43 *Organochlorine Residues and Eggshell Thinning in Southern African Raptors*

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The effects of certain residual organochlorines on survival and reproduction of birds of prey are well known (Newton 1979, 1984). Most research on the effects of these chemicals on raptor populations has been done in western Europe and North America. Because use of DDT, dieldrin and related organochlorines has largely stopped in these regions, many raptor populations are recovering, and concern for the effects of residual poisoning has diminished (Ratcliffe 1980, Newton and Haas 1984, other chapters in this book). Use of organochlorines has now shifted to countries in Central and South America, Africa, and Asia. There is every reason to predict that raptor populations in these areas will decline significantly unless the use of these chemicals is restricted. It is vital to have information on quantities and kinds of chemicals being applied, current health of raptor populations, and levels of residues in raptors. We review data on the latter issue for raptors in southern Africa — the region lying south of the Zambesi, Cunene and Okavango rivers. We also present data on eggshell thinning in this region. Finally, we examine those areas and potential problems most in need of study.

DATA SOURCES AND METHODS

We attempted to extract all original pesticide residue data for wild raptors (excluding migrants) from the following studies: Butler and Sibbald (unpubl. ms.), de Kock and Watson (unpubl. ms.), Kiff et al. (1983), Mundy et al. (1982), Peakall and Kemp (1976, 1980), Robertson and Boshoff (unpubl. ms.), Snelling et al. (1984), Tannock et al. (1983), Thomson (1984c), and Whitwell et al. (1974). The accumulated data consist of 201 samples collected between 1960-84: 180 egg samples and 21 tissue samples from full-grown birds. Results from eggs in the same clutch were pooled. The analytical methods used are described in the publications from which results were drawn, and the unpublished results were obtained using methods described by Butler et al. (1983). Our data are presented on a ppm wet weight basis; results published as "dry wt" were converted by multiplying by 0.25.

Eggshell thickness was measured using the Ratcliffe Index (Ratcliffe 1967) for eggs in the Transvaal Museum (Pretoria), Durban Natural History Museum, and various private collections. Results obtained by Mundy et al. (1982) for Cape Vultures and African White-backed Vultures are included.

RESULTS

Distribution of Residue Samples. — Most samples came from Zimbabwe (n=105) and the Transvaal (n=63). Those from Botswana (n=12) and the Cape Province (n=14) were of Cape Vultures. The remaining five samples were collected in Natal. No data were available for Mozambique, Swaziland, Lesotho, Namibia and, in South Africa, the Orange Free State, Venda, Bophuthatswana, Transkei and Ciskei. The data were dominated by two species: Cape Vulture (n=44) and African Fish Eagle (n=54 from Zimbabwe, n=3 from Natal). The only other species represented by more than 10 samples were Black Sparrowhawk (n=19) and African White-backed Vulture (n=12). The remaining samples were spread between 18 species of diurnal raptors and six species of owls. For certain analyses, samples were pooled according to the preferred diet of the raptor species, as follows: bird predators (n=40), fish predators (n=58), mammal predators (n=11), general vertebrate predators (n=15), invertebrate predators (n=12) and scavengers (n=65).

DDT and Metabolites. — Of 200 samples tested, 198 had detectable residues of DDT or DDE and TDE; the compounds were not detected in an African Crowned Eagle and a Wahlberg's Eagle, both from Zimbabwe. DDE levels were much higher than either DDT or TDE. DDT residues >0.5 ppm, perhaps indicating significant recent contamination, were found in a Cape Vulture egg (1960) from South Africa and six samples from Zimbabwe: a Black Sparrowhawk (1980), three African Fish Eagles (1980, 1980, 1981), a Pel's Fishing Owl (1980) and a Verreaux's Eagle Owl (1972). Bird- and fish-eating raptors were more contaminated than other predators (Figure 1, Table 1). Of 40 samples from bird-eaters, 34 (85%) showed levels >5.0 ppm DDE, 23 contained >10.0 ppm, and 12 had residues >20.0 ppm, the highest being 79 ppm and 118 ppm in Black Sparrowhawks. All bird-eating species were apparently contaminated to a similar degree (Table 1).

