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p,p′-DDE Residues in Eggs of European Kestrel *Falco tinnunculus* from Tenerife, Canary Islands, Spain

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The use of organochlorine pesticides has had adverse effects on wild bird populations by means of two mechanisms: increase of mortality and reproductive failures (Newton 1979). Reproductive failures have been mainly associated with the use of p,p'-DDT and its subsequent metabolization to p,p'-DDE, which produces a decrease of eggshell thickness (Ratcliffe 1970), a fact described up to now in 18 bird families (Blus 1995).

Although the use of the insecticide p,p'-DDT was banned in Spain in 1977, its metabolite p,p'-DDE is still present in wildlife (Hernández et al. 1988; Negro et al. 1993) and its effects on Spanish wild bird populations are poorly known. Predatory birds such as the red kite (*Milvus milvus*) have disappeared in this century from the Canary Islands, or are declining, such as the Egyptian vulture (*Neophron percnopterus*). The use of pesticides in intensive farming and the treatments against African locust (*Schistocerca gregaria*) plagues have been cited as important causes of the decline of these two raptors (Martín 1987).

Bird populations from islands are especially sensitive to changes in their environment, and these populations can extinguish in a higher degree than their continental relatives (Fuller 1987). In this study, we have taken a raptorial bird species, the European kestrel (*Falco tinnunculus*) from Tenerife, to determine the levels of p,p'-DDE in eggs in order to evaluate the role of this contaminant in the reproductive biology of this falcon and in the decline of other raptors from the same range. No studies had been made regarding the impact of organochlorine pesticides on terrestrial vertebrates in the Canary Islands.

MATERIAL AND METHODS

Fourteen eggs that had failed to hatch and fragments of shells from 70 hatched eggs were collected during or after the breeding season in 46 nests between 1988 and 1994 in Tenerife, which is one of the Canary Islands (Figure 1). Egg contents were frozen until analysis and eggshell thickness was measured in 5 places near the egg equator using a digimatic caliper accurate to ±0.01 mm.

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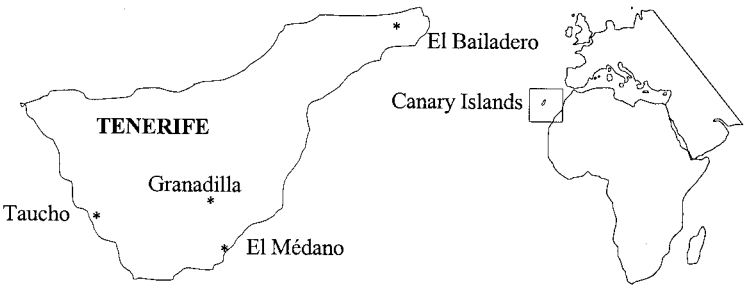

Figure 1. Sampling points of European kestrel eggs in Tenerife.

A subsample of egg contents (0.2 g) was processed following previously published methods using o,p'-DDE as internal standard (Guitart et al. 1990) and analysis was carried out by GC-ECD (Mateo et al. 1998). The recovery of the method with three fortified samples with p,p'-DDE was between 83-88%. Concentrations of p,p'-DDE were corrected for egg moisture because of the different status of desiccation at the time of collection, so values were expressed in dry weight (DW). The concentration in wet weight (WW) was later estimated with the value of dry weight (27.11%) found by Provini and Galassi (1999) in European kestrel eggs.

Concentration and total burden of p,p'-DDE and eggshell thickness were compared among zones or years of collection with a one-way ANOVA test and the relationships between concentration and total burden of p,p'-DDE and eggshell thickness were studied with Pearson's correlations. Cultivated fields, where organochlorine were possibly used in the past, are in the lower-elevation parts of the island near to the coast. We used Pearson's correlations to study the relationship between the elevation of the nest and p,p'-DDE and eggshell thickness.

RESULTS AND DISCUSSION

The only organochlorine compound found in eggs was p,p'-DDE (Table 1); other compounds, if present, should be at concentrations very much lower than p,p'-DDE. The absence of chlorinated compounds of industrial origin, such as polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB), which are usually found in tissues and eggs of wild birds in continental Spain (Hernández et al. 1986; Mateo et al. 1998), indicates that agriculture was the main source of organochlorine compounds in Tenerife Island.

The absence of p,p'-DDT reflects the ban of p,p'-DDT more than ten years before egg collection. In zones of Africa where p,p'-DDT is still sprayed against tsetse fly, Douthwaite (1992) observed 92.2% of ΣDDTs in the form of p,p'-DDE in fish eagle (*Haliaeetus vocifer*) eggs in places not treated for more than 6 years, while it was 77.5% in places treated during the last year.

The mean p,p'-DDE concentration in European kestrel eggs from Tenerife Island was 17.9 μg/g DW, which equate to 4.9 μg/g WW. This value is higher than the concentrations detected in eggs of most of the raptors studied in Spain (Table 2). Although no data is available of the amounts of pp'-DDT used in the past in Spain, the Canary Islands are the Spanish region with the highest expenses of pesticides per ha in the 1990s (García-Baudín 1998). Comparing with other analyses of European kestrel eggs, these from Tenerife Island have similar levels of p,p'-DDE as those from Britain more than two decades ago (3.64 μg/g WW, Ratcliffe 1970), but are more contaminated than those from Calabria (Italy) or the Czech Republic, where eggs had 1.30 μg/g DW of p,p'-DDE (Provini and Galassi 1999) and 0.19 μg/g DW of ΣDDTs (Kredl and Kren 1986), respectively.

