Table I. The organochlorine levels recorded in Antarctic birds from various localities; where known, the mean level (p.p.m.), range or standard deviation is given in brackets

Species	*Tissue*	*Location*	*Number in sample*	*p,p′ DDE*	*p,p′ DDT*	*Others*	*Reference*
Adult birds							
Pygoscelis adeliae	Pectoral muscle	Ross Sea	7	n.d.	0·07 (0·02–0·18)	Nine other tissues analysed but nothing detected	1
	Liver (wet weight)	Ross Sea	6	0·028 (0·010–0·083)	0·008 (0·000–0·016)	p,p′ DDD 0·003 (0·000–0·016)	2
	Fat (wet weight)	Ross Sea	4	0·053 (0·019–0·083)	0·023 (0·000–0·069)	p,p′ DDD n.d.	2
Pygoscelis antarctica	Liver (wet weight)	Signy Island	11	0·006 (0·001–0·018)	0·005 (0·001–0·010)		3
	Blubber (wet weight)	Signy Island	10	0·032 (0·013–0·048)	0·008 (0·005–0·012)		3
	Abdominal fat (wet weight)	Signy Island	5	0·039 (0·029–0·048)	0·008 (0·006–0·011)		3
Oceanites oceanicus	Whole bird (lipid)	Cape Hallett	10	2·2 (±0·7)	0·6 (±0·2)	PCB 11·0 (±4·0)	4
	Whole bird (lipid)	Anvers Island	9	45·8 (±37·1)	3·30 (±3·09)	PCB 185·3 (±133·4)	4
Pagodroma nivea	Whole bird (lipid)	Cape Hallett	10	0·11 (±0·60)	0·05 (±0·03)	PCB 0·34 (±0·13)	4
Catharacta skua maccormicki	Pectoral muscle	Ross Sea	12	0·104 (0·000–0·400)	0·043 (0·00–0·150)		1
	Viscera	Ross Sea	1	0·04	0·03		1
	Heart	Ross Sea	13	0·148 (0·030–0·380)	0·148 (0·000–0·680)		1
	Pancreas	Ross Sea	10	0·269 (0·050–1·200)	0·215 (0·000–0·370)		1
	Kidney	Ross Sea	12	0·402 (0·010–2·800)	0·098 (0·000–0·670)		1
	Lungs	Ross Sea	11	0·227 (0·010–1·500)	0·13 (0·00–0·49)		1
	Gut	Ross Sea	1	0·01	0·05		1
	Brain	Ross Sea	1	0·04	n.d.		[illegible]
	Ovary	Ross Sea	3	0·12 (0·00–0·26)	n.d.		1
	Testes	Ross Sea	3	0·06 (0·03–0·10)	0·1 (0·0–0·3)		1
	Chick	Ross Sea	2	0·015 (0·00–0·03)	n.d.		1
Catharacta skua lonnbergi	Liver	Signy Island	2	2·45 (0·89–4·00)	0·28 (0·23–0·33)		3
	Fat	Signy Island	2	15·9 (5·8–26·0)	1·70 (0·89–2·50)		3
Phalacrocorax atriceps	Liver	Signy Island	2	0·013 (0·011–0·015)	0·006 (0·003–0·009)		3
	Fat	Signy Island	2	0·096 (0·051–0·140)	0·013 (0·013–0·023)		3
Chionis alba	Liver	Signy Island	3	0·048 (0·014–0·100)			3
Eggs							
Pygoscelis adeliae	Lipid	Cape Hallett	3	0·046 (0·006–0·095)	0·029 (0·005–0·065)		4
	Lipid	Anvers Island	2	2·413 (0·086–4·74)	0·224 (0·048–0·400)		4
	Lipid	Cape Crozier	5	0·095	0·033		4
Pygoscelis antarctica	Lipid	Signy Island	3	0·021 (0·014–0·032)	0·008 (0·005–0·012)		3
Sterna vitatta	Lipid	Anvers Island	9	0·72 (±0·27)		PCB 1·74 (±0·59)	4
Macronectes giganteus	Lipid	Anvers Island	3	1·39 (0·37–2·80)	0·42 (0·12–1·00)	PCB 3·5 (2·0–6·0)	4
Catharacta skua lonnbergi	Lipid	Anvers Island	1	8·7	2·0	PCB 45·2	4
Catharacta skua maccormicki	Lipid	Anvers Island	3	17·4 (8·2–28·0)	1·6 (0·7–2·1)	PCB 33·1 (28·1–36·9)	4
Oceanites oceanicus	Lipid	Cape Hallett	4	3·1 (1·7–3·9)	1·1 (0·6–1·7)	PCB 13·8 (10·2–17·7)	4
Pagodroma nivea	Lipid	Cape Hallett	10	0·11	0·08	PCB n.d.	4

n.d. Tested for but not detected.

