickness (mm)	Weight (g)
990111/1	BYG	Egg with partially developed embryo, Laid 16/11/95 Collected 22/1/96	22	8.0	0.54	366
990111/2	YGB	Egg with well developed embryo Laid 9/11/97 Collected 21/1/98	24	4.6	0.58	365
990111/3	GYR	Egg with no embryo development, rotten Laid 24/11/95 Collected 30/1/96	15	9.0	0.58	314
990111/4	WBG	Egg with no embryo development Laid 8/11/97	30	7.2	0.59	355
990111/5	GRG	Egg with no embryo development Laid 10/11/97 Collected 27/11/97	40	7.4	0.56	423
990111/6	RGB	Egg with no embryo development Laid 12/11/97 Collected 1/1/98	32+	7.8	0.63	250
990111/7	RGB	Egg with well developed embryo Laid 12-11-95 Collected 25/1/96	30+	5.4	0.53	295
990111/8	GB	Chick (age 14 days) Hatched 21/1/98 Collected 4-2-98	36	7.4		850
990111/9	BYG	Chick (age 12 days) Hatched 30/1/98 Collected 11/2/98	24	7.6		282
990111/10	ORW	Chick (age 6 days) Hatched 30/1/98 Collected 24/1/98	13	5.6		447

Table 2. PCDD/F and PCB concentrations in Northern Royal albatross eggs and chicks from Taiaroa Head.

ESR sample #	Sample details	PCB sum ng/g	PCDD/F pg/g	PCB pg/g	Total I-TEQ pg/g	PCB sum ng/g lipid	PCDD/F pg/g lipid	PCB-TEQ pg/g lipid	Total I-TEQ pg/g lipid
990111/2	97/98, Egg	58.9	1.78	11.10	12.88	1280	38.7	241.3	280.0
990111/4	97/98, Egg	31.7	0.90	6.02	6.92	440	12.5	83.6	96.1
990111/5	97/98, Egg	18.8	0.64	4.15	4.79	254	8.6	56.1	64.7
990111/6	97/98, Egg	57.2	0.90	7.05	7.95	733	11.5	90.4	101.9
Mean		**41.7**	**1.06**	**7.08**	**8.14**	**677**	**17.8**	**117.8**	**135.7**
990111/1	95/96, Egg	83.2	1.59	12.20	13.79	1040	19.9	152.5	172.4
990111/3	95/96, Egg	31	0.88	5.69	6.57	344	9.8	63.2	73.0
990111/7	95/96, Egg	65.4	1.13	8.25	9.38	1211	20.9	152.8	173.7
Mean		**59.9**	**1.20**	**8.71**	**9.91**	**865**	**16.9**	**122.8**	**139.7**
990111/8	97-98, Chick	15.7	0.42	2.78	3.20	212	5.6	37.6	43.2
990111/9	97-98, Chick	89.2	1.67	13.70	15.37	1174	22.0	180.3	202.2
990111/10	97-98, Chick	55.1	1.06	10.10	11.16	984	18.9	180.4	199.3
Mean		**53.3**	**1.05**	**8.86**	**9.91**	**790**	**15.5**	**132.7**	**148.2**

Sample details include the season of collection e.g 1995/1996 and whether analysis was on an egg embryo or chick.
PCB and PCDD/F values are calculated including 1/2LOD values
Values are /g sample wet weight unless otherwise indicated

Table 3. Comparison of the levels of PCDD/F, PCB and selected organochlorine pesticides in Northern Royal albatross from Taiaroa Head with levels recorded in other albatross and New Zealand seabirds.