Table 1. Residues of p,p'-DDE (μg/g dry weight) in European kestrel eggs from Tenerife.

Zone	n	Mean±s.d.	Range
El Bailadero	2	2.85±3.29	(0.53-5.2)
Taucho	2	14.3±1.50	(13-15)
Granadilla	5	19.7±17.7	(3.8-44)
El Médano	5	23.6±3.43	(20-28)
Total	14	17.9±12.3	(0.53-44)

There were not significant differences in p,p'-DDE concentrations or eggshell thickness among years or zones of collection, although the highest concentrations of p,p'-DDE were observed in eggs from the intensively cultivated parts in the south of the island and the lowest ones were obtained in El Bailadero, the mountainous part of the northeast (Figure 1, Table 1). The estimated arithmetic mean±s.d. of p,p'-DDE egg burden (n=14) was 43.5±40.2 μg and the eggshell thickness (n=84) was 0.23±0.03 mm. Eggshell thickness was not significantly correlated with the p,p'-DDE concentration ($r=-0.26$, $p=0.37$) or with the egg burden of p,p'-DDE ($r=-0.27$, $p=0.34$). The elevation of the nest was not significantly correlated with p,p'-DDE concentration ($r=-0.39$, $p=0.17$), the egg burden of p,p'-DDE ($r=-0.26$, $p=0.38$) or the eggshell thickness ($p>0.9$). Although there is a trend of p,p'-DDE concentration decreasing with the elevation, it was not significantly proved with this small sample.

The mean concentration observed in European kestrel eggs from Tenerife is at the threshold level described by Newton (1979) of 4-5 μg/g WW that produces more than 15% of eggshell thinning in many raptorial birds. Population declines are usually observed with eggshell thinning of 18-20% or more over several years (Blus 1995). According to studies of trends in organochlorine residues in birds after the ban of p,p'-DDT (Newton et al. 1993), one may expect to have found higher concentrations in European kestrel eggs from Tenerife Island two decades earlier, and these would have been well over the threshold level. Although the population of

Table 2. Mean (range) p,p'-DDE concentrations (μg/g wet weight) in predatory bird eggs in Spain.

Species	Year	n	p,p'-DDE	Source[a]
European kestrel	1988-93	14	4.85[b]	Present
Falco tinnunculus			(0.14-12)	study
Black kite	1981-83	11	1.54[b]	1
Milvus migrans			(0.20-4.4)	
	1982-85	27	0.99[c]	2
			(0.20-4.4)	
	1985-86	21	0.17-0.69[cd]	3
			(0.12-3.2)	
Red kite	1979-81	4	0.39[b]	4
Milvus milvus				
	1981-83	10	0.65[b]	1
			(0.17-1.6)	
Black vulture	1982-85	9	0.07[c]	2
Aegypius monachus			(0.05-0.10)	
Marsh harrier	1982-85	17	1.45[c]	2
Circus aeruginosus			(0.20-5.0)	
Northern goshawk	1982-85	2	41.5[c]	2
Accipiter gentilis			(37-46)	
Eurasian buzzard	1979-81	2	0.20[b]	4
Buteo buteo				
	1985-86	4	0.20-0.29[cd]	3
			(0.13-0.32)	
Golden eagle	1985-86	3	0.26[c]	3
Aquila chrysaetos			(0.06-0.68)	
Spanish imperial eagle	1972-84	32	3.25[b]	5
Aquila adalberti			(0.31-12)	
Booted eagle	1981-83	4	1.47[b]	1
Hieraaetus pennatus			(0.56-3.7)	
	1985-86	6	1.68-2.38[cd]	3
			(0.34-8.2)	
Hobby	1982-83	7	3.29	1
Falco subbuteo			(1.9-6.7)	
Lesser kestrel	1988-91	32	2.09[b]	6
Falco naumanni			(0.05-20)	
Peregrine falcon	1985-86	3	9.75[c]	3
Falco peregrinus			(2.6-66)	

[a] 1: González et al. (1984), 2: Hernández et al. (1986), 3: Hernández et al. (1988), 4: González et al. (1983), 5: González and Hiraldo (1988), 6: Negro et al. (1993).
[b]Arithmetic mean; [c]Geometric mean.; [d]Means from two zones.

European kestrel in the Canary Islands, with two subspecies (*F. t. canariensis* and *F. t. dacotiae*), is not endangered (Carrillo and Delgado 1996), other predatory birds (such as the red kite or the Egyptian vulture) have disappeared in all or in part of the Canary Islands, including Tenerife. The decline of the red kite was greatest between 1925 and 1950; thus, it began before the introduction of p,p'-DDT and another primary cause such as a reduction of carrion in the field was also present (Martin 1987).

In the case of the Egyptian vulture, the decline began in the 1950s, just after the first use of organochlorine pesticides, mainly γ-HCH, against the locust plagues (del Cañizo 1954). Acute poisoning of birds of this species by the ingestion of dead locusts was observed after these treatments (Martín 1987). The results of the present work show a concentration of p,p'-DDE in European kestrel eggs, which was probably higher two or three decades earlier and could have produced eggshell thinning in this raptor of the Canary Islands. We conclude that the use of organochlorine pesticides may have contributed to the decline of other raptor species from the same range, such as the red kite and the Egyptian vulture, by means the two possible mechanisms (Newton 1979), direct mortality and reproductive failure.

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