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ORGANOCHLORINE POLLUTANTS, NEST-DEFENSE BEHAVIOR AND REPRODUCTIVE SUCCESS IN MERLINS

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ABSTRACT.—In a population of Merlins nesting on the Canadian prairies, the eggs of females with large DDE burdens had significantly lower quality shells, disappeared more frequently, and hatched less frequently than normal. Few of the behavioral responses of such females to territorial intrusions appeared to be significantly altered. We conclude that the changes in nest site defense which accompany DDE contamination are of minor importance in the associated reproductive failure of falcons.

Laboratory studies of the effects of organochlorine pollutants on avian reproduction have frequently revealed behavioral abnormalities in the adults (Jeffries 1971, Peakall and Peakall 1973, Winn 1973, Haegele and Hudson 1977). Studies of heavily contaminated wild birds indicate that behavioral abnormalities may be a significant factor in reproductive failure (Milstein et al. 1970, Snyder et al. 1973, Fyfe et al. 1976, Fox et al. 1978). We present here the first field study in which the behavior of nesting females with various degrees of organochlorine contamination in a single population is compared, and we discuss the relationship to reproductive success.

The Merlin (*Falco columbarius*), like its congener the Peregrine (*F. peregrinus*), is heavily contaminated with, and sensitive to, organochlorine pollutants (Temple 1972, Fyfe et al. 1976, Newton et al. 1978, Fox 1979). Over the past decade the Canadian Wildlife Service has studied contaminant levels and reproductive success of this species on the grasslands of southeastern Alberta. Early in these investigations Fyfe et al. (1976) observed that pairs whose eggs contained high levels of organochlorine pollutants (predominantly *p',p'*-DDE) deserted their clutches more frequently and defended their nests less actively than less contaminated pairs. In 1975 and 1976, we attempted to quantify these differences.

METHODS

All known nesting sites of Merlins in the study area located in southeastern Alberta were checked for occupancy. The eggshell quality of all clutches (n = 22, 1975; n = 29, 1976) was determined using the nondestructive beta-backscatter method. Backscattering is a simultaneous measure of thickness, density and ultrastructure and is highly correlated with the thickness index of Merlin eggshells (Fox et al. 1975). The clutches were ranked according to eggshell quality. Each year, the five clutches with the lowest shell quality and the five clutches with the highest shell quality were selected for study. If any clutch was lost prior to behavioral testing, the unused clutch next in rank was substituted into the appropriate test group. One egg was collected at random from all test clutches for determination of thickness index (Ratcliffe 1967) and organochlorine content (Reynolds and Cooper 1975). Since shell quality and organochlorine content of the egg reflect the pollutant burden of the female at laying, and no measure of contamination was available for the males, the quantification of behavior was confined to the females.

Aerial attacks (stooping) and vocalizations of females were studied under three experimental situations: (1) the incidence of stooping and vocalization during our visit to determine shell quality mid-incubation, (2) the number and intensity (closeness to the intruder) of stoops, and the incidence and percentage of the time the female vocalized per minute (intensity) in a 20-min observation period were recorded while a live adult female Merlin was tethered near the nest site when young were about two weeks old, and (3) while, in 1975, a live adult Ferruginous Hawk (*Buteo regalis*) or, in 1976, a Red-tailed Hawk (*B. jamaicensis*), was tethered in the same position on another visit less than 96 h later. Stoops were classified as "weak" if the Merlin did not come closer to the intruder than 3 m, "moderate" if between 2 and 3 m, and "extreme" if closer than 1 m. Vocalization was classified as "infrequent" if the Merlin called for less than 20 s per minute, "intermittent" if it called 20–40 s per minute, and "continuous" if it called more than 40 s per minute of observation. The "intruders" were tethered at approximately the same distance from each nest, on portable perches which were used at all nest sites, thus standardizing the variables of visibility, height and distance from the nest. Observations of reactions to tethered birds were made from a seated position in the open approximately 250 m from the nest site and recorded on a coded data sheet. In both years, all tests of an experimental situation were conducted on all pairs within a 72 h period. For statistical analysis the data for both years were pooled and the 10 pairs with the highest DDE content in their eggs were designated the "contaminated" group; the remaining 10 nests were designated the "uncontaminated" group. Nonparametric statistics were used throughout.

RESULTS AND DISCUSSION

In only three of 12 comparisons were there

TABLE 1. Differences in the behavior of "contaminated" and "uncontaminated" female Merlins in response to territorial intrusion.

