

Eggshell Quality and Organochlorine Residues in Eggs of Merlins, *Falco columbarius*, in Southeastern Montana

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Eggshell weight and thickness indices of Richardson's Merlin (*Falco columbarius richardsonii*) eggs collected in southeastern Montana were significantly ($p \leq 0.01$) lower than pre-1946 samples. Montana eggshells showed reductions of 13% in shell weight and 20% in shell thickness indices when compared to eggshells collected before 1946. The decreased eggshell weights and thickness indices and the occurrence of 7 organochlorine compounds in Merlin eggs recently collected in southeastern Montana indicates that this raptor population merits periodic monitoring.

Key Words: Organochlorines, Merlin, *Falco columbarius*, pesticides, Montana.

Reductions in eggshell weights and thickness indices of numerous raptors have been associated with accumulations of organochlorine residues, particularly DDE, in breeding adults (Newton 1979). Decreases in eggshell thickness accompanied by population declines have been reported for Bald Eagles (*Haliaeetus leucocephalus*), Ospreys (*Pandion haliaetus*), and Peregrine Falcons (*Falco peregrinus*) (Hickey and Anderson 1968).

Organochlorine pesticide contamination was first correlated with decreased eggshell weights and thickness indices and lower reproductive success of Merlins (*Falco columbarius*) in Great Britain (Ratcliffe 1970; Newton 1973; Newton et al. 1978, 1981). Detrimental effects of chlorinated hydrocarbons on Merlin reproductive success have also been detected in Canada (Fox 1971; Temple 1972; Fyfe et al. 1976; Hodson 1976; Fox and Donald 1980). In the United States, published information is limited to analyses of pesticide residues in three eggs that failed to hatch at a Montana nest (Ellis 1976).

This paper presents eggshell weights and thickness indices and organochlorine residue concentrations in eggs of Richardson's Merlins (*F. c. richardsonii*) collected in southeastern Montana. These mensural characteristics are compared with measurements of pre-pesticide era (pre-1946) Merlin eggshells from various locations in the northern Great Plains. Potential effects of reduced eggshell quality and pesticide contamination on reproduction of Merlins in this area are discussed.

Study Area

The study area encompassed 39 448 ha in southeastern Montana. Habitat used by breeding Merlins consisted of forested hills and sandstone buttes

ranging to approximately 300 m above the adjacent grasslands. Vegetative cover on the area was composed of approximately 27% forest cover and 67% Big Sagebrush (*Artemisia tridentata*)-grassland interspersed with barren buttes. The dominant tree species was Ponderosa Pine (*Pinus ponderosa*); primary grass species were Western Wheatgrass (*Agropyron smithii*), and Blue Grama (*Bouteloua gracilis*).

Methods

During 1978 through 1981, 18 intact Merlin eggs that failed to hatch were collected from 18 different clutches for analyses of eggshell weight and thickness. Contents of eggshells were removed through a hole ≤ 3 mm in diameter, and eggshells were washed and air-dried for at least 90 days. Merlin eggshells in museum collections were used as the control for comparison of eggshell quality. The museum eggs had been collected between 1865 and 1945 in the northern Great Plains of North America (Montana, North Dakota, Alberta, Saskatchewan); eggshells with holes > 3 mm in diameter were rejected. Eggshell dimensions were not significantly different among Merlin eggs collected throughout the northern Great Plains (Bent 1938; Brown and Amadon 1968; Fox 1971).

Length and breadth of eggshells collected during the study and the museum eggshells were measured to 0.01 mm, and each eggshell was weighed to the nearest 1 mg. Eggshell thickness indices were calculated by the formula $w/(l \times b)$; where w = weight (mg); l = length (mm), and b = breadth (mm) (Ratcliffe 1967). Differences between mean eggshell weights and thickness indices of the Montana sample and the