Of the 58 samples from piscivores, one was a Pel's Fishing Owl egg containing 27.5 ppm DDE. The other 57 were African Fish Eagles, 46

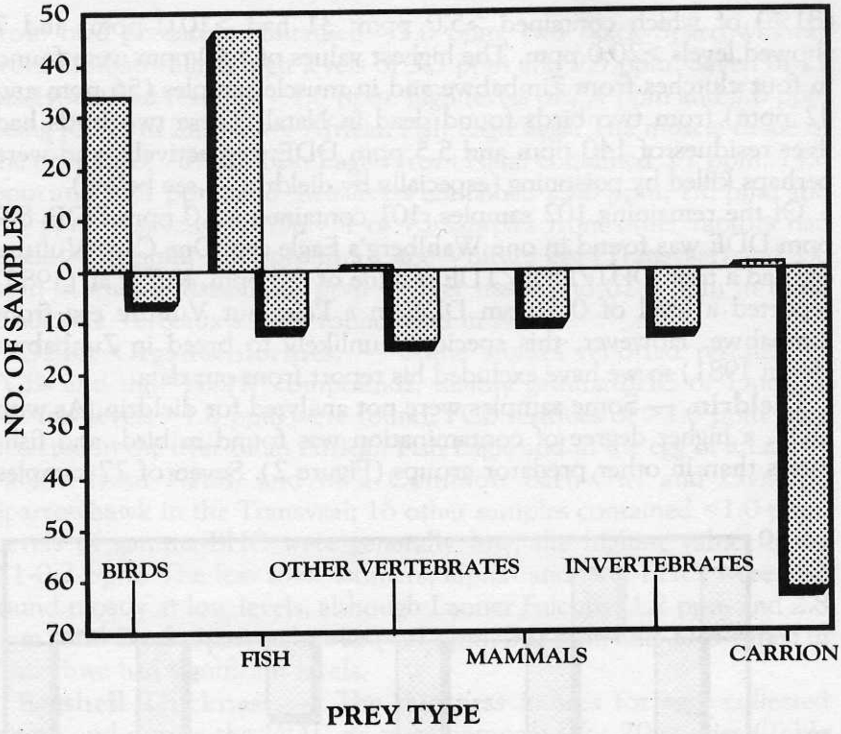

FIGURE 1. Comparative levels of DDE contamination in southern African raptors, according to their main prey of birds, fish, mammals, other vertebrates, invertebrates, or carrion. Number of samples containing >5.0 ppm (above) or <5.0 ppm (below) DDE wet wt.

TABLE 1. Frequency of samples showing various levels of DDE contamination (ppm wet wt) in southern African bird- and fish-eating raptors.

Species	>20.0	19.9-10.0	9.9-5.0	<5.0	Total no. of samples
Black Sparrowhawk	8	4	6	1	19
African Goshawk	0	1	0	1	2
Ovampo Sparrowhawk	0	1	4	1	6
Little Sparrowhawk	1	0	0	0	1
Lanner Falcon	1	4	1	2	8
Peregrine Falcon	2	1	0	1	4
African Fish Eagle	7	24	15	11	57
Pel's Fishing Owl	1	0	0	0	1
Total	20	35	26	17	98

(81%) of which contained >5.0 ppm; 31 had >10.0 ppm, and 7 showed levels >20.0 ppm. The highest values of >40 ppm were found in four clutches from Zimbabwe and in muscle samples (56 ppm and 42 ppm) from two birds found dead in Natal. These two birds had liver residues of 140 ppm and 5.5 ppm DDE, respectively, and were perhaps killed by poisoning (especially by dieldrin — see below).

Of the remaining 102 samples, 101 contained <5.0 ppm DDE; 8.9 ppm DDE was found in one Wahlberg's Eagle egg. One Cape Vulture egg had a total DDT/DDE/TDE residue of 6.0 ppm. Kiff et al. (1983) reported a level of 0.6 ppm DDE in a Palm-nut Vulture egg from Zimbabwe. However, this species is unlikely to breed in Zimbabwe (Irwin 1981) so we have excluded his report from our data.

