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CHAPTER 25

Contamination by PCBs and Organochlorine Pesticides of Belgian Birds of Prey, Their Eggs and Their Food, 1969–1982

C. JOIRIS AND K. DELBEKE

SUMMARY

Three complementary methods were used in order to describe and to understand the contamination of Belgian birds of prey: the analysis of unhatched eggs ($n = 350$), the analysis of raptors found dead ($n = 189$) and the determination of changes in eggshell thickness ($n = 1432$). The results obtained by the three methods are coherent.

As an example, the contamination by residues of the DDT group is discussed in some details. The level of the contamination is clearly species dependent: the birds-eating species are more contaminated than the mammals-eating raptors.

For some species (owls), a difference of contamination is found between two zones in Belgium: owls coming from the northern, agricultural zone are more contaminated than birds of the same species coming from the southern, forest zone. Their eggs also show a higher DDT level and a greater eggshell thinning.

Year-to-year variations in the level of DDT contamination are also detected for the owls and their eggs.

The analysis of some prey items (House Sparrow and small mammals) show that the main factor allowing to understand all results lies in the diet characteristics of the raptors: the more birds they eat, the higher their contamination. This is valid for the different species, and for the differences in contamination noted for a given species in the northern and southern zones, as well as from one year to the other.

The main conclusions are: first, that it is very useful to utilize different methods in order to determine the contamination of biological material, and second, that

an integrated study is needed in order to understand the levels of contamination and their variations. This study must include data on the population dynamics of the raptors, and mainly on their local feeding habits. In such conditions only can birds of prey be utilized as 'bioindicators' of terrestrial ecosystems, and can the differences of their contamination, as a function of space and of time, be understood.

INTRODUCTION

In terrestrial ecosystems, birds of prey can be considered as good 'bioindicators' ('targets') for stable pollutants: they are at the top of food pyramids and thus have high levels of persistent pollutants accumulating along the food web, such as organochlorine residues. They also represent an integration of small-scale variations of the contamination, because of their range and of their life-span. It must be kept in mind that the situation is completely different in aquatic ecosystems, where the carnivores of the highest level do not necessarily have the highest contamination. First, because the ecological structure of aquatic ecosystems cannot be represented as pyramids of biomass, as the productivity (the ratio production to biomass, or the turn-over time) of the different levels can be completely different (from a few days for phytoplankton to a few years for fish). Second, because the animals do not necessarily get their contaminants through their food only: fish, for instance, can be directly contaminated from the water and only partially through polluted food.

When starting a study on the contamination of Belgian terrestrial ecosystems in 1969, we were severely limited in the possibilities of analyses and in the financial support, and chose birds of prey as the best biological material. For ethical reasons, we decided not to destroy any raptor, but to use biologically lost material: unhatched eggs and raptors found dead. This leads of course to somewhat biased results, as the samples include sterile eggs and those birds having died because of a high pesticides level. But the main cause of mortality in raptors being still of human origin—shooting, accidents with cars and trains—the bias seems rather limited and acceptable in the frame of such a study.

RESULTS AND DISCUSSION

A summary of the obtained results is presented in this section; as an example, the contamination by residues of the DDT-group (that is mainly DDE) is used in the discussion.

The contamination of unhatched raptor's eggs is clearly species dependent. As far as DDT is concerned, the levels are low in mammal-eating raptors, and high in bird-eating raptors. When the species are classified as a function of their diet, the contamination is increasing with increasing percentage of birds in their food (Table 25.1).