	Northern Royal Taiaroa Head[1] /g wet weight	Northern Royal Taiaroa Head[1] /g lipid	Northern Royal Chatham Is.[2] /g wet weight	Laysan alb. Midway Is.[3] /g wet weight	Black-footed alb. Midway Is.[3] /g wet weight	Wandering alb. Auckland Is.[4] /g lipid	Mutton bird Taiaroa Head[5] /g lipid	Various seabirds New Zealand[6] /g wet weight
PCDD/F I-TEQ	1.12 pg	17.4 pg	1.02 pg	19.4 pg	37.4 pg			
PCB I-TEQ	7.78 pg	120 pg	5.03 pg	30.7 pg	86.6 pg			
PCBs total	49.5 ng	758 ng	33.7 ng	198.5 ng	688 ng	620 ng	1,830 ng	120 - 6960 ng
Beta -HCH	0.08 ng	1.25 ng	<0.05 ng				2,562 ng	
HCB	5.01 ng	78.5 ng	4.26 ng				nd	nd - 110 ng
Heptachlor epoxide	1.17 ng	18.4 ng	0.92 ng					
p,p'-DDE	58 ng	965 ng	38.54 ng	121 ng	1550 ng	546 ng	13500 ng	20 - 1270 ng
p,p'-DDT	6.2 ng	108 ng	7.34 ng	11.5 ng	35.5 ng	230 ng	1540 ng	nd - 67 ng

nd = not detected

[1] data from current study examining levels in eggs collected over 1995-96 and 1997-98.

[2] data from Jones (1999) describing levels in eggs collected from the Chatham Islands 1996-97.

[3] TEQ and PCB data from Jones *et al.* (1996), DDT group data from Auman *et al.* (1997) describing levels in albatross eggs on Midway Atoll.

[4] described in Bennington *et al.* 1975, data is from Wandering albatross eggs collected on Adams Island 1972-73.

[5] study of Dacre (1974) describing residues in the fat of Mutton birds collected from Taiaroa Head and Stewart Island in 1969.

[6] PCB data from Solly & Shanks (1976), pesticide data from Lock & Solly (1976), who measured muscle residues in a variety of New Zealand seabirds

Table 4. Concentrations (pg/g wet weight) of PCDD/F congeners in Northern Royal albatross eggs and chicks from Taiaroa Head.

PCDD/F congener	Collection date and sample number #990111/									
	Eggs 1997/98				Eggs 1995/96			Chicks 1997/98		
	2	4	5	6	1	3	7	8	9	10
2378 TCDF	0.99	0.44	0.47	0.36	1.6	0.57	0.82	0.36	1.5	0.77
Non 2378 TCDF	<0.06	<0.04	<0.04	2.2	<0.08	<0.04	<0.05	<0.03	<0.05	<0.04
2378 TCDD	0.21	0.11	0.072	0.086	0.17	0.097	0.15	<0.06	0.17	0.14
Non 2378 TCDD	<0.1	<0.06	<0.07	1.9	<0.08	<0.07	<0.07	<0.06	<0.07	<0.06
12378 PeCDF	0.54	0.24	0.21	0.42	0.41	0.25	0.40	0.12	0.56	0.39
23478 PeCDF	1.5	0.80	0.56	0.90	1.3	0.84	0.83	0.41	1.2	0.78
Non 2378 PeCDF	<0.06	<0.04	<0.04	2.4	<0.05	<0.05	<0.04	<0.03	<0.04	<0.04
12378 PeCDD	0.96	0.45	0.31	0.49	0.83	0.41	0.67	0.21	0.99	0.63
Non 2378 PeCDD	<0.1	<0.06	<0.07	2.8	<0.08	<0.08	<0.08	<0.06	<0.07	<0.07
123478 HpCDF	<0.6	<0.09	<0.1	0.19	0.36	<0.1	0.13	<0.08	0.21	<0.1
123678 HpCDF	<0.4	<0.1	<0.07	0.19	0.14	<0.1	0.093	<0.06	0.18	0.11
234678 HpCDF	<0.4	0.19	0.12	0.17	0.22	0.15	0.15	<0.08	0.27	0.14
123789 HpCDF	<0.1	<0.03	<0.03	<0.04	<0.04	<0.04	<0.04	<0.03	<0.06	<0.03
Non 2378 HpCDF	<0.1	<0.04	<0.05	1.0	<0.06	<0.06	<0.05	<0.04	<0.04	<0.05
123478 HpCDD	<0.2	<0.07	<0.07	<0.09	<0.09	<0.1	<0.09	<0.06	<0.2	<0.08
123678 HpCDD	1.0	0.66	0.38	0.56	0.83	0.53	0.66	0.17	1.1	0.62
123789 HpCDD	0.23	0.11	0.089	0.13	<0.2	<0.1	0.12	<0.06	0.23	0.14
Non 2378 HpCDD	<0.2	<0.07	<0.07	1.0	<0.09	<0.1	<0.09	<0.06	<0.08	<0.08
1234678 HpCDF	<0.08	<0.04	<0.03	<0.1	<0.05	<0.06	<0.06	<0.04	0.20	<0.05
1234789 HpCDF	<0.06	<0.03	<0.04	<0.03	<0.04	<0.05	<0.05	<0.03	<0.03	<0.03
Non 2378 HpCDF	<0.08	<0.04	<0.05	<0.05	<0.06	<0.06	<0.06	<0.04	<0.05	<0.05
1234678 HpCDD	<0.1	<0.2	<0.2	<0.02	<0.2	<0.1	<0.1	<0.07	0.82	0.27
Non 2378 HpCDD	<0.1	<0.07	<0.08	<0.02	<0.09	<0.1	<0.09	<0.07	<0.08	<0.08
OCDF	<0.2	<0.1	<0.1	<0.07	<0.2	<0.1	<0.09	<0.06	<0.3	0.16
OCDD	<0.4	<0.5	<0.6	<0.7	<0.5	<0.3	<0.7	<0.4	6.1	1.9