Intruder	Response	Condition of female		P[a]
		"Uncontaminated"	"Contaminated"	
Human	Attacked	4/10	4/10	—
	Vocalized	6/10	9/10	$0.25 < P < 0.50$
Merlin	Attacked	7/10	9/10	$0.25 < P < 0.50$
	Frequency of attack[b]	8.8	16.3	$P = 0.25$
	Intensity of attack[c]	1-6-81	12-27-124	$0.005 < P < 0.01$
	Vocalized	10/10	9/9	—
	Intensity of vocalization[d]	63.5-61-17.5	63.5-39-22.5	$0.10 < P < 0.25$
Buteo	Attacked	10/10	7/10	$0.10 < P < 0.25$
	Frequency of attack	49.3	32.1	$0.90 < P < 0.75$
	Intensity of attack	33-90-370	11-21-225	$P < 0.005$
	Vocalized	10/10	7/10	$0.10 < P < 0.25$
	Intensity of vocalization	64-88.5-82	69-55-50.5	$0.025 < P < 0.05$

[a] Statistical significance based on Fisher exact or chi-square test.
[b] Mean number of attacks in 20-min observation period.
[c] Total number of stoops of weak, moderate and extreme intensity in 20-min observation period.
[d] Total number of minutes of infrequent, intermittent and continuous vocalization in 20-min observation period.

significant differences in the behavioral response of "uncontaminated" and "contaminated" females (Table 1). This is in sharp contrast to the differences observed in shell quality and reproductive performance (Table 2). Although the differences in response to the human intruder were not statistically significant, the belligerent aerial attack more prevalent in the "uncontaminated" Merlins deterred our activities far more effectively than the passive vocalization frequently uttered by "contaminated" individuals. "Contaminated" females attacked the tethered Merlin more frequently than "uncontaminated" females, but their stoops were significantly less intense and their vocalizations less frequent. Some "uncontaminated" females struck the tethered Merlin repeatedly and some grappled with it on the ground. Two of 10 "contaminated" females incubated in the presence of the tethered buteo. Those "contaminated" females that did attack did so with significantly more intense stoops and significantly less vocalization. We repeatedly saw one or both members of a pair vigorously attack perched or flying buteos of both species near the nest site. An aerial attack demands more energy and is more dangerous to the attacker than a vocal protest. It is nonetheless much more effective in driving an intruder from the territory.

Female Merlins become more reluctant to leave the nest as incubation progresses but may protest intrusions vocally. Nest defense is most intense when young are half grown. Significantly more "contaminated" than "uncontaminated" females were in their first week of incubation when the response to human intrusion was measured but no such bias was apparent in the age of the chicks when testing with the tethered Merlin and buteo took place.

Fyfe et al. (1976) found significantly higher DDE residues in the eggs of pairs that were absent from the territory when the egg was collected than in eggs from sites where one or both adults attacked the intruding investigator. Those pairs in which one or both adults vocalized and remained in the area but did not attack, or in pairs where both adults left the immediate area had DDE burdens which were intermediate in concentration. This implies an inverse relationship between DDE burden and the intensity of nest site defense. No such statistical relationship was found in the present study. However, 18 of the 20 pairs studied would be classified as "aggressive" by Fyfe et al.

We had no measure of the pollutant burden in the mates of females observed in this study. There is no reason to assume that mating is not random as to pollutant burden. Male Merlins show site-tenacity; females do not and the pair bond is not permanent (Hodson 1975). Mates of females studied showed no obvious differences between the "contaminated" and "uncontaminated" group. Males and females differed markedly, however, in response to the territorial intrusions. In 42% of the intrusions (n = 45) males vocalized and attacked whereas in 74% of the intrusions (n = 47) the females responded in this manner ($P < 0.005$). This lack of aggression on the part of males contrasts with Fox's observations of this species in the late 1950's before reproductive failure was noted (Fox 1964). Similarly, aggressive behavior has decreased in male Pere-

TABLE 2. Differences in the reproductive performance of "contaminated" and "uncontaminated" female Merlins subjected to behavioral testing and the shell quality and residue content of their eggs.

	"Uncontaminated"	"Contaminated"	P[a]
Nests	10	10	
Eggs	41	34	
Eggs disappeared	1 (2%)	9 (27%)	$P < 0.005$
Eggs hatched	37 (90%)	9 (56%)	$P < 0.005$
Young fledged	37 (100%)	19 (100%)	—
Thickness index	1.20 (1.12–1.42)[b]	1.00 (0.88–1.31)	$P < 0.002$
DDE	2.81 (0.98–6.02)[c]	16.6 (6.56–90.9)	$P < 0.001$
Dieldrin	0.13 (tr–0.83)	0.25 (tr–1.25)	$P > 0.05$
Heptachlor Epoxide	0.45 (tr–1.18)	0.56 (0.30–6.16)	$P > 0.05$
PCB	1.01 (0.22–2.91)	1.01 (0.50–1.88)	$P > 0.05$
Total mercury	0.04 (0.02–0.09)	1.10 (0.03–0.14)	$P > 0.05$

[a] Statistical significance based on chi-square or Mann-Whitney statistic.
[b] Median (range).
[c] Residues reported as median (range) on a ppm wet-weight basis.

grines nesting along the Coleville River between the 1950's and 1970's (T. Cade, pers. comm.). We can only speculate that these behavioral changes have a common cause.

