THE NESTING, REPRODUCTIVE PERFORMANCE, AND CHLORINATED HYDROCARBON RESIDUES IN THE RED-TAILED HAWK AND GREAT HORNED OWL IN SOUTH-CENTRAL MONTANA

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In this paper, we describe the nesting, reproductive performance, and chlorinated hydrocarban residues, and evaluate current population status of the Red-tailed Hawk (*Buteo jamaicensis*) and Great Horned Owl (*Bubo virginianus*) in south-central Montana. We conducted the field work during June and July, 1966, and March-July, 1967, incidental to but as background information for studies of the response of juvenile Red-tailed Hawks and Golden Eagles (*Aquila chrysaetos*) to DDT in their diet (Seidensticker, 1968) and the population status of the Golden Eagle (Reynolds, 1969).

THE STUDY AREA

The topography of northern Park, western Sweetgrass, and southern Meagher Counties, Montana, where we conducted this study, is characterized by river flood plains, gentle transitional foothills, and timbered mountain slopes. An alpine zone occurs at the highest elevations. Elevations range from 10,00 feet in the Bridger, Gallatin, Crazy, and Absaroka Mountain Ranges, which border the area, to 4,000 feet along the Yellowstone, Boulder, and Shields Rivers.

Cottonwood trees (*Populus* spp.) and willows (*Salix* spp.) dominate vegetation on the river and creek flood plains at the lower elevations where we concentrated our search for hawk and owl nests.

METHODS

We located hawk and owl nests using the procedure outlined by Craighead and Craighead (1956:196–199).

To obtain tissue for analysis of chlorinated hydrocarbon insecticide residues, we used a biopsy technique (Seidensticker, 1970*a*) or sacrificed the bird. Each egg that we analyzed came from a different nest. We placed large tissue samples and eggs in separate double polyethylene bags; small samples (collected via biopsy) were placed in clean, screw-top, five ml vials. We stored all samples in a freezer. The WARF Institute, Inc., Madison, Wisconsin, analyzed tissues and eggs with a gas chromatograph following the procedure outlined by the U.S. Food and Drug Administration (USFDA, 1964).

Samples from one Great Horned Owl egg and one Red-tailed Hawk egg were re-extracted, cleaned up, and hydrolyzed (treated with alcoholic KOH) to check for polychlorinated biphenyls (Risebrough et al., 1969; Anderson et al., 1969).

D. W. Anderson of the University of Wisconsin measured and weighed the hawk and owl eggshells using the procedures described by Hickey and Anderson (1968).

NESTING AND REPRODUCTIVE PERFORMANCE

Breeding Season.—Our observations indicated that the Red-tailed Hawk is at least partially migratory but the Great Horned Owl is not.

In 1967, the first Red-tailed Hawk on the study area was observed on 24 March and the first territorial selection probably began near the end of March. Laying dates recorded in 1967 ranged from 11 April to 8 May (median 24 April); hatching dates ranged from 18 May to 10 June (median 29 May); brood departure dates ranged from 26 June to 13 July (median 4 July). The total breeding season spanned about 105 days.

In 1967, based on the earliest observed hatching date, the first selection of territory by Great Horned Owls began during mid-February, the first egg hatched on 29 March, and the last brood fledged on 20 June. The breeding season in 1967 was about 125 days. The breeding season started about 10 days earlier and ended about two weeks later than the 1947 breeding season reported by Craighead and Craighead (1956) for the Great Horned Owl in Wyoming.

Nest Location and Density.—Of 55 nests used by Red-tailed Hawks located during the two years of study, we found 41 (74 per cent) in cottonwood trees, four in Douglas firs (*Pseudosuga menziesii*), three on cliffs, three in dead snags, two in quaking aspen (*Populus tremuloides*), one in an Engelmann spruce (*Picea engelmanni*), and one in a limber pine (*Pinus flexilis*). Cottonwoods were the only common tall trees growing on the river and creek flood plains where most of the nests were found.

Of 10 nests that the Red-tailed Hawks had used in 1966, hawks occupied four in 1967.

We made no effort to locate every nest in the study area, but we did search intensively in five different areas where, we believe, we located all hawk nests. Distances between adjacent nests ranged from 3.1 miles to 0.2 mile and averaged 1.3 miles.

