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Comparative Toxicology of Organochlorine Pesticides to Avian Species

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The relative importance of dieldrin and DDT/DDE in the decline of the Peregrine Falcon *(Falco peregrinus)* was vigorously debated at the International Peregrine Symposium at Sacramento in 1985 (Nisbet, in press; Risebrough and Peakall, in press). This debate is not merely academic, since it has important implications for pesticide usage in those parts of the world where organochlorines are still widely used.

In order to contribute to the technical basis of the debate, this paper reviews the comparative toxicology of the commonly used organochlorine pesticides to the commonly used avian test species - Mallard *(Anas platyrhynchos)*, Ring-necked Pheasant *(Phasianus colchicus)*, Japanese Quail *(Coturnix coturnix japonica)*, and to the two raptorial species - American Kestrel *(Falco sparverius)* and Barn Owl *(Tyto alba)* - for which there are experimental data. The experimental findings are compared with those from field studies.

ACUTE TOXICITY

The LC50 of some oganochlorine pesticides to three avian species commonly used for testing, taken from Heath *et al.* (1972), are given in Table 1. It will be noted that only the cyclodiene pesticides (aldrin, dieldrin and endrin) and heptachlor are consistently more acutely toxic than DDT, although chlordane is more toxic in two out of three species.

The time that various dietary levels of organochlorine pesticides take to cause 100% mortality to Japanese Quail has been determined by DeWitt (1956). These data are tabulated in Table 2.

The relative toxicities obtained among the cyclodienes are similar, using this approach, to those obtained with the LC50 tests, with aldrin and endrin appreciably more toxic than dieldrin. This test indicates, however, a greater discrepancy between the toxicities of dieldrin and DDT, in the order of 100:1 rather than about 10:1 (Table 1). Nevertheless the finding of Porter & Wiemeyer (1972) that dietary levels of 2.8 ppm DDE caused some mortality of American Kestrels after 14-16 months indicates that dietary DDE will also cause mortality.

Table 1. Five day LC50 for some organochlorine pesticides to three avian species.

	Mallard	Pheasant	Japanese Quail
Aldrin	155	57	34
Chlordane	858	430	350
DDD	4814	579	3165
DDE	3572	841	1355
DDT	1869	311	568
Dieldrin	185	56	57
Endrin	22	14	18
Heptachlor	480	224	93
Lindane	5000	561	425
Methoxychlor	5000	5000	5000
Mirex	5000	1540	5000
Toxaphene	538	542	686

From Heath *et al.* (1972)

Table 2. Time taken to cause 100% mortality in Japanese Quail of dietary levels of organochlorine pesticides.

Pesticide	Dietary level (ppm)	Time to 100% mortality (days)
Aldrin	50	6
	20	8
	10	13
	5	28
	1	47
Dieldrin	20	40
	10	61
	5	87
	1	76
Endrin	50	3
	20	8
	10	14
	5	21 (73% mortality)
	1	105 (70% mortality)
DDT	150	15 (53% mortality)
	100	120 (30% mortality)

After DeWitt (1956)

REPRODUCTIVE EFFECTS

Regrettably the data on the effects on reproduction under experimental conditions (Table 3) are by no means as complete as one would like; there appear to be no detailed experimental studies on the effects of chlordane, heptachlor, or heptachlor epoxide on reproduction of the species under consideration. Henny *et al.* (1983), however, have carried out field studies on the effect of heptachlor epoxide on kestrels.

The marked inter-species variation of DDE-induced eggshell thinning is well-known (Peakall 1976; Kiff, in press). The species considered in Table 3 are either insensitive (pheasant, quail) or moderately sensitive (mallard). In the case of the latter the studies involved artificial incubation which greatly reduced the effect caused by eggshell thinning.

Table 3. Effects on reproduction.