Table 5. Concentrations (pg/g wet weight) of PCB congeners in Northern Royal albatross eggs and chicks from Taiaroa Head.

	Collection date and sample number #990111/									
PCB	Eggs 1997/98				Eggs 1995/96			Chicks 1997/98		
IUPAC #	2	4	5	6	1	3	7	8	9	10
77	0.024	0.0084	0.012	0.023	0.033	0.019	0.023	0.0082	0.039	0.023
126	0.080	0.043	0.031	0.048	0.086	0.041	0.057	0.020	0.096	0.073
169	0.11	0.072	0.038	0.044	0.096	0.046	0.059	0.027	0.11	0.069
28+31	0.13	0.056	0.059	0.13	0.11	0.11	0.087	0.064	0.29	0.092
52	0.0090	0.0095	0.0094	0.021	0.032	0.019	0.0093	0.037	0.032	0.012
74	0.29	0.17	0.11	0.14	0.29	0.13	0.20	0.062	0.25	0.31
70	0.026	0.015	0.018	0.039	0.049	0.028	0.031	0.033	0.042	0.021
81	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
101	0.10	0.040	0.030	0.11	0.20	0.072	0.068	0.19	0.056	0.055
99	1.3	0.45	0.39	1.1	1.5	0.45	1.4	0.28	1.4	1.1
110	0.023	0.016	0.015	0.034	0.041	0.022	0.017	0.085	0.026	0.027
123	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
118	4.2	2.0	1.4	2.9	5.1	2.2	3.6	1.1	5.1	4.1
114	0.077	0.039	0.026	0.049	0.085	0.041	0.057	0.020	0.083	0.080
105	1.1	0.42	0.33	0.93	1.4	0.61	1.1	0.29	1.5	1.2
153	18	10	5.9	16	25	9.2	19	4.6	27	17
138	8.6	3.5	2.3	9.8	13	3.9	12	2.6	12	9.3
167	2.6	1.2	0.79	2.4	3.6	1.2	3.0	0.67	3.8	2.6
156	1.6	0.74	0.51	1.2	1.8	0.70	1.4	0.35	1.8	1.5
157	0.31	0.14	0.13	0.31	0.48	0.18	0.34	0.092	0.58	0.43
187	0.67	0.27	0.12	0.88	1.3	0.21	1.0	0.20	0.39	0.31
183	2.6	1.4	0.69	2.1	3.3	0.83	2.9	0.50	3.2	1.8
180	12	7.6	4.1	12	17	6.2	13	3.0	20	9.4
170	3.3	2.0	1.0	4.7	5.8	2.9	4.1	0.91	8.3	4.0
189	<0.08	0.058	0.029	0.12	0.17	0.074	0.076	0.018	0.20	0.083
202	0.041	0.019	0.011	0.043	0.072	0.018	0.053	0.017	0.032	0.024
196	0.66	0.50	0.27	0.85	1.0	0.87	0.72	0.20	1.9	0.59
194	0.55	0.57	0.28	0.93	1.2	0.65	0.72	0.18	0.37	0.57
208	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01
206	0.20	0.16	0.093	0.16	0.30	0.18	0.17	0.032	0.42	0.13
209	0.11	0.056	0.048	0.047	0.12	0.040	0.063	0.018	0.17	0.095