We located 15 active Great Horned Owl nests and found 13 (86 per cent) of the nests in cottonwood trees, one in a Douglas fir and one on a cliff. Eight owls nested in abandoned hawk (*Buteo*) nests, four in abandoned Black-billed Magpie (*Pica pica*) nests, one in an abandoned Golden Eagle eyrie, one in an abandoned Common Crow nest (*Corvus brachyrhynchos*), and one on a cliff.

In 1967 owls occupied two of 10 nests used by Red-tailed Hawks in 1966. On 10 April 1967, we found a Great Horned Owl incubating two eggs in an old hawk nest. When we checked this nest again on 11 May, we found a female Red-tailed Hawk incubating two eggs.

Without obtaining absolute quantitative data or nesting densities, we found

TABLE 1

CAUSES OF 16 RED-TAILED HAWK NEST FAILURES IN SOUTH-CENTRAL MONTANA, 1966 AND 1967

Cause of failures	Before or during incubation		Nestling Period		Total
	Known	Probable	Known	Probable	
Man	2	4	1	–	7
Great Horned Owl	–	2	1	1	4
Disease	–	–	2	–	2
Wind	–	–	1	1	2
Common Crow	1	–	–	–	1
Total	3	6	5	2	16

a Red-tailed Hawk to Great Horned Owl nest ratio of 3:1 which is equivalent to that found by Craighead and Craighead (1956) in Jackson Hole, Wyoming.

Nesting Success.—We recorded the success or failure of 54 of the 55 nests of Red-tailed Hawks that we found. No young were fledged from 27 (50 per cent) of the nests; of the 27 nest failures, 15 (59 per cent) occurred before or during the incubation period while seven (22 per cent) occurred during the nestling period. We could not determine when five of the nest failures occurred.

From both direct and indirect evidence, we were able to determine the cause or probable cause of 16 of the 27 nest failures that were recorded (Table 1). As investigators, we caused the failure of one nest during the nestling stage. After we climbed to two nests, the hawks deserted them, and it is possible that we were responsible. These failures are listed as man-caused in Table 1. Other man-related causes listed in Table 1 included the shooting of adult hawks and taking eggs. Of the 11 nests that failed and were not listed in Table 1, we climbed into six. Other investigators have reported that many times Red-tailed Hawks desert if they are disturbed by climbing into the nest prior to or early in the incubation period (Fitch et al., 1946; Luttich et al., 1971). We do not believe that investigator influence was a principal cause of nest failures not listed in Table 1. We purposely avoided climbing into nests early in the incubation period but in two cases when we misjudged and climbed to nests that contained one egg, two eggs were present in both nests at a later time.

Red-tailed Hawks that nested close to Great Horned Owl nests were not successful in fledging young. This phenomenon was reported and discussed by Craighead and Craighead (1956), Hager (1957), and Luttich et al. (1971).

TABLE 2

PRODUCTIVITY IN ACTIVE AND SUCCESSFUL NESTS OF RED-TAILED HAWKS AND GREAT HORNED OWLS IN SOUTH-CENTRAL MONTANA, 1966 AND 1967

	Red-tailed Hawk		Great Horned Owl	
Number per nest	Nests studied	Mean ± SE	Nests studied	Mean ± SE
Eggs in complete clutches	22	2.9 ± 0.1	6	2.2 ± 0.2
Newly hatched young	15	2.6 ± 0.2	6	2.2 ± 0.2
Large downy young	12	2.2 ± 0.2	9	1.9 ± 0.2
Fledglings	15	1.7 ± 0.2	6	1.8 ± 0.2

Young fledged from seven (64 per cent) of the 11 Great Horned Owl nests in which we were able to determine success or failure. Man (other than the investigators) caused at least two of the four nesting failures.

Clutch Size and Egg Hatchability.—Minimum egg counts at 22 Red-tailed Hawk nests averaged 2.9 (Table 2): 4 nests with two eggs; 15 with three; and 3 with four. Minimum egg counts at six Great Horned Owl nests averaged 2.2 (Table 2): five nests with two eggs and one with three.

We found four addled eggs in Red-tailed Hawk nests with no nest containing more than one and no addled eggs in Great Horned Owl nests in which young hatched successfully. There was little difference in the average clutch size and the average brood size of newly hatched Red-tailed Hawks; there was no difference between average clutch size and average brood size of newly hatched young Great Horned Owls (Table 2). This indicated to us that egg hatchability was good for both species in nests that produced young.