	Dosage (ppm in diet) causing effect.				
	eggs/hen	% fertility	% hatch	% survival	reference
		Mallard			
Dieldrin	-	20	20	-	Davidson & Sell (1974)
DDT	-	20*	20	-	
DDE	-	40	10	-	Heath *et al.* (1969)
DDT	-	40	10-25	-	
		Pheasant			
Aldrin	2-10	2-10	1-2	1-2	DeWitt (1956)
Dieldrin	1-2	10	1-2	1-2	
Endrin	2-10	10	1-2	2-10	
DDT	>50	100	100	100	
Dieldrin	>1mg/day	>1mg/day	>1mg/day	>1mg/day	Stromberg (1977)
		Japanese Quail			
	eggs/female	% fertility	% hatch		
DDT	-	40	40		Davidson *et al.* (1976)
DDT	-	200-400	200-400		Smith *et al.* (1969)
Dieldrin	>3.1	-	-		Call & Harrell (1974)
Dieldrin	10-20	10-20	10-20		Walker *et al.* (1969)

*200 ppm DDT caused heavy mortality, but in surviving birds there was little effect on reproduction. Eggshell thinning occurred, but artificial incubation was used in this study.

The American Kestrel has been used to study the effects of dietary dieldrin + DDT (Porter & Wiemeyer 1969), DDE (Wiemeyer & Porter 1970), DDE, PCB, and PCB + DDE. Unfortunately the effect of dieldrin alone has not been studied. The main effects with the combination of dieldrin and DDT were increased egg disappearance, increased egg destruction by parent birds and reduced eggshell thickness, all of which could have been caused by DDT alone.

The only study of reproductive effects on a raptorial bird in which dieldrin and DDE were examined both separately and in combination is that of Mendenhall *et al.* (1983). These workers studied the effect of 3 ppm DDE and 0.5 ppm dieldrin on the Barn Owl. DDE was associated with significant eggshell thinning, egg breakage, embryo mortality and reduced production. Dieldrin was associated with slight eggshell thinning, but no reduction of reproductive success. The effects of the combination of DDE and dieldrin were similar to that of DDE alone.

FIELD STUDIES

These are difficult to interpret since several organochlorines, most notably DDE, PCBs and dieldrin, are always present. The results of the pioneering studies of Enderson & Berger (1970) on the effects of dieldrin fed to Prairie Falcons *(Falco mexicanus)* via dosed, tethered Starlings *(Sturnus vulgaris)* are bedevilled by high and variable background levels of DDE. Henny *et al.* (1983) in their studies on the effect of heptachlor on the American Kestrel tackled this problem by dividing the data into those with eggs less than or greater than 5 ppm DDE. On this basis they concluded that levels of heptachlor epoxide greater than 1.5 ppm were associated with decreased reproduction.

By far the best data set available on the effect of organochlorines on raptor breeding biology is that accumulated by Newton and co-workers on the European Sparrowhawk *(Accipiter nisus).*

Newton (1974) summarises the effects seen as follows: "marked and significant decline in nesting success occurred on farmed areas in Britain from 1947. This was almost entirely due to an increase in egg breakages and in the failure of incubated eggs to hatch. No change occurred in the number of eggs laid and, once hatched, the young survived well. The frequency of egg breakage was about the same in 1947-55 as in 1956-70, but after 1955 there was a significant increase in the number of incubated eggs that failed to hatch. This was associated with the finding of many 'dead-in-shell' embryos in the later period (as well as more addled eggs). The implication is that, while eggshell thinning and egg breakage occurred throughout the period of DDT usage, the death of partly formed embryos occurred only after the cyclodienes came in". The residue levels in eggs from failed nests of Sparrowhawks were 116 ppm DDE and 27 ppm dieldrin on a lipid weight basis (Newton & Bogan 1978). If one assumes 8% lipid, then these values are equivalent to 9 and 2 ppm wet weight respectively. These values can be compared with 12-41 ppm DDE and 4-9 ppm dieldrin in the experiments of Mendenhall and co-workers on the Barn Owl. Since no data are available on accipiters, the possibility that the difference is caused by inter-species variation cannot be ruled out. Nevertheless their conclusion that DDE had a much more severe effect on reproduction in wild raptors than dieldrin, which contributed to their decline primarily through adult mortality, seems to provide the best summary of currently available information.

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