Table 6. Organochlorine pesticide concentrations (ng/g wet weight) in Northern Royal albatross eggs and chicks from Taiaroa Head

ESR sample #	Sample details	Beta-HCH	Gamma-HCH	HCB	Heptachlor epoxide	Alpha-chlordane	Gamma-chlordane	p,p'-DDE	p,p'-TDE	o,p'-DDT	p,p'-DDT	DDT/DDE (%)
990111/2	97/98, Egg	0.11	0.012	9.1	2.10	0.34	0.053	140	4.40	0.035	17.0	12.1
990111/4	97/98, Egg	0.06	0.011	5.2	0.98	0.23	0.062	36	0.16	0.046	3.8	10.6
990111/5	97/98, Egg	0.08	0.015	3.8	0.85	0.16	<0.05	17	0.11	0.031	3.2	18.8
990111/6	97/98, Egg	0.08	0.036	3.5	0.80	0.23	0.091	39	0.81	0.034	5.9	15.1
Mean		**0.08**	**0.019**	**5.4**	**1.18**	**0.24**		**58**	**1.37**	**0.037**	**7.5**	**14.2**
990111/1	95/96, Egg	0.12	0.019	5.4	1.70	0.53	0.110	72	4.30	0.091	5.8	8.1
990111/3	95/96, Egg	0.04	0.018	4.6	0.84	0.22	0.078	39	5.40	<0.02	0.0	0.1
990111/7	95/96, Egg	0.08	0.014	3.5	0.94	0.18	<0.05	62	1.30	0.039	7.5	12.1
Mean		**0.08**	**0.017**	**4.5**	**1.16**	**0.31**		**58**	**3.67**	**0.065**	**4.4**	**8.6**
990111/8	97-98, Chick	0.04	0.050	3.2	0.38	0.33	0.110	20	2.30	0.700	7.0	35.0
990111/9	97-98, Chick	1.30	3.800	9.5	1.90	0.28	0.079	52	0.29	0.160	4.6	8.8
990111/10	97-98, Chick	0.10	0.069	7.5	3.20	0.27	0.056	90	0.67	0.120	6.5	7.2
Mean		**0.48**	**1.306**	**6.7**	**1.83**	**0.29**	**0.082**	**54**	**1.09**	**0.327**	**6.0**	**14.9**

Sample details include the season of collection e.g 1995/1996 and whether analysis was on an egg embryo or chick.