Nestling Survival in Successful Nests.—Although nestling Red-tails died in nests which were successful, we have limited data on these deaths (Table 2). In two nests the youngest of three nestlings disappeared, and in two nests the youngest of two nestlings disappeared. One nestling with a swollen eye fledged. The blood sucking dipterous larva of *Protocallophora* sp. (identified for us by Dr. C. B. Philip) infected almost all hawk nestlings, but we could attribute no mortality to these larvae.

We have no data on nestling mortality in successful Great Horned Owl nests.

Reproductive Success and Population Status.—Henny and Wight (in press), using band recoveries, unpublished nesting records, and a structural model that permitted the use of mortality and recruitment rates to determine the status and trend of a population, found that between 1.33 and 1.38 Red-tails must be fledged per nesting attempt to maintain a stable population. They found that Red-tailed Hawks above 42°N latitude on the average fledged

1.84 young per successful nest. This figure approximates the 1.7 ± 0.2 young fledged per successful nest which was recorded in this study. If 1.84 young are produced per successful nest the nesting success must be 71–74 per cent to maintain a stable population. The 50 per cent nesting success we recorded, and hence the lower number of young fledged per nesting attempt (0.9) in our study, is clearly below that which is necessary to maintain a stable population based on the mortality rate calculated from banding recoveries.

Henny and Wight (in press) reported that the Red-tailed Hawk population in the United States appeared to be maintaining itself. Post-World War II counts of migrating Red-tailed Hawks flying over Hawk Mountain showed a decline from Pre-World War II levels, but they have remained constant at a lower level (Spofford, 1969). From the data available, it appears that the Red-tailed Hawk population over North America as a whole has remained stable.

Stewart's (1969) life table constructed from banding data shows that the mortality rate of Great Horned Owls (32 per cent) is less than that reported for the Red-tailed Hawk (35 and 42 per cent). Thus, fewer young need be produced to maintain a stable population and the 1.2 owls fledged per nesting attempt recorded in this study may be adequate.

CHLORINATED HYDROCARBON RESIDUES AND EGGSHELL MEASUREMENTS

Insecticide Residues.—All raptor tissue and egg samples analyzed bore measurable levels of DDE, DDT, DDD, and dieldrin (Table 3), and all samples except those taken from nestling and fledgling Red-tailed Hawks contained heptachlor epoxide. DDE was the most abundant residue in all samples, but these data (Table 3) indicate a generally low level of contamination from an acute-toxicity point of view. The sublethal effects of these levels are not certain.

Breast muscles taken from newly hatched nestling and fledgling Red-tails show no build-up of residues (Table 3). Fledglings were taken from the same nest from which nestlings were taken.

Residues in tissue taken via biopsy from Red-tails were higher than the residues found in whole pectoralis muscles taken from hawks of the same age (Table 3). Seidensticker (1970*a*) showed that samples taken via biopsy tend to give more variable results than whole muscles, probably because of the variable amounts of adipose tissue that are taken with muscle tissue in the biopsy.

We found (Table 3) that the viable eggs of hawks and owls have similar relatively low residue levels, and this may indicate a general low residue level in the fat of adult female hawks and owls (Anderson et al., 1969). We do not

TABLE 3

CHLORINATED HYDROCARBON INSECTICIDE RESIDUES IN RED-TAILED HAWK AND GREAT HORNED OWL TISSUE AND EGGS, SOUTH-CENTRAL MONTANA, 1967

		Residues in ppm wet wt							
		DDE		DDT + DDD		Dieldrin		Heptachlor epoxide	
	N	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Red-tailed Hawk									
Viable eggs	2	0.92	0.24– 1.60	0.05	0.03–0.06	0.30	0.16–0.44	0.16	0.09–0.24
Nonviable eggs	3	4.19	1.08–10.30	0.48	0.04–1.33	0.39	0.23–0.63	0.51	0.30–0.80
Nestlings (whole pectoralis muscle)	2	1.26	0.43– 2.10	0.14	0.09–0.20	0.12	0.05–0.19	0.02	0 –0.04
Fledgling									
Whole pectoralis muscle	2	0.87	0.49– 1.25	0.10	0.10	0.09	0.02–0.16	0	—
Biopsy (muscle and fat)	5	3.17	1.27– 6.87	1.33	0.40–2.30	0.38	0.10–1.40	0	—
Great Horned Owl									
Viable eggs	3	0.74	0.36– 1.13	0.07	0.02–0.22	0.16	0.11–0.24	0.11	0.02–0.23
Adult (whole pectoralis muscle & fat)	1	7.33	—	1.86	—	0.15	—	0.19	—