References: 1. George and Frear (1966); 2. Sladen and others (1966); 3. Tatton and Ruzicka (1967); 4. Risebrough and Carmignani (1972).

ORGANOCHLORINE LEVELS IN TWO SPECIES OF ANTARCTIC BIRDS

By J. W. H. CONROY *and* M. C. FRENCH*

ABSTRACT. Tissues from giant petrels (*Macronectes giganteus*) and emperor penguins (*Aptenodytes forsteri*) were examined for organochlorine residues. None was detected in the emperor penguins but p,p′ DDE was found in the giant petrels. No PCBs were detected. The data suggest that birds living more or less completely in the Antarctic regions have lower levels of contamination than those spending at least part of their life away from Antarctic regions.

SINCE the finding of DDT in Antarctic seals and birds by Sladen and others (1966) was announced, further investigations on other species at different localities in the Antarctic have shown that the original results are not unique. George and Frear (1966) analysed birds, seals, fish and invertebrates from the McMurdo Sound area (lat. 77°51′S., long. 166°40′E.), while Tatton and Ruzicka (1967) analysed birds, fish and indirectly "krill" (*Euphausia* spp.) from Signy Island (lat. 60°43′S., long. 45°38′W.). More recently, Risebrough and Carmignani (1972) published their findings on several bird species and reviewed the current situation concerning organochlorine residues in the Antarctic ecosystem.

Table I lists the species so far examined and the levels of contamination recorded.

In addition to finding organochlorines in the Wilson's storm petrel (*Oceanites oceanicus*), Risebrough and Carmignani (1972) showed that birds from widely separated breeding colonies, Anvers Island (lat. 64°35′S., long. 63°35′W.) and Cape Hallett (lat. 78°18′S., long. 170°25′E.), had markedly different levels of contamination. They suggested that this was the result of the two populations having different wintering grounds, Anvers Island birds in the North Atlantic† and Cape Hallett birds in Australian waters (Serventy, 1952). Anderline and others (1972) found similar differences in the levels of some heavy metals in the same two populations of Wilson's storm petrels.

This paper deals with the results of tissue analysis from known-aged birds of two species, both having circum-polar breeding distributions, but different breeding localities and non-breeding distributions—the giant petrel and the emperor penguin.

Emperor penguins only breed south of the Antarctic Circle (Budd, 1962) and are rarely found north of lat. 60°S. (Watson and others, 1971). By contrast, giant petrels have a wider latitudinal breeding distribution, from Gough Island (lat. 40°10′S., long. 4°45′W.) in the north to the Antarctic continent in the south (Mougin, 1968; Conroy, 1972; Johnstone, 1972). The species disperses north from its breeding areas to the shores of South America, South Africa, Australia and New Zealand (see Conroy (1972) for reference list). The diet of the emperor penguin is varied but consists mainly of squid and fish (Bierman and Voous, 1950; Prévost, 1961); however, during the winter the deeper layers of plankton may be exploited (Isenmann, 1971). By contrast, the giant petrels are scavengers and predators (Conroy, 1972).

Previous work on organochlorine residue levels in these species consists of the examination of three giant petrel eggs from Anvers Island (Risebrough and Carmignani, 1972) and two emperor penguins from the Ross Sea area (George and Frear, 1966; Sladen and others, 1966). The results are shown in Table I.

MATERIALS AND METHODS

Collection of material

The giant petrels were part of a collection of known-aged birds obtained on Signy Island during the 1968–69 austral summer. They were shot and weighed, measured and sexed. A piece of liver, weighing about 200 g., was removed using sterilized instruments, wrapped in aluminium foil, placed in a sealed glass jar, frozen and transhipped to the United Kingdom. The emperor penguin specimens were collected during the 1971 winter from the colony at Halley

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† A Wilson's storm petrel, ringed as a breeding adult on Signy Island, was recently recovered off the coast of New Jersey, U.S.A., the first record of a marked bird from the Scotia arc/Antarctic Peninsula in this area (Beck and Brown, 1972).