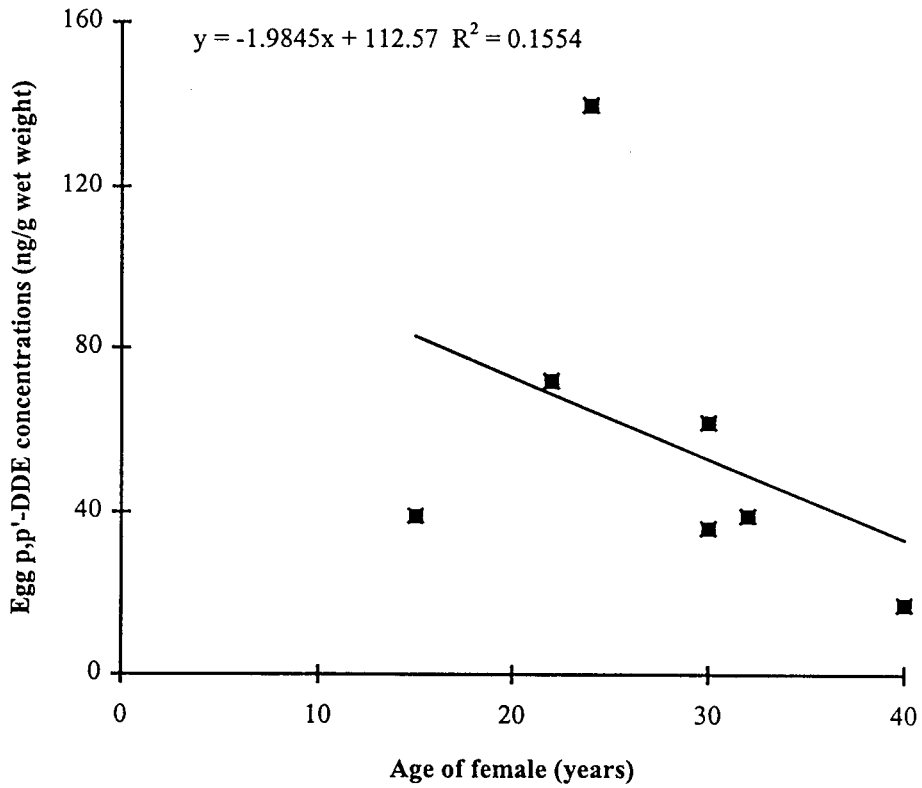

Figure 3. Linear regression between the age of Taiaroa Head albatross females and egg p,p'-DDE concentration.

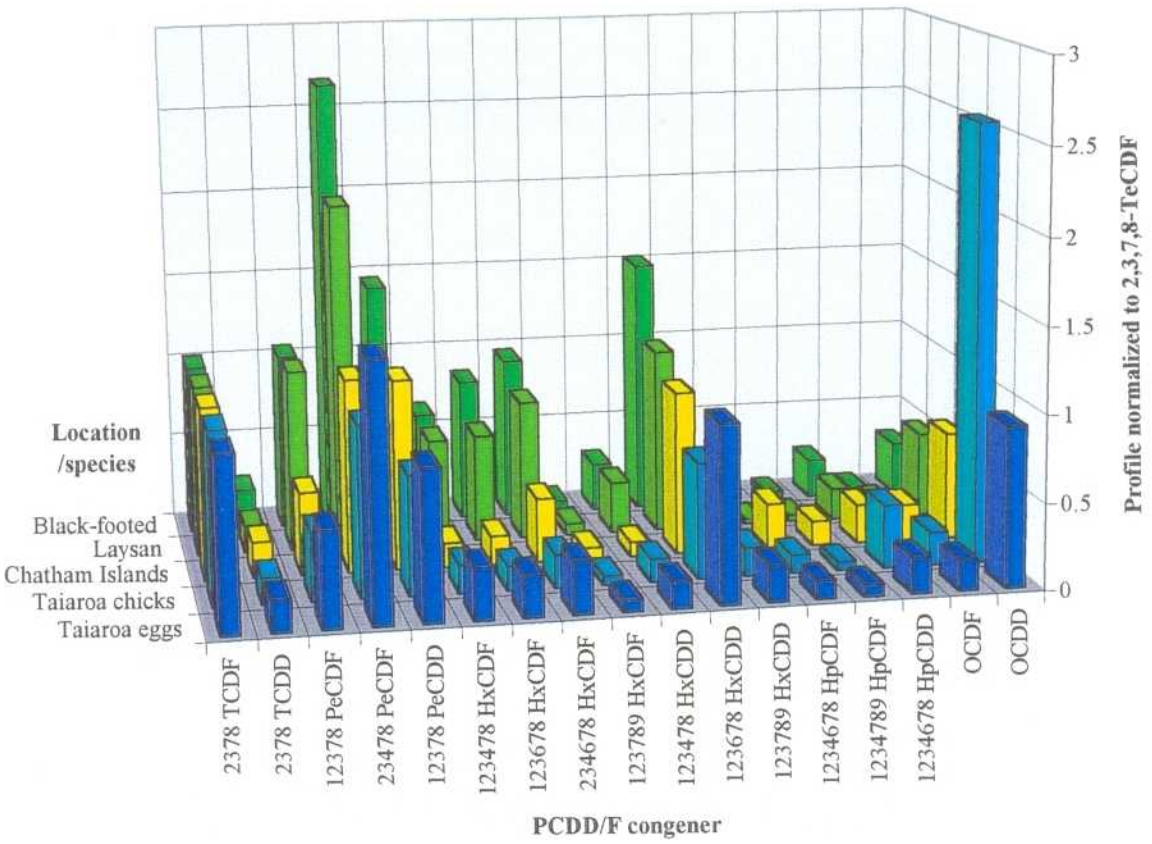

Figure 1. PCDD/F congener profile normalised to 2,3,7,8-TeCDF for northern royal albatross chicks and eggs from Taiaroa Head, eggs from the Chatham Islands, and Laysan and black-footed albatross eggs from Midway Atoll.