know why one hawk egg (nonviable) contained levels so much higher than the others. It weighed about the same as the viable hawk eggs, so the high residue level did not result from desiccation. In some instances birds acquire egg residues before they arrive on the breeding grounds (Anderson et al., 1969) and this egg may represent exposure in a dissimilar non-breeding area for the migratory Red-tailed Hawk.

Polychlorinated Biphenyls.—We conducted this study before the discovery of polychlorinated biphenyls (PCB) in the tissue of North American wildlife and the possibility of PCB interference with the determination of other residues. Anderson et al. (1969) and Risebrough et al. (1969) showed that PCB compounds affect analysis for DDT and DDD and that PCB residues may be mistakenly identified at DDT and DDD. In Table 4 we show the residues present in samples taken from one hawk and one owl before and after hydrolysis. The values obtained from these two samples indicated that there were low levels of PCBs present and little or no DDD or DDT present.

TABLE 4

RESIDUE LEVELS OF DDE, DDD, DDT, AND PCB IN HYDROLYZED AND NON-HYDROLYZED EGGS, SOUTH-CENTRAL MONTANA, 1967

	Residues in ppm wet wt.	
	Great Horned Owl egg	Red-tailed Hawk egg
DDE		
Non-hydrolyzed	0.630	1.240
Hydrolyzed	0.590	1.250
DDD		
Non-hydrolyzed	0.027	0.017
Hydrolyzed	0.021	0.017
Actual ppm	<0.010	<0.010
DDT		
Non-hydrolyzed	0.031	0.021
Hydrolyzed	0.031	0.022
Actual ppm	<0.010	<0.010
Est. PCBs	0.210	0.250

PCB levels in our samples are of the same general magnitude as those found in eggs of the Golden Eagle (0.23 ppm wet weight), Sparrow Hawk (*Falco sparverius*) (0.09), Pigeon Hawk (*Falco columbarius*) (0.39), Barn Owl (*Tyto alba*) (0.47 and 0.66) but far below the level found in a Peregrine Falcon (*Falco peregrinus*) egg (10.21), reported by Risebrough et al. (1968). In Britain, 0– < 1 and 0 residue levels were found in 5 Buzzard (*Buteo buteo*) and 20 Golden Eagle eggs respectively (Prestt et al., 1970).

The available evidence indicates that, like the chlorinated hydrocarbon pesticides, PCBs are persistent, accumulate in the body fat of animals, and are widespread in the environment. While PCBs apparently have a low avian toxicity, they are similar to dieldrin in their ability to induce hepatic enzymes that alter hormone concentrations. Thus, PCB could be a component cause of the breeding failure observed in some raptor populations (Risebrough et al., 1968; Prestt et al., 1970).

Eggshells.—The declining populations of raptoral birds in Great Britain (Ratcliffe, 1967) and North America (Hickey and Anderson, 1968) have produced thin-shelled eggs. Correlative evidence suggested that DDE inhibits calcium metabolism which results in eggshell thinning. Controlled experiments have confirmed this correlation (Porter and Wiemeyer, 1969; Peakall, 1970).

In Table 5 we compare weight and thickness of Great Horned Owl and Red-

TABLE 5

WEIGHT AND THICKNESS OF GREAT HORNED OWL AND RED-TAILED HAWK EGGSHELLS FROM 1967, COMPARED WITH PRE-1946 MUSEUM SPECIMENS FROM THE SAME GENERAL AREA[a]

		Thickness (mm)			Weight (g)		
Species	Period	No.	Mean ± SE (range)	Per cent change	No.	Mean ± SE (range)	Per cent change
Great Horned Owl	Pre-1946	65	0.3622 ± 0.0048	—	65	4.834 ± 0.064	—
Great Horned Owl	1967	3	0.3866 (0.37–0.41)	+6.7	3	5.353 (5.05–5.57)	+10.8
Red-tailed Hawk	Pre-1946	57	0.4286 ± 0.0052	—	97	6.108 ± 0.077	—
Red-tailed Hawk	1967	5	0.3850 (0.37–0.40)	–10.9	5	5.344 (5.18–5.47)	–12.5