Table 25.1 Organochlorine pesticides and PCB contamination of unhatched eggs of birds of prey, collected in Belgium from 1969 to 1979 (ppm/wet weight, median values).[1–3,12] The species are classified in function of increasing percentage birds in the diet

Species	Diet % birds	(ref.)	*n*	PCB	Lin.	HCB	H.E.	Diel.	Total 1	ΣDDT
Pernis apivorus	0	4	5	0.6	0.02	0.002	0.06	0.01	0.09	0.08
Aegolius funereus	2	4	11	1.2	0.01	0	0.01	0.01	0.05	0.04
Buteo buteo	4.5	4	17	1.8	0.03	0	0.08	0.03	0.17	0.02
Falco tinnunculus	4.5	4	23	0.3	0.02	0	0.04	0	0.06	0.04
Athene noctua	5	5	13	1.4	0.03	0	0.13	0	0.17	0.14
Tyto alba	5	6–8	171	1.8	0.01	0	0.49	0.18	0.68	0.53
Asio otus	12.5	10	2	0.7	0.10	1.11	0.12	0.30	1.62	5.36
Strix aluco	13.5	9	77	0.4	0.01	0	0.04	0.01	0.06	0.12
Circus pygargus	—	—	6	1.4	0.01	0	0.06	0.01	0.08	0.10
Accipiter gentilis	92	4	5	4.5	0.03	0	0.13	0.49	0.67	1.12
Accipiter nisus	98	4	20	3.4	0.02	0	0.30	0.25	0.57	2.43

Lin., Lindane; H.E., Heptachlore epoxide; Diel., Dieldrin; Total 1, Lindane + Heptachlore epoxide + Dieldrin; ΣDDT, DDT + DDE + DDD.
n, Number of eggs analysed.

For the Barn Owl (*Tyto alba*) and the Tawny Owl (*Strix aluco*), a difference in contamination is to be noted as a function of the geographical origin of the samples: the eggs coming from the northern zone (i.e. north of the rivers Sambre, Meuse and Vesdre) and more contaminated than the eggs coming from the southern zone (Table 25.2).

Yearly variations are also noted in the contamination of Barn Owl's eggs (the limited amount and distribution does not allow determination whether the same phenomenon exists for other owl species or not) (Table 25.3).

The study of the contamination of the dead raptors leads to the same type of

Table 25.2 Geographical differences in the DDT contamination of three owls.[1–3,11,12,15] DDT (ppm/wet weight, median values)

Species	Zone	Diet % birds	(ref.)	DDT Eggs	(*n*)	Muscle	(*n*)	Liver	(*n*)
Tyto alba	S	0	6–9	0.04	(22)	0.31	(8)	0.49	(8)
Strix aluco	S	2	9	0.12	(36)	0.02	(2)	0.19	(2)
Asio otus	S	3	—	—		0.08	(8)	0.01	(8)
Tyto alba	N	10	6–9	1.14	(101)	2.52	(24)	1.69	(24)
Strix aluco	N	20	9	0.18	(9)	0.91	(7)	0.39	(7)
Asio otus	N	30		—		3.86	(20)	9.49	(20)

S, southern zone; N, northern zone (see text).
See legend Table 25.1.

Table 25.3 DDT contamination of the Barn Owl (*Tyto alba*) in different years[1,3,11,12,15] (ppm/wet weight, median values)

Date	ΣDDT					
	Eggs	(*n*)	Muscle	(*n*)	Liver	(*n*)
1972	0.03	(17)	—		—	
1973	0.87	(21)	0.40	(3)	0.72	(3)
1974	0.11	(46)	0.24	(3)	0.17	(3)
1975	0.29	(22)	1.36	(9)	0	(9)
1976	0.95	(6)	1.21	(3)	0.93	(5)
1977	1.28	(26)	3.62	(2)	3.43	(2)
1978	1.60	(27)	0.52	(5)	0.39	(5)
1979	0.81	(5)	1.50	(11)	7.97	(9)

conclusions: the DDT level is species dependent, and the contamination shows a general tendency to increase with increasing percentage of birds in the diet (Table 25.4). For the Tawny Owl, the Barn Owl and the Long-eared Owl (*Asio otus*), a difference in the northern and the southern birds is also found (Table 25.2). A yearly variation in the contamination is also detected (Table 25.3).