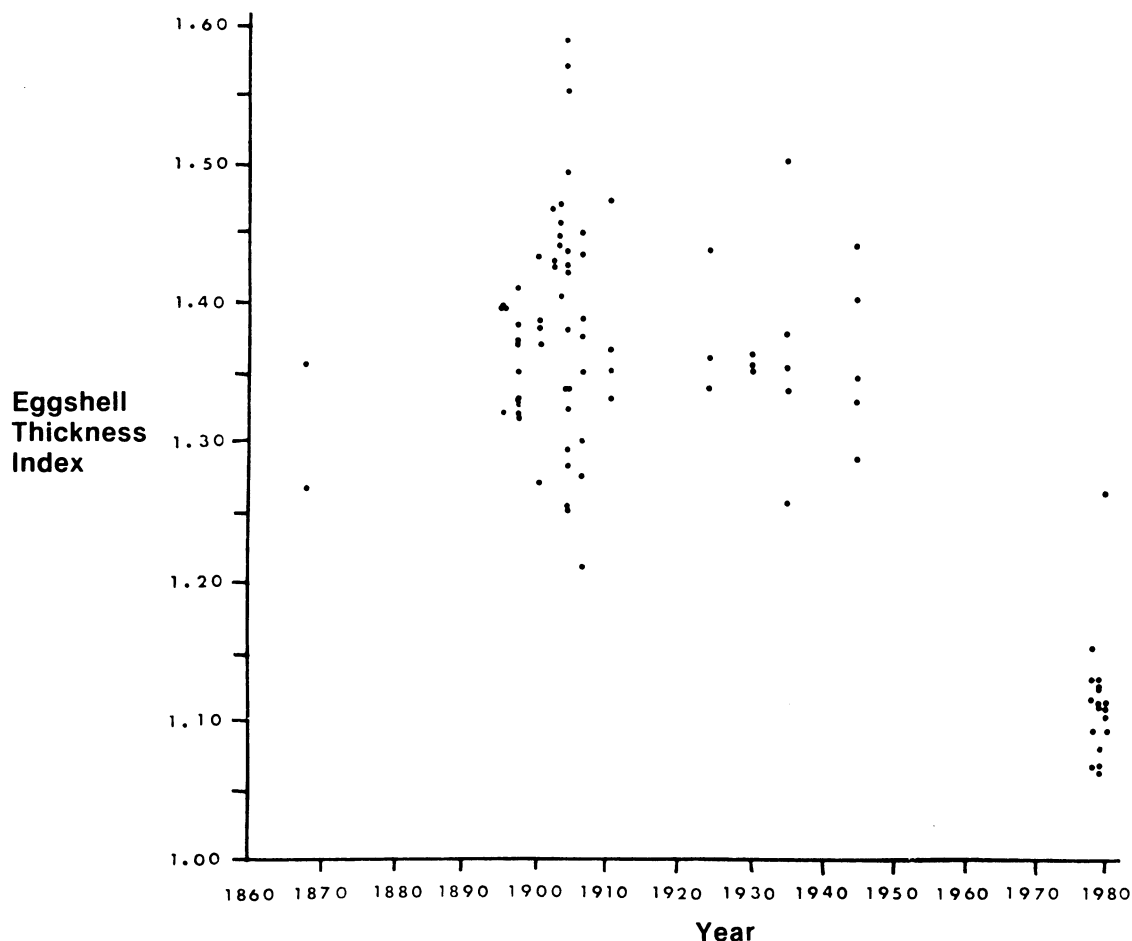


FIGURE 1. Changes in Richardson's Merlin eggshell thickness indices. Pre-1946 indices are from museum specimens collected in the northern Great Plains. More recent indices (1978–1981) were calculated from eggs collected in southeastern Montana.

1946 sample were compared with heterogeneous variance *t*-tests (Steel and Torrie 1980), and results were considered significant at $\alpha \leq 0.05$.

Four Merlin eggs were collected from four different clutches to be analyzed for concentrations of organochlorines. The eggs were wrapped in aluminum foil, frozen, and shipped to Patuxent Wildlife Research Center for analyses. Contents were removed from eggshells and analyzed for DDE, DDD, DDT, dieldrin, heptachlor epoxide, oxychlordane, cis-chlordane, trans-chlordane, cis-nonachlor, endrin, toxaphene, and polychlorinated biphenyls (PCB). Analytical methodology followed standard procedures described by Cromartie et al. (1975). Results are presented in ppm (corrected wet weight).

Results

Weights of the eighteen eggshells ranged from 1440 to 1570 mg ($\bar{x} = 1468$, S.D. = 34), compared to a range of 1326 to 1870 mg ($\bar{x} = 1677$, S.D. = 127) for 71 pre-1946 Merlin eggshells. Average weight of the Montana eggshells was 13% lower ($t = 15.0$, $P \leq 0.01$) than the average weight of the pre-pesticide eggshells. Eggshell thickness indices for the recent Merlin eggshells ranged from 1.02 to 1.21 ($\bar{x} = 1.07$, S.D. = 0.04). These indices were 20% lower ($t = 30.4$, $P \leq 0.01$) than the pre-1946 thickness indices, which ranged from 1.20 to 1.54 ($\bar{x} = 1.33$, S.D. = 0.07) (Figure 1).