[a] Pre-1946 data were provided by D. W. Anderson and J. J. Hickey, University of Wisconsin.

tailed Hawk eggshells with the same measurements taken from eggshells collected in the same general area prior to 1946 (pre-DDT). The Great Horned Owl eggshells show a slight increase but the Red-tailed Hawk eggshells show a decrease. Hickey and Anderson (1968) found that the weight of Red-tailed Hawk and Great Horned Owl eggshells in California increased slightly in recent years. In a more recent analysis, these workers (Anderson and Hickey, in press) reported that some Red-tailed Hawk eggshell samples show a decrease in thickness and weight from pre-DDT days with the largest decrease shown by our Montana sample.

DISCUSSION AND CONCLUSIONS

Hickey and Roelle (1969) and Peakall (1970) reported that the recent reproductive failures of raptor populations included some or all of the following symptoms: (1) abnormally late breeding, (2) failure to lay eggs, (3) reduced clutch size, (4) failure to re-lay after the loss of an initial clutch of eggs, (5) thinner eggshells, (6) egg breakage and eating, (7) increased embryonic mortality, and (8) increased nestling mortality. These have been termed the *raptor-pesticide syndrome* by Peakall (1970).

We did not observe abnormally late breeding in either the hawk or owl populations that we studied. Seidensticker (1970*b*) reported that in 1967 many Red-tails hatched just as young ground squirrels (the most important prey species of nesting Red-tails) became available. Hence, breeding in the portion of Red-tailed Hawk population that successfully hatched eggs appeared to be synchronous with the food supply.

Our data indicate similar nest densities in the hawk and owl populations that we studied and in populations studied by Craighead and Craighead (1956) in Jackson Hole, Wyoming, in 1947.

The Great Horned Owl did not have the thin eggshells that were observed in declining raptor populations by Ratcliffe (1967), Hickey and Anderson (1968), and Fyfe et al. (1969). We did find thinning in Red-tailed Hawk eggshells. The eggs of some Red-tailed Hawks contained higher chlorinated hydrocarbon pesticide residues than the eggs of Great Horned Owls. This may have been the result of dissimilar non-breeding area exposure for the resident Great Horned Owl and the migratory Red-tailed Hawk. However, in 1967, clutch size and egg hatchability in nests that produced young appeared to be normal for both species, and we did not observe egg breakage or eating of eggs.

Nesting success in the Red-tailed Hawk population was below that considered necessary for the population to maintain itself. Most nests that failed did so before or during incubation. Some of the nest failures that occurred during this period could in reality have been failures to lay eggs which resulted from patho-physiological depressed hormone concentrations caused by chlorinated hydrocarbon pesticide residues (Peakall, 1970). But more direct, man-related causes are known to have been an important factor in some nesting failures.

Because individual hawks and owls in the populations we studied were not marked, we were not able to obtain renesting data.

Our data indicated that some nestling hawks died but the number of young fledged per successful nest was not below that reported in other studies. Chlorinated hydrocarbon pesticide residues were not high from an acute-toxicity point of view.

SUMMARY

We report on the nesting and reproductive performance of the Red-tailed Hawk and Great Horned Owl in south-central Montana during 1966 and 1967. Hawk and owl breeding seasons spanned 105 and 125 days respectively in 1967. Great Horned Owls wintered on the study area, but at least some Red-tailed Hawks winter south of the study area. Both hawks and owls nested primarily in cottonwood trees. The clutch size and number fledged from successful nests of Red-tailed Hawks averaged 2.9 and 1.7 respectively while Great Horned Owl clutch size and number fledged per successful nest averaged 2.2 and 1.8 respectively. The number of young fledged per recorded nesting attempt averaged 0.9 for the hawk and 1.2 for the owl. Nesting success for the hawk was 50 per cent and 64 per cent for the owl. All tissue and eggs contained measurable but relatively low levels of DDE, DDT, DDD, and dieldrin, and some samples contained heptachlor epoxide. The one hawk and one owl egg analyzed contained PCBs. The Great Horned Owl did not have thin eggshells but we did find thinning in Red-tailed Hawk eggshells.

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