Another method to be used in order to follow the secondary effects of the organochlorine pesticides consists in measuring the eggshell thickness, eggshell thinning being mainly due to a DDT contamination.[13] We used two methods: the direct determination of the eggshell thickness and the determination of the 'Ratcliffe's index', defined as the ratio between the product of the outer

Table 25.4 Organochlorine pesticides and PCB contamination of birds of prey found dead between 1972 and 1982 (breast muscle and liver) (ppm/wet weight, median values)[1,11,12,15]

Species	Diet (% birds)	*n*	PCB Muscle	PCB Liver	Total I Muscle	Total I Liver	DDT Muscle	DDT Liver
Circus aeruginosus	—	1	0.33	0.29	—	0.05	—	0.04
Pernis apivorus	0	1	—	0.07	—	0.35	—	0.13
Milvus milvus	—	1	0.50	2.30	0.12	0.63	0.10	0.42
Buteo buteo	4.5	28	0.88	0.67	0.32	0.45	0.06	0.05
Falco tinnunculus	4.5	18	0.91	0.91	0.75	1.53	0.07	0.10
Athene noctua	5	31	0.43	0.76	0.76	0.64	0.38	0.15
Tyto alba	5	44	7.60	10.00	1.25	2.47	1.26	0.97
Asio otus	12.5	32	1.82	1.52	0.64	1.95	0.79	2.06
Strix aluco	13.5	13	4.31	0.90	1.48	3.95	0.33	0.62
Falco columbarius	90	2	—	2.69	—	5.16	51.3	55.2
Accipiter nisus	98	18	5.17	3.84	1.21	0.81	2.31	2.15

n, Number of birds analysed; Total I, mainly Heptachlore epoxide. See legend Table 25.1.

measurements of the egg (both in mm) to the weight of the eggshell (in mg).[14] The results of both methods are strongly correlated (for example see Figure 25.1).

The obtained results are coherent with the levels of DDT detected in the eggs and in the birds of prey: a strong decrease of eggshell thickness can be noted for the bird-eating raptors only, while the species having a lower DDT contamination keep normal eggshells (Table 25.5). For some species, the

Table 25.5 Changes of eggshell thickness in Belgian birds of prey, during the periods 1950–1982. The results are expressed in function of the pre-1950 values taken as 100 percent.[12,16]

Species	Diet (% birds)	Period (years)	*n*	Percentage decrease[a] Thickness	Percentage decrease[a] Index
Pernis apivorus	0	50–59	8	(−2.9)	(−4.8)
		60–69	10	(6.2)	(−0.6)
		70–79	4	(−12)	(6.4)
Buteo buteo	4.5	50–59	36	(2.5)	3.5
		60–69	41	5.3	4.6
		70–79	16	0	(−2.4)
Falco tinnunculus	4.5	50–59	26	8.3	(−1.5)
		60–69	23	0	(−0.8)
		70–79	48	0	(−0.8)
Athene noctua	5	50–59	22	9.1	(4.7)
		60–69	29	9.1	6.7
		70–79	13	0	(−2.7)
Tyto alba	5	50–59	20	0	(−3.2)
		60–69	19	(8.7)	16.0
		70–79	153	4.2	9.8
Asio otus	12.5	50–59	25	4.2	6.8
		60–69	11	(8.7)	14.6
		70–79	24	25	30.6
Strix aluco	13.5	50–59	16	0	−5.6
		60–69	25	(7.1)	0
		70–79	32	0	(1.4)
Falco subbuteo	50	50–59	3	(12.5)	(14.9)
		60–69	12	(12.5)	18.0
Accipiter gentilis	92	50–59	15	12.8	13.8
		60–69	23	10.0	14.9
		70–79	7	(−4.5)	(−6.7)
Accipiter nisus	98	50–59	21	27.3	25.2
		60–69	63	27.3	26.4
		70–79	5	(16.7)	(9.4)
Falco peregrinus	100	50–59	6	(9.1)	18.2
		60–69	6	(28.6)	29.1

See legend Table 25.1.
[a] The values are presented between parentheses when not significant at the 0.02 level in a Student T-test.