Dieldrin. — Some samples were not analyzed for dieldrin. As with DDE, a higher degree of contamination was found in bird- and fish-eaters than in other predator groups (Figure 2). Seven of 27 samples

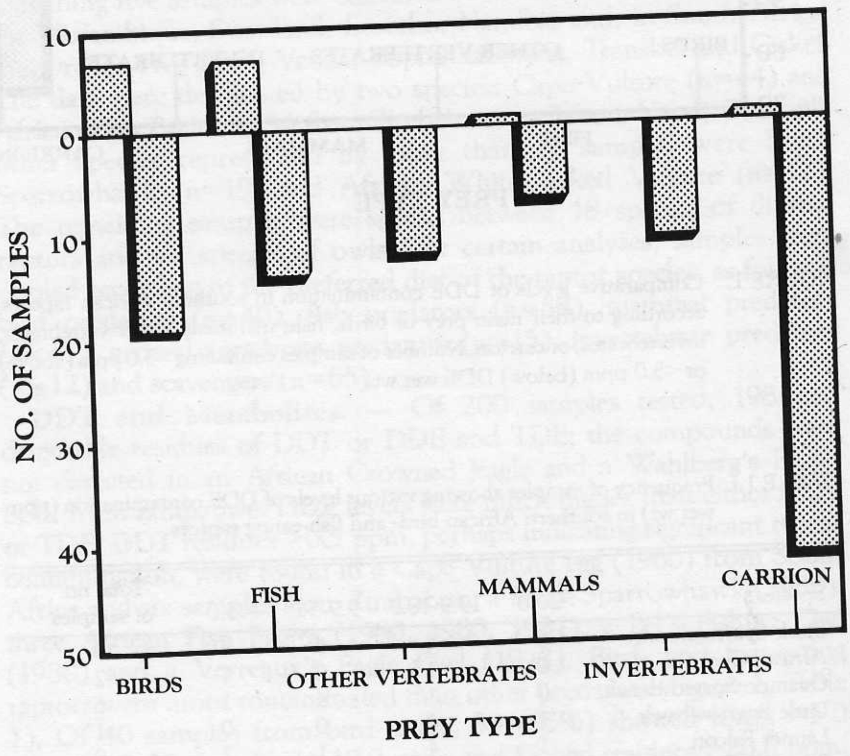

FIGURE 2. Comparative levels of dieldrin contamination in southern African raptors, according to their main prey of birds, fish, mammals, other vertebrates, invertebrates, or carrion. Number of samples containing >1.0 ppm (above) or <1.0 ppm (below) dieldrin wet wt.

from bird predators contained >1.0 ppm; two Black Sparrowhawks *from Zimbabwe had high levels of 3.3 ppm and 9.5 ppm. Seven of 21 piscivores had residues >1.0 ppm, high levels of 2.4 ppm and 5.6 ppm* being found in Zimbabwe African Fish Eagle eggs. The muscle tissue of the only three African Fish Eagles from Natal contained 3.7 ppm, 14.0 ppm and 14.1 ppm, and their livers contained 23.0 ppm, 7.0 ppm and 1.5 ppm, respectively. Only 4 of 73 samples from other raptors had levels >1.0 ppm: 2.5 ppm in a Cape Vulture egg (Transvaal) and 1.6 ppm in muscle tissue, 2.2 ppm in liver tissue and 67.0 ppm in brain tissue of a Verreaux's Eagle found dead in Natal.

Other Organochlorines. — Some studies reported residues of PCBs and the "HCH" compounds, mainly gamma-BHC or Lindane, but few levels >1.0 ppm were found. PCB residues of >1.0 ppm were detected in the liver of an African Fish Eagle and in the egg of a Lanner Falcon from Natal, and in a Common Barn-Owl and Ovampo Sparrowhawk in the Transvaal; 16 other samples contained <1.0 ppm. Levels of gamma-BHC were generally low, the highest values being 0.1-0.2 ppm. The less toxic isomers, alpha- and beta-BHC, were also found mostly at low levels, although Lanner Falcons (1.2 ppm and 2.8 ppm) and Black Sparrowhawks (1.5 ppm, 3.0 ppm and 31.5 ppm) in Zimbabwe had significant levels.