DDE residues were detected in four eggs analyzed for organochlorine compounds ($\bar{x} = 6.7$, S.D. = 3.8); DDE residues in 3 eggs were above 6 ppm (7.2, 8.7, 9.6 ppm). Trace amounts of dieldrin ($\bar{x} = 0.1$, S.D. = 0.1),

heptachlor epoxide (\bar{X} = 0.2, S.D. = 0.2), oxychlordane (\bar{X} = 0.1, S.D. = 0.1), cis-chlordane (\bar{X} = 0.1, S.D. = 0.1), trans-chlordane (\bar{X} = 0.1, S.D. = 0.1), and PCB (\bar{X} = 0.3, S.D. = 0.4) were also detected in some samples. Organochlorine compounds not detected included DDD, DDT, cis-nonachlor, endrin, and toxaphene.

Discussion

The decrease in eggshell weight (13%) from pre-1946 levels is similar to declines in eggshell weights of Merlin eggs collected in Britain and in Canada. Mean weights in Britain declined 13% (from 1.6 g for eggshells collected from 1900-49, to 1.4 g for eggshells collected between 1951 and 1964) (Ratcliffe 1970). Merlin eggshells collected in Canada from 1950 to 1969 were 23% lower in weight when compared with a sample collected from 1930 to 1949 (Fox 1971).

Studies in Great Britain and North America have documented decreases in thickness indices of eggshells since the pre-pesticide era. Merlin eggshell thickness indices in one British study declined 13% compared with eggshells collected before pesticide use (Newton 1973). However, thickness indices decreased 21% and 22% in the Peak District and Northumberland, Great Britain, respectively (Newton et al. 1978, 1981). A 9% decrease in thickness indices in Merlin eggshells from eastern Canada was reported by Temple (1972). In Alberta, eggshell thickness indices decreased 10% from pre-pesticide levels for samples containing low concentrations of organochlorines and 25% for samples with high organochlorine contamination (Fox and Donald 1980). The 20% decrease in thickness indices of our sample of Montana Merlin eggs is within the upper range of results reported previously.

It is impossible to identify precisely the source of the seven organochlorines found in Merlin eggs in southeastern Montana. Dieldrin and DDT were used in Montana in the 1960s and early 1970s (G. McOmber, Montana Department of Agriculture, personal communication). Merlins that breed in Montana may also accumulate organochlorine residues by consuming contaminated prey along migratory routes or in wintering areas. Merlins banded in Alberta have been recovered as far south as Mexico and Costa Rica (U. Banasch, Canadian Wildlife Service, personal communication), and Henny et al. (1982) indicated that Peregrine Falcons are accumulating pesticides on wintering grounds in Latin America. Regardless of the source, the presence of organochlorines in Merlin eggs from southeastern Montana indicates that pesticide contamination may be contributing to a lowered eggshell weight and index of thickness in this area.

The DDE residues in the four eggs analyzed were lower than peak concentrations reported for other Merlin populations. DDE concentrations in Merlin eggs collected in Britain were as high as 19.8 ppm wet weight (Ratcliffe 1970), and concentration of DDE averaged 9.4 ppm wet weight in three eggs from the same clutch collected in central Montana (Ellis 1976). Concentrations in three eggs in the present study may be high enough to affect the reproductive success of this population (O. H. Pattee, U. S. Fish and Wildlife Service, personal communication).

Dieldrin has also been implicated as a possible cause of eggshell thinning (Ratcliffe 1970). Sub-lethal levels of dieldrin consumed by Prairie Falcons, *Falco mexicanus*, have been correlated with reductions in eggshell thickness indices (Enderson and Berger 1970). Greater toxicity has been reported for birds with dieldrin residues than birds with residues of DDT or its metabolites (Fyfe et al. 1969). Heptachlor and chlordane (including chlordane products) probably do not induce eggshell thinning, but have been reported to be toxic at higher levels of accumulation (Fyfe et al. 1969; Blus et al. 1983).

The significant decrease in eggshell quality and the presence of DDE residues above 6 ppm in 3 of 4 Merlin eggs from southeastern Montana are cause for concern. Reproductive success of this population ranged from 3.0 to 3.3 fledglings per active nest and averaged 3.7 fledglings per successful nest (Becker and Sieg 1985), results comparable to or somewhat higher than the results of similar studies in Canada (Fox 1964; Fox 1971; Hodson 1976; Oliphant and Thompson 1978; Fox and Donald 1980). It is possible that the addled eggs collected in southeastern Montana may have presented a picture of poorer eggshell quality than was actually the case. Because it is not known whether eggshell quality and organochlorine residue levels are stable or still changing, further monitoring of these factors as well as reproductive success is recommended to enable managers to identify trends in Merlin reproductive performance.

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