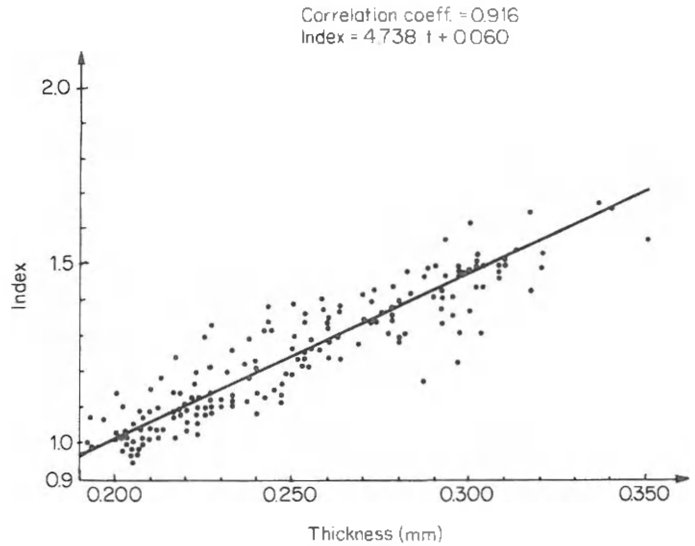

Fig. 25.1 Relation between index and thickness: the example of the Sparrowhawk, *Accipiter nisus*

decrease is progressive and the highest thinning is detected for the period 1960–69 (for example see Figure 25.2).

The comparison of eggshells coming from the two zones shows again a clear geographical difference for the Barn Owl and the Tawny Owl: no decrease in the southern zone, significant decrease in the northern zone (Table 25.6).

A first important aspect to be pointed out is that the results obtained with three different methods: contamination of the eggs, contamination of the raptors and changes of eggshell thickness, are coherent and lead to the same conclusions. The coherency of the results can be quantitatively expressed as a series of

Table 25.6 Geographical differences in the eggshell thinning for three owls[12,16]

Species	Zone	Diet (% birds)	*n*	Percentage decrease Thickness	Index
Tyto alba	S	0	21	(−4.0)	(−9.8)
Strix aluco	S	2	39	(−3.3)	−9.8
Asio otus	S	3	23	4.2	(−6.8)
Tyto alba	N	10	167	4.2	9.9
Strix aluco	N	20	37	19.0	20.2
Asio otus	N	25	20	7.1	(3.6)

See legend Tables 25.3 and 25.5.

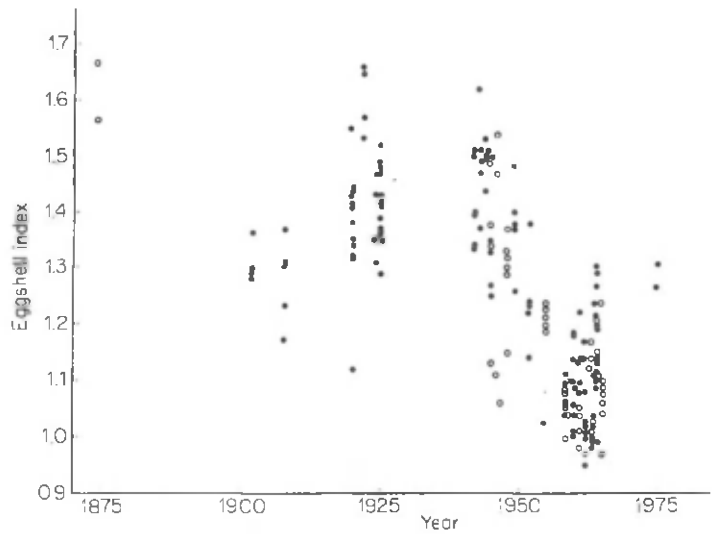

Fig. 25.2 Evolution of the value of the Ratcliffe index for the eggshell of the Sparrowhawk, *Accipiter nisus*. ○ Northern zone; ● southern zone

relationships between the different parameters: contamination of liver versus muscle, eggs versus muscle, eggshell thinning as a function of DDT contamination of the muscle, of the eggs and of the diet of the raptors (Figures 25.3 to 25.7). This provides a precious confirmation for the validity of these conclusions.