The eggshells of the "uncontaminated" group were 10% thinner than the pre-DDT mean for this geographical population in contrast to those of the "contaminated" group whose shells were 25% thinner (Table 2). The thickness index was inversely correlated with DDE content ($r_s = -0.806$, $P < 0.01$). Of the pollutant residues measured, DDE was the only one that was present in significantly higher concentrations in the "contaminated" group (Table 2).

One of the 10 nests with the highest shell quality failed prior to behavioral testing, compared to four of the 10 nests with the lowest shell quality. A much larger proportion of the eggs of "contaminated" females disappeared (Table 2). These losses included both partial and complete clutches and may reflect decreased nesting drive resulting in increased desertion and less effective nest defense against predators.

Although it is assumed that many females who abandon nest sites prior to egg-laying are heavily contaminated with organochlorines, this relationship cannot be established from field studies. Failure of territorial pairs to lay eggs was a major cause of reproductive failure of the European Sparrowhawk (*Accipiter nisus*) in Scotland and was attributed to scarcity of food (Newton 1976). As many as 37% of Merlin nesting sites that showed signs of occupancy early in the season, both in England (Newton et al. 1978) and on our study area (Hodson 1975), do not have active nests after the majority of the population has laid. The birds at these sites may not have found mates, may have nested at alternate sites, may have been insufficiently nourished to breed, or their pair bond and nesting drive may have been inadequate. Possibly the most aberrant individuals in the population were not observed in this study.

When food is scarce, birds may spend more time foraging and nest defense may be decreased to conserve energy. Hence, lipid reserves may be depleted while the levels of circulating organochlorine residues are increased. However, we saw no indication that the prey populations were inadequate (Hodson 1975). Abnormal nest defense has been reported in Lake Ontario Herring Gulls (*Larus argentatus*), which are heavily contaminated with organochlorine pollutants (Fox et al. 1978), and in female Mallards (*Anas platyrhynchos*) dosed with dieldrin (Winn 1973). Dieldrin-dosed male Mallards exhibiting less territoriality and aggressiveness in an experimental arena had decreased levels of three neurotransmitting biogenic amines in their brains (Sharma et al. 1976); however, the physiological basis for the behavioral abnormalities observed in field studies has yet to be established.

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RECENT PUBLICATIONS

Distributional List of Chinese Birds. Revised edition.—Zheng Zo-xin (Cheng Tso-hsin). 1976. Science Press, Peking. [In Chinese.] This checklist for the birds of China is thoroughly revised and updated from the original edition (1955-8). Given for each of the 1,166 species is the scientific and common nomenclature, a synopsis of range and seasonal occurrence within China, and the taxonomy of subspecies, if any. A long table summarizes the distribution of species according to biological regions of the country. Distribution maps, references, index. A reference tool for curators and systematists.

A Revised List of Birds of Barro Colorado Island, Panama.—Edwin O. Willis and Eugene Eisenmann. 1979. Smithsonian Contributions to Zoology No. 291, Smithsonian Institution Press, Washington, DC. 31 p. Paper cover. This list reports the status and records of the 366 species of birds that have been recorded on or near Barro Colorado Island. Brief notes on habits are given for some species. The authors find that 51 formerly resident species have disappeared from the island and discuss the reasons therefor. By documenting a distressingly common situation in the neotropics, this report transcends a local list.

Birds of Pacific Rim National Park.—D. F. Hatler, R. W. Campbell, and A. Dorst. 1978. Occasional Paper No. 20, British Columbia Provincial Museum, Victoria. 194 p. Paper cover. $3.00. "Pacific Rim National Park extends as a narrow band of shore frontage and coast forest for more than 75 miles along the west coast of Vancouver Island." Difficult of access, the region is ornithologically one of the least-known parts of Canada. This report is largely an annotated list of the birds, based on field work by the authors and the published or unpublished records of other observers. It also gives detailed results of several transects and nesting data for four seabirds. Maps, photographs, gazetteer, references, and index. A good foundation has here been laid for further investigations of the status, habits, and ecology of the birds.

A Bibliography of British Columbia Ornithology. Volume 1.—R. W. Campbell, H. R. Carter, C. D. Shepard, and C. J. Guiguet. 1979. Heritage Record No. 7, British Columbia Provincial Museum, Victoria. 185 p. Paper cover. $4.00. A list of 2,100 references is made accessible by indexes according to species, geography, and author. The limits of the work are explained and the sources are listed. A useful reference for those working on the birds of the Pacific northwest.

Birding Areas of Iowa.—Edited by Peter C. Petersen. 1979. The Iowa Ornithologists' Union. 152 p. Paper cover. $4.50 plus .50 postage. Available: Pat Layton, 1560 Linmar Dr., Cedar Rapids, IA 52404. This guide assembles articles by 31 contributors that were originally published in *Iowa Bird Life*. Each chapter covers a region of the State, giving directions to the areas and naming the birds that may be found. The treatment is uneven but exceptionally detailed. Many maps. Locality and species indexes. A field assistant for birders in Iowa.