Bay (lat. 75°30′S., long. 26°32′W.), where they breed on the sea ice in the lee of the ice cliff (Dalgliesh, 1956). Part of the cliff broke off and fell on the colony killing adult birds and causing eggs to be deserted (Patterson, 1971). Up to three tissues, including liver, pectoral muscle, yolk and body fat, were removed from nine still-frozen specimens (two embryos, three chicks and four adults). All material was examined at the Nature Conservancy's Toxic Chemical Section, Monks Wood Experimental Station.

Methods

Tissue samples were first ground with sand and anhydrous sodium sulphate and then extracted with a hot mixture of redistilled hexane and acetone to a final volume of 250 ml. The final extract was reduced to 2 ml. on a hot water bath (80° C) and subjected to the analytical procedure described by French and Jefferies (1971).

Additional techniques were used to confirm the identity of the residues found; p,p′ DDE was chemically converted to 44-dichlorobenzophenone and p,p′ DDT to p,p′ DDE; both these derivatives were analysed by gas–liquid chromatography.

RESULTS

In the emperor penguin no traces of organochlorines were found in any of the tissues examined, up to limits of detection of 0·001 p.p.m. The only organochlorine recorded in giant petrel livers was p,p′ DDE except in one, an 8 year old male with 0·007 p.p.m. p,p′ DDT. The results are shown in Table II. The average level of DDE for 12 samples of giant petrel livers was 0·012

TABLE II. THE DETECTED LEVELS OF p,p′ DDE IN THE LIVERS OF AGED AND SEXED GIANT PETRELS (*Macronectes giganteus*) COLLECTED FROM SIGNY ISLAND

Age (years)	*Sex*	*p,p′ DDE*
80 days	f	0·002
5	m	0·010
5	m	0·010
6	m	0·008
6	m	0·010
6	f	0·014
7	m	0·003
7	f	0·014
8	m	0·030
8	f	0·016
13	f	0·015
15*	m	0·010

* This is the minimum age of the bird; it had been ringed as an adult 10 years previously and, since males may breed for the first time around 5 years (Conroy, 1972), 15 years is the minimum age of this bird, but it is likely to be older.

PCBs, p,p′ TDE, p,p′ DDT, HEODs and BHCs were also tested for but not detected.

(s.d. ±0·007, range 0·002–0·030 p.p.m.). When the data are analysed with respect to age (Fig. 1), they suggest an increase in the residue level with age, the lowest level 0·002 p.p.m. being recorded from an unfledged chick, aged about 80 days. Unfortunately, the data as presented do not give a significant relationship, but it is possible that contamination has occurred only in recent years, and because adult giant petrels do not migrate to or spend as much time in the low latitudes as immature birds the probability of contamination is less (George and Frear, 1966). Alternatively, Conroy (1972) suggested that recoveries of ringed

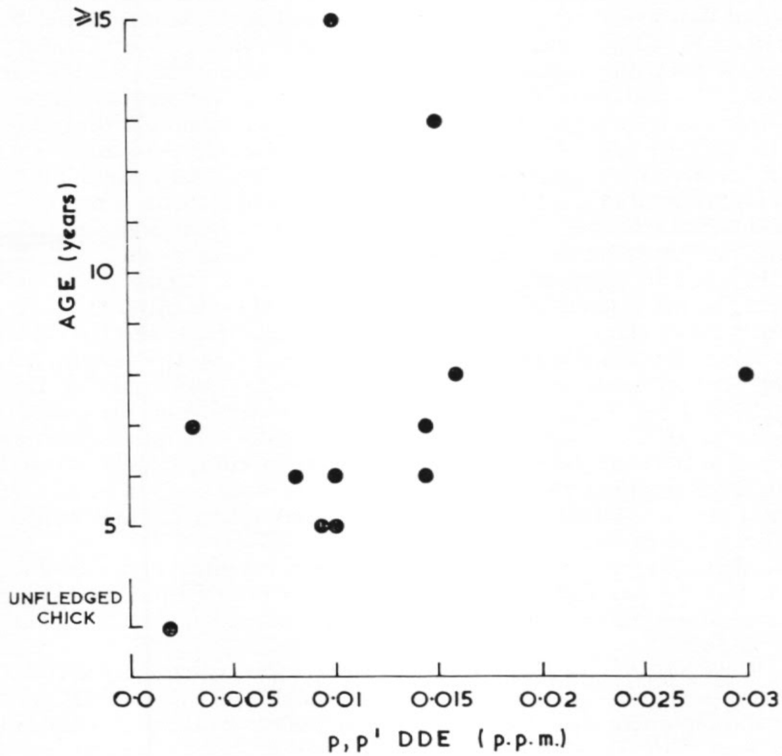

Fig. 1. The levels of p,p′ DDE recorded in the livers of known-aged giant petrels (*Macronectes giganteus*) collected at Signy Island.

black-browed albatrosses (*Diomedea melanophris*) (Sladen and others, 1968) indicated that adult birds are less likely to be found nearer land, where pollution concentrations are higher than on the high seas. Thus older birds, possibly spending less time in contaminated waters, should have lower levels than immature birds, which because of their wanderings during their pre-breeding years encounter contamination more often. Either hypothesis could explain the relatively low levels of contamination in adult birds of over 13 years.