Another point to be discussed is the geographical variations: it is interesting to understand why two populations of the same species (owls), living not far from each other, can show such important differences in their contamination. Two main factors could explain this difference. On the one hand, the northern region is an agricultural and industrial one: it seems logical to suppose that the utilization of pesticides is high and that the ecosystem is heavily contaminated; the southern region consists mainly of forests and meadows: the use of pesticides is probably limited and the contamination of the ecosystem low. But on the other hand, the diet of the owls is not identical in both regions: they eat more birds in the northern zone than in the southern[6–10] and this can also explain a higher DDT level in owls from the northern zone.

In order to determine the relative importance of those two mechanisms, a series of prey items were taken in the two regions and analysed. The results show a clear difference in the DDT contamination of sparrows and small mammals, but no significant difference between the zones (Table 25.7). The differences in feeding habits are thus the main cause of the different DDT contamination of owls in the two zones.

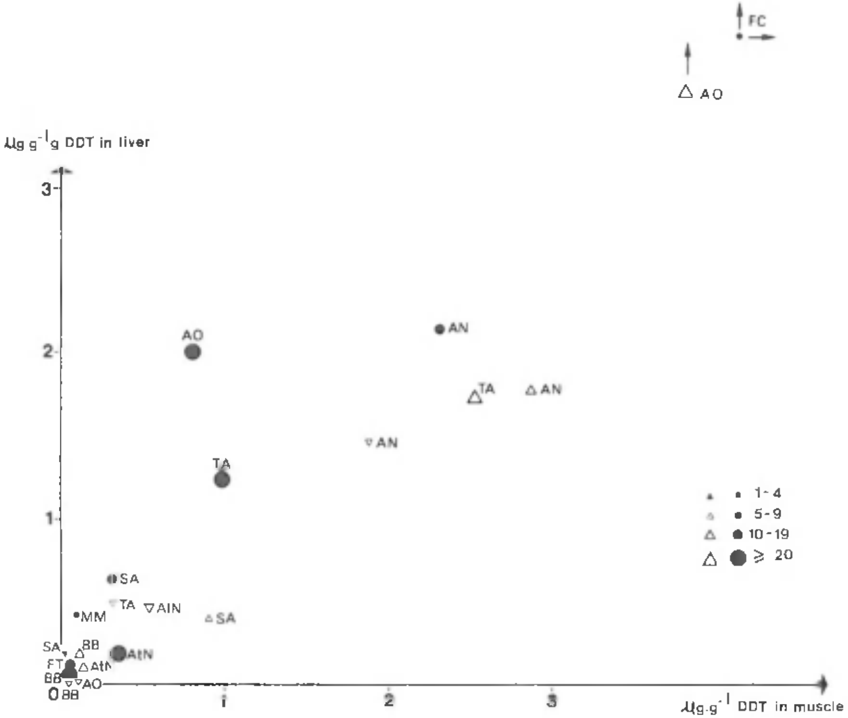

Fig. 25.3 Relation between the DDT contamination of liver and breastmuscle of raptors found dead in Belgium (median values) (1, 11, 12, 15). △ Northern region; ▽ Southern region; ● both regions; BB: *Buteo buteo*; AN: *Accipiter nisus*; FT: *Falco tinnunculus*; FC: *Falco colombarius*; At N: *Athene noctua*; AO: *Asio otus*; SA: *Strix aluco*; TA: *Tyto alba*. The number of the samples are reflected by the size of the symbols. *Asio otus* (North) has a median liver DDT level of 9.49 $\mu g\, g^{-1}$ (ppm); the *Falco columbarius* has a muscle and liver DDT contamination of respectively 51.3 and 55.2 $\mu g\, g^{-1}$.

This means that populations of a given owl species can be contaminated at different levels, even if they live in equally contaminated ecosystems. This also implies that an integrated study is needed in order to understand and compare values of contamination by organochlorine pesticides in birds of prey: the population dynamics, and mainly the diet characteristics are to be known in order to interpret such results. As these feeding habits can show important local and yearly variations, a detailed local study is necessary together with each study of the contamination.