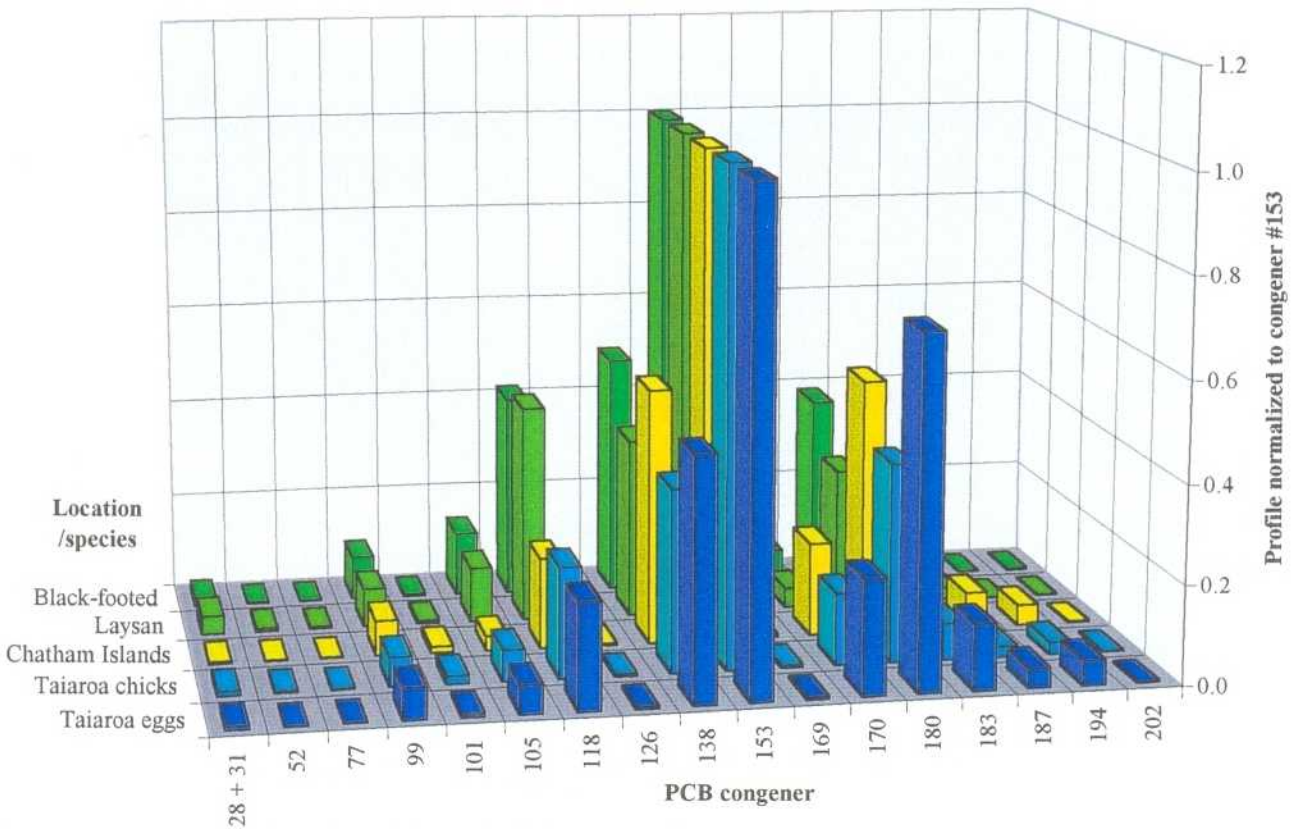

Figure 2. PCB congener profile normalised to congener #153 for northern royal albatross chicks and eggs from Taiaroa Head, eggs from the Chatham Islands, and Laysan and black-footed albatross eggs from Midway Atoll.