There also appears to be a higher level of contamination in adult females (mean 0·015± 0·001, range 0·014–0·016 p.p.m.) than males (mean 0·012±0·008, range 0·003–0·030 p.p.m.). The difference is not significant and we cannot draw any firm conclusions, although the discrepancy could reflect different diets or different pelagic distributions of the sexes during the non-breeding season. No relationship between body weights and level of contamination was found.

A comparison between the Signy Island birds (Table II) and the Anvers Island eggs (Risebrough and Carmignani, 1972) showed the levels of p,p′ DDE found in the eggs to be higher, averaging 0·08 p.p.m. of fresh weight. This value was obtained from the average per cent lipid of 5·8 and average p,p′ DDE level 1·39 p.p.m. of lipid weight (calculated by W. P. R. Bourne (personal communication) from Risebrough and Carmignani's (1972) data). From studies on the eggs and adults of other species of Antarctic birds, the levels in the eggs do tend to be higher (Table I).

Discussion

The data tend to show that organochlorine levels are higher in birds whose pelagic wanderings take them away from the Antarctic to more highly contaminated areas. Species, such as giant petrels and Wilson's storm petrels, South Polar and brown skuas, are well-known oceanic wanderers (Roberts, 1940; Eklund, 1961; Sladen and others, 1968; Conroy, 1972) while sheathbills travel from the Antarctic to the Falkland Islands and South American coasts (Reynolds, 1935; Escalante, 1959; Jones, 1963). By contrast, blue-eyed shags, snow petrels, Adélie, chinstrap and emperor penguins probably restrict their non-breeding movements to the waters near the pack-ice edge (Watson and others, 1971). George and Frear (1966) drew similar conclusions from their collections in the Ross Sea, the much-travelled South Polar skuas having considerably higher levels of DDT and DDE than Adélie and emperor penguins.

The main difference between the giant petrels collected from Signy Island and the eggs collected from Anvers Island has been the discovery of PCBs in the eggs, while none was detected in the adult birds. If this represents a true absence, it may reflect different pelagic distributions of the two populations, for the Anvers Island birds travel to South America and the Signy Island ones mainly to South Africa and Australia. Each area has different pollutant levels. It is a suggestion which is not based on any ringing/recovery evidence, few ringed adult petrels having been recovered away from breeding grounds (Conroy, 1972). However, ringed giant petrel chicks from Signy Island are seldom recovered along the east coast of South America (Conroy, 1972). Sladen and others (1968) have demonstrated differences in the pelagic dispersal of the black-browed albatross between breeding populations in neighbouring island groups. Birds ringed on the Falkland Islands were more likely to be recovered along the South American sea-board than the birds ringed on South Georgia, which were more common off South African and eastern waters.

More detailed analyses of selected species are needed from different breeding localities in the Antarctic. In order to establish the actual relationship between human habitation and the organochlorine levels being recorded in the birds, collections should be made both near to and distant from bases.

Tatton and Ruzicka (1967) remarked that the bird samples from Signy Island were collected far from the British station. The island, however, is small and blue-eyed shags fish in the bay opposite the station where their fish samples were collected. Despite precautions, this bay receives some waste from the station and from the ships anchoring in it, so that the blue-eyed shags feed on fish which are possibly in direct contact with a localized source of pollution.

It may be concluded that contamination of the Antarctic ecosystem is in part due to fall-out and dispersal from other parts of the world, where organochlorines are in every-day use. The higher levels of contamination in birds which wander far from the Antarctic than in those which remain nearby, and the difference in the levels found in the same species from different breeding (and probably also wintering) localities show that the main sources of contamination lie not within the Antarctic seas but in areas to which the birds disperse during the non-breeding season.

However, the importance of local human contamination in the Antarctic merits further detailed investigation. There are records of high levels of lead in the livers of South Polar skuas found dead at Cape Hallett (Johnson, 1971), and it is thought that some unknown contaminant may have killed several sheathbills on Signy Island (Howie and others, 1968).

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