A third aspect is the ecological stability of the residues. As the utilization of organochlorine pesticides was forbidden in our regions from the late sixties on, it is normal to expect a progressive decrease in the contamination of our ecosystems. But 10 years after the ban of, for instance, DDT, its concentration

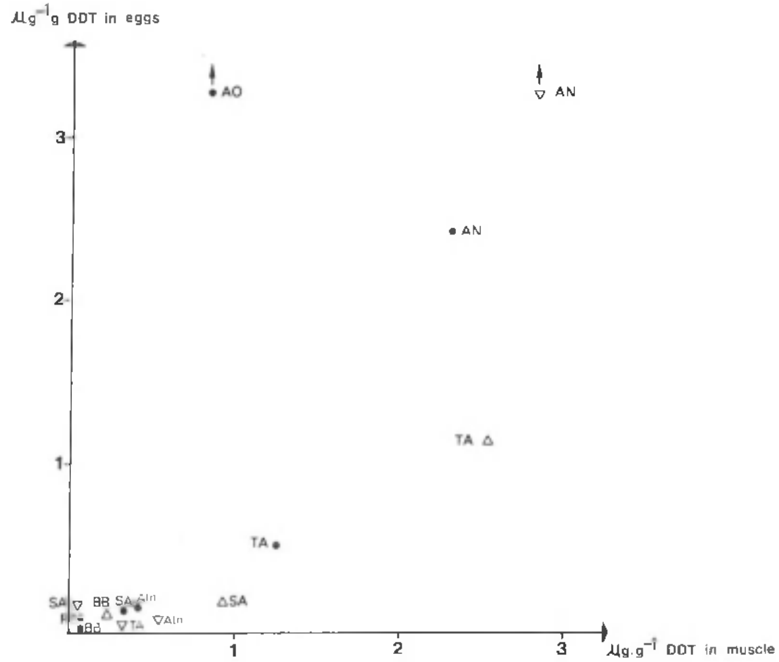

Fig. 25.4 Relation between the DDT contamination of unhatched eggs and breastmuscle of raptors found dead in Belgium (median values) (1–3, 11, 12, 15). △ Northern region; ▽ Southern region; ● both regions. BB: *Buteo buteo*, North (10 birds, 6 eggs), both regions (28, 17); AN: *Acipiter nisus*, South (6, 2), both (18, 20); FT: *Falco tinnunculus* (18, 23); At N: *Athene noctua*, South (10, 7), both (31, 13); AO: *Asio otus* (32, 2); SA: *Strix aluco*, North (7, 9), South (2, 36), both regions (13, 77); TA: *Tyto alba*, North (24, 101), South (8, 22), both (44, 17). *Accipiter nisus* (South) and *Asio otus* had DDT levels in their eggs of respectively 10.4 and 5.4 $\mu g\, g^{-1}$ (ppm).

Table 25.7 Organochlorine pesticides of some prey-items taken in the two zones of Belgium[12,17] (ppm/wet weight, mean values)

Species	Zone	*n*	Lin.	HCB	H.	H.E.	Diel.	ΣDDT
House sparrow	S 1973	10	0	nd	nd	0.025	0.001	0.146
Passer domesticus	S 1978	14	0.026	0.002	0.089	0.024	0.0003	0.013
	N 1977	10	0.029	0.001	0.154	0.052	0.001	0.021
	N 1978	11	0.054	0.006	0.160	0.049	0.014	0.034
Total		45	0.028	0.003	0.130	0.037	0.004	0.049
Small mammals	S 1973	12	0.184	nd	nd	0.073	0.008	0
	S 1978	11	0.018	0.002	0.082	0.013	0.008	0.001
	N 1978	10	0.070	0.002	0.170	0.108	0.113	0.001
Total		33	0.094	0.002	0.123	0.064	0.040	0.001

See legend Table 25.1; nd, not determined.