Eggshell Thickness. — The thickness indices for eggs collected before and during the DDT era were compared for 20 species (Table 2). All had thinner eggshells during the period of DDT use, but differences between the two periods were statistically significant ($P<0.05$) in only seven species: African Fish Eagle (13% thinner), Gabar Goshawk (10% thinner), Western Marsh Harrier (9% thinner), Wahlberg's Eagle (6% thinner), Greater Kestrel (5.5% thinner) and Cape Vulture (3.5% thinner). The data were highly variable, however, and larger samples are probably required to confirm real differences. For example, the very small difference in Cape Vulture eggs was significant because 58 and 76 eggs were available for measurement for the two periods, respectively (Mundy et al. 1982).

The degree of eggshell thinning varied greatly between species, but was not generally related to their diet (Table 2), as expected from differences in DDE contamination (Figure 1). The only Ratcliffe Index value (2.14) for one clutch of Black Sparrowhawk eggs from the pre-DDT period was higher than for all 12 clutches ($\bar{x}$=1.76) collected after 1947. Kiff et al. (1983) reported eggshell thinning in other vultures, but none of the differences between the periods before and after the introduction of DDT were statistically significant. The only eggshell thickness data for African Peregrines (Peakall and Kiff 1979) suggest substantial thinning, although the samples were too small to show significance.

TABLE 2. Indices of eggshell thickness (and number of clutches measured) before and after the first use of DDT (1947) in southern African raptors for which 3 or more clutches were available in each period. Data for Cape and African White-backed Vultures after Mundy et al. (1982).

Species	Main prey	Pre-1947 Index	Post-1947 Index	% reduction
African Fish Eagle	fish	2.93 (6)	2.54 (12)	13.3[a]
Little Sparrowhawk	birds	1.06 (4)	0.95 (6)	10.4
African Harrier Hawk	vertebrates	2.01 (3)	1.81 (3)	10.0
Gabar Goshawk	vertebrates	1.23 (12)	1.11 (3)	9.8[a]
Western Marsh Harrier	vertebrates	1.65 (6)	1.50 (7)	9.1[a]
Verreaux's Eagle	mammals	3.17 (5)	2.91 (4)	8.3
Wahlberg's Eagle	vertebrates	2.08 (36)	1.95 (13)	6.3[a]
Greater Kestrel	insects	1.45 (9)	1.37 (13)	5.5[a]
Rufous-breasted Sparrowhawk	birds	1.35 (6)	1.28 (3)	5.2
Lizard Buzzard	vertebrates	1.37 (34)	1.31 (4)	5.0
Jackal Buzzard	vertebrates	2.16 (7)	2.06 (8)	4.8[a]
Lanner Falcon	birds	1.75 (3)	1.67 (21)	4.6
Shikra	vertebrates	1.18 (47)	1.13 (8)	4.2
African White-backed Vulture	carrion	3.48 (31)	3.35 (50)	3.7
Ovampo Sparrowhawk	birds	1.41 (7)	1.36 (10)	3.6
Cape Vulture	carrion	3.96 (58)	3.82 (76)	3.5[a]
Tawny Eagle	vertebrates	2.89 (3)	2.81 (7)	2.8
Bateleur	vertebrates	3.23 (4)	3.17 (6)	1.9
African Hawk Eagle	vertebrates	2.33 (3)	2.30 (14)	1.1
Black-shouldered Kite	mammals	1.22 (5)	1.21 (8)	0.8

[a] $P < 0.05$.

DISCUSSION

We have attempted to identify patterns of contamination and eggshell thinning. However, because these data are subject to many sources of error and bias, small quantitative differences cannot be given much emphasis. Moreover, the degree of contamination and level of thinning may be exaggerated because many samples were obtained from addled eggs and birds found dead. The degree of bias is hard to estimate because most samples lack information on egg fertility or cause of death. Nevertheless, about 83% of samples from bird- and fish-eaters contained more than 5 ppm DDE (Table 1), a level which may be associated with lowered productivity in sensitive species (Newton 1979). This suggests that a significant proportion of these raptors have depressed reproductive rates. By contrast, the much lower levels of contamination in other raptors suggest their hatching rates are normal.