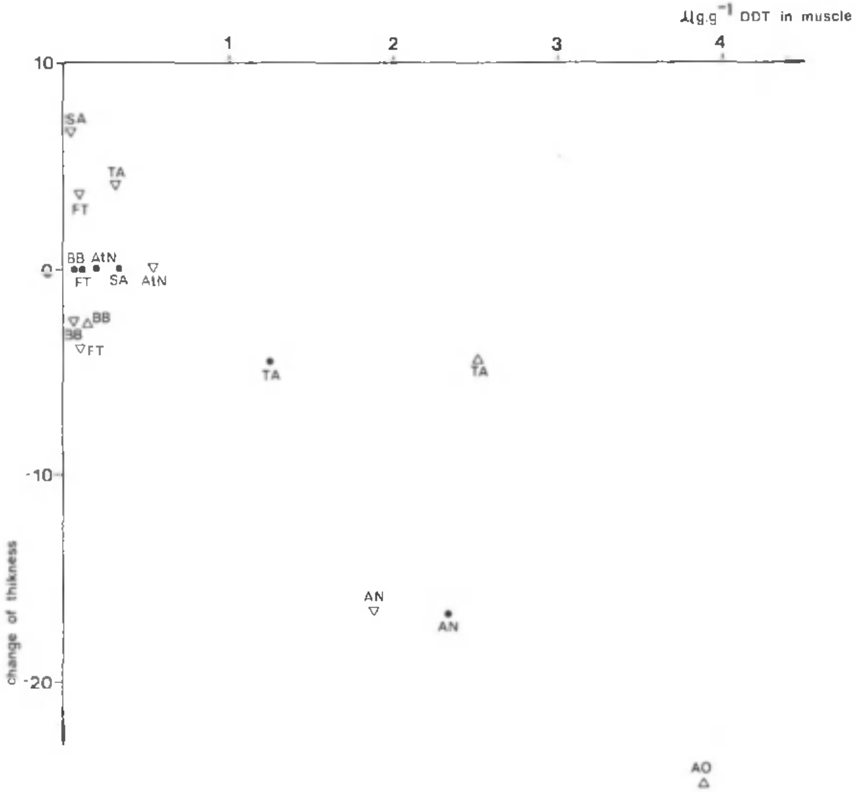

Fig. 25.5 Relation between the eggshell thickness change and the DDT contamination of the birds' breastmuscle. Only eggshells collected since 1970 are considered (median values) (1, 11, 12, 15, 16). △ North region; ▽ Southern region; ● both regions; BB: *Buteo buteo*, North (10 birds, 9 eggs), South (9, 4), both (18, 16); AN: *Accipiter nisus*, South (6, 5), both (18, 5): FT: *Falco tinnunculus*, North (9, 14). South (3, 5), both (18, 48); At N: *Athene noctua*, South (10, 12), both (31, 13); AO: *Asio otus*, North (18, 24); SA: *Strix aluco*, South (2, 18), both (13, 32); TA: *Tyto alba*, North (24, 101), South (8, 7), both (44, 153).

only starts to slowly decrease in nature: this shows a much higher stability than is expected from the biological stability in individual animals.[12,18] Another argument is to be found in the yearly variations of the contamination: the reappearance of high levels after years of low contamination does not seem to be due to the use of DDT (the ban is considered as being effective). This means that residues excreted and eliminated from the raptors are recycled within the ecosystem and re-accumulated along the food web: the ecological stability is thus the main parameter influencing the decrease of the DDT contamination in natural ecosystems, not the biological stability as measured in isolated animals.

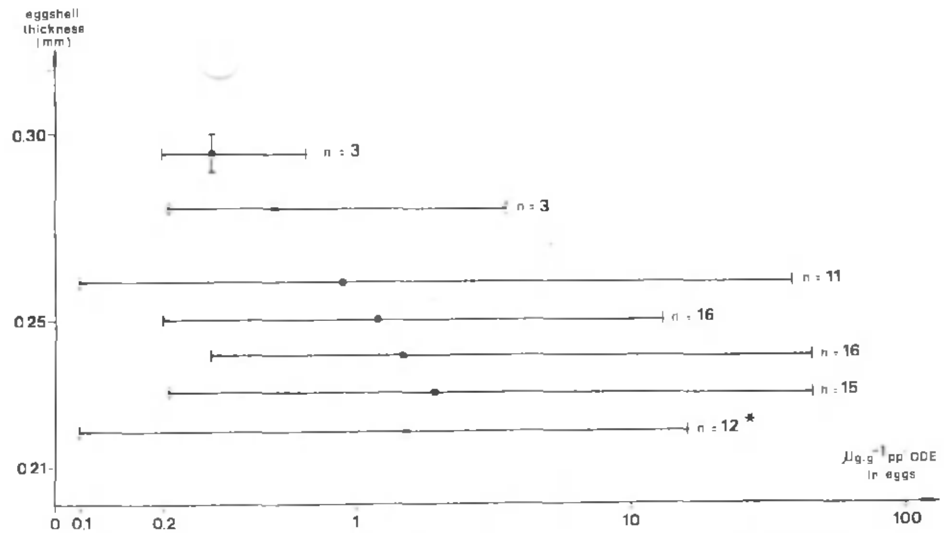

Fig. 25.6 Relation between the shell thickness and the DDE contamination of unhatched eggs of the Barn Owl (*Tyto alba*) (median values, minimum – maximum; n = number of samples; * including 2 eggs with a shell thickness of 0.21 mm).

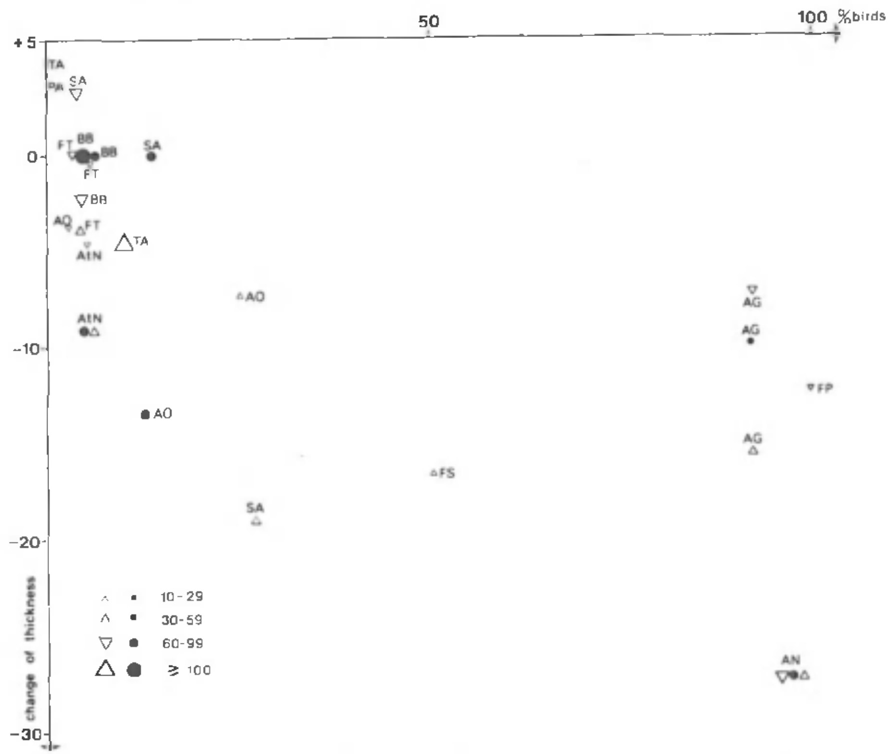

Fig. 25.7 Change of eggshell thickness in the period 1950–1970 as a function of the percentage of birds in the diet of the raptors. See legend Figure 25.3. PA: *Pernis apivorus*; AG: *Accipiter gentilis*; FP: *Falco peregrinus*; FS: *Falco subbuteo*.