The high number of eggs with more than 5.0 ppm DDE (Figure 1) suggests that eggshells should have been thinner than those measured (Table 2). This incongruity might be owing to inadequate sample sizes and to the fact that much of the eggshell thickness data was obtained from eggs taken by egg collectors.

Dieldrin residues were also higher in fish- and bird-eating raptors than in other species. Levels above 1.0 ppm in eggs may be associated with reproductive failure in some species, while levels above 5-10 ppm in adult tissues are probably lethal (Ratcliffe 1980, Blus 1982). The frequency of high dieldrin levels suggests that many bird- and fish-eating raptors in southern Africa are affected detrimentally by this chemical. The data on other organochlorines are too inadequate to assess.

Zimbabwe, Transvaal, and Natal are the only areas for which samples from bird- and fish-eating raptors are available, and since the latter are the only species likely to show substantial levels of organochlorine residues (Newton 1984), these areas are the only ones in southern Africa for which data on pesticide contamination has been collected. No useful information is available for the much larger remainder of the region, including such large countries as Namibia, Mozambique and Botswana, and the Cape and Orange Free State provinces of South Africa.

Although some samples are small and differ in species composition, the data suggest that raptors in Zimbabwe and the Transvaal are contaminated to about the same order of magnitude. Those from Natal had amongst the highest DDE, dieldrin and PCB residues and may suffer from greater residues if the five samples are representative. DDT use in the Transvaal and Natal has been limited since 1976 to malaria mosquito control in the eastern and coastal areas. While dieldrin was withdrawn from general use in 1982, there is a continued source from the degradation of aldrin which is still used for certain applications. Zimbabwe uses DDT and dieldrin for a variety of puposes, and rates of application are apparently high (Thomson 1984c).

The data presented here suggest that residues of some organochlorines are sufficiently high to cause reproductive failure and mortality in southern African raptors. However, no information is available on possible demographic effects, largely because few raptor populations have been monitored to any degree during the last two decades. Cape Vultures (Piper et al. 1981) and Verreaux's Eagles (Gargett 1977) have been studied in detail, but are unlikely to show significant effects of residual organochlorines. Some populations may have increased as a result of other environmental changes. For example, African Fish Eagles have occupied newly built dams, Black Sparrowhawks and several other accipiters now breed in plantations over large regions previously lacking suitable nesting habitat, and Lanner Falcons now occupy nest sites on power line structures, buildings, quarries, etc. (Steyn 1982, Tarboton and Allan 1984). These changes may have balanced the negative effects of pesticides on these species. Population declines of other species which have not benefited from recent changes may not have been detected. In a related case of chemical poisoning, reductions in numbers of Bateleurs and Cape Vultures are partly attributable to feeding on strychnine-poisoned meat (Benson and Dobbs 1984, Tarboton and Allan 1984).

There is little information on quantities of organochlorines used in southern Africa. This problem is complicated by the great number of political authorities in each region; there are at least 11 autonomous governments each of which may have its own system of controlling and using pesticides.

We believe the data reviewed here demonstrate that organochlorine residues in southern Africa are high enough to have a significant impact on the dynamics of some raptor populations. More research is needed on the question of pesticide contamination in southern Africa. We see three aspects needing study: (1) There is an urgent need to monitor the health of raptor populations, in particular selected bird- and fish-eating species which could show negative changes attributable to residual poisoning. (2) Pesticide residues should be monitored throughout the region on a sustained and regular basis in selected species so that comparative changes can be detected. The monitoring program should cover as many kinds of residual pesticides as possible, including heavy metals for which virtually no information is currently available. (3) Conservation agencies should gather information on the quantities and application of different pesticides used in southern Africa. These agencies would then be in a position to identify problems of excessive pesticide use in particular areas, and to recommend restrictions.

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