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UNHATCHED EGGS IN SWAINSON'S HAWK NESTS

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Abstract.—Unhatched eggs were recorded during banding visits to 987 nests of the Swainson's Hawk in western Saskatchewan between 1972 and 1988. In 104 of these nests there were 129 unhatched eggs, representing 10.5% of the nests and 6.3% of the eggs. Twenty-six of the unhatched eggs (20%) contained visible embryos. Although this hawk migrates through Central and South America, where DDT is still widely used, the organochlorine residue and PCB content of unhatched eggs collected from nests in the Canadian Prairies in 1984 and 1985 were low. The percentage of unhatched eggs was highest in 1985, the peak year for grasshopper abundance and use of insecticides for grasshopper control.

HUEVOS SIN ECLOSIONAR EN NIDOS DE *BUTEO SWAINSONI*

Sinopsis.—Entre 1972 y 1988, se tomaron datos sobre huevos sin eclosionar de 987 nidos de *Buteo swainsoni* estudiados en el oeste de Saskatchewan. En 104 de estos nidos, se encontraron 129 huevos sin eclosionar, lo que representa al 10.5% de los nidos y 6.3% de los huevos, respectivamente. Ventiseis (20%) de los huevos que no eclosionaron contenian embriones. Este halcón migra a través de Centro y Sur América, en donde todavía se utilizan insecticidas como el DDT. No obstante, los residuos de organoclorinados y contenido de PCB en los huevos coleccionados entre 1984–1985 resultaron ser bajos. El porcentaje de huevos sin eclosionar resultó más alto durante el 1985, año en donde hubo un pico en la abundancia de saltamontes y mayor uso de insecticidas para el control de estos.

Ecological and sociobiological factors affecting the hatchability of wild bird's eggs have been discussed by Koenig (1982) and Rothstein (1973). Remarkably little has been written about unhatched eggs of wild raptors, although Cameron (1913) observed the common presence of unhatched eggs in nests of the Swainson's Hawk (*Buteo swainsoni*).

One of us (CSH) has recorded unhatched eggs in 987 Swainson's Hawk nests in Saskatchewan since 1972. The annual frequency of occurrence varies widely. In 1985, a peak year in a major grasshopper outbreak, when 3.6 million ha of cropland in Saskatchewan were sprayed with short-lived neurotoxic pesticides to control grasshoppers, we were alarmed at the higher frequency of unhatched hawk eggs. In the past, widespread use of insecticides, mainly dieldrin, to control grasshoppers, led to marked population declines of the Merlin (*Falco columbarius richardsonii*) and the

Prairie Falcon (*Falco mexicanus*) on the Canadian prairies (Fyfe et al. 1976).

We have analyzed our data in an attempt to determine what if any associations exist among the frequency of unhatched eggs in nests of Swainson's Hawks, grasshopper infestations and the insecticides currently used for grasshopper control in Saskatchewan.

METHODS

Since 1972, CSH and many volunteer assistants recorded the presence of unhatched eggs when they visited Swainson's Hawk nests to band the young. Visits to nests prior to hatching were avoided because in earlier visits to seven nests during incubation, all females deserted (Houston 1974). Eggs in nests with newly-hatched young were not disturbed because hatching is asynchronous and such eggs may have been viable. If the smallest nestling was ≥1 wk old, unhatched eggs were shaken vigorously. Eggs that had an audible "slosh," indicating structural breakdown and bacterial decomposition, were classed as addled and removed from the nest, together with firm eggs unhatched with nestlings ≥2 wk old.

Prior to 1986, all 89 unhatched eggs were wrapped in aluminum foil, labelled, frozen and shipped to the National Wildlife Research Centre in Ottawa at the end of the field season. Only four of these eggs were firm and did not "slosh." Later, 67 of these eggs were examined in Ottawa after a long period of freezing. The eggs, still wrapped in foil, were partially thawed overnight in a 5 C refrigerator, scored with a solvent-cleaned scalpel and the contents placed in hexane-rinsed glass jars. The presence and stage of development of any embryos were recorded. Of the eggs collected in 1984 and 1985, the contents of 2–5 were amalgamated into eight pools, based on geographic location, and then analyzed for organochlorine residues (Peakall et al. 1986). The remaining eggs were archived in the Canadian Wildlife Service National Specimen Bank.

In 1986–1988, all 40 eggs were candled at the Poultry Science Laboratory, University of Saskatchewan, by RDC, within 3 d of collection, then broken and, in 1986 and 1987, submitted for bacteriological analysis, and in 1988 submitted to Lynn W. Oliphant for embryo analysis. We could not distinguish which of the 29 eggs without visible embryos were infertile or which had early embryos already destroyed by advanced decay and bacterial growth (see Moseley and Landauer 1949, Romanoff and Romanoff 1949).

The temporal relationship between nesting parameters and grasshopper abundance was determined using a semi-qualitative index, the predicted grasshopper infestation density score (e.g., Mukerji and Braun 1985) for the Rural Municipality #290 of Kindersley-Elna, where most of the nests were located. Spearman's coefficient of rank correlation was used as the measure of association.

As a result of the short half-life of modern neurotoxic pesticides (dimethoate, carbaryl, carbofuran, chlorpyrifos and deltamethrin), it was not possible to analyze the eggs for residues of these chemicals.

TABLE 1. Unhatched eggs in 987 nests of Swainson's Hawk, 1972–1988.

Year	# active nests	# nests with young	# young per nest	% nests with unhatched eggs	# unhatched eggs	% unhatched eggs	# eggs in nests with young	# eggs in nests with no young
1972	60	60	2.43	6.7	4	2.7	4	0
1973	27	26	1.96	14.8	5	8.9	3	2
1974	33	33	2.39	9.1	3	3.7	3	0
1975	23	23	1.91	0	0	0	0	0
1976	8	8	2.38	0	0	0	0	0
1977	40	40	2.10	22.5	9	9.7	9	0
1978	44	44	2.32	2.3	1	1.0	1	0
1979	44	43	2.26	13.6	6	5.8	5	1
1980	43	42	2.00	11.6	5	5.6	4	1
1981	61	58	2.12	8.2	11	8.2	2	9
1982	63	62	1.85	7.9	5	4.2	4	1
1983	87	84	2.05	6.9	9	5.0	3	6
1984	62	60	1.73	14.5	10	8.8	8	2
1985	71	66	2.05	19.7	21	13.5	10	11
1986	105	103	2.08	8.6	12	5.3	10	2
1987	121	116	1.82	9.9	13	5.4	7	6
1988	95	90	1.71	12.6	15	13.0	7	8
Total	987	958	2.02	10.5	129	6.3	80	49

RESULTS

Overall there were 129 unhatched eggs in 104 of the 987 nests, 10.5% of the nests and 6.3% of the eggs laid. The frequency of nests with addled eggs ranged from 0 in 1975 to 22.5% in 1977 (Table 1). All eggs failed to hatch in 29 nests (2.9%) where adults were still present. Of these, 16 nests had one, 6 had two, and 7 had three eggs, a mean clutch size (1.69) smaller than that of successful nests where eggs hatched (2.10). Of the 75 nesting attempts producing live young and unhatched eggs, the most frequent combination was one unhatched egg and one young (46 nests), followed by one unhatched egg with two young (21 nests). There were also four nests with one unhatched egg and three young; two with two unhatched eggs and one young; one with two unhatched eggs and two young; one with three unhatched eggs and one young.

Of 987 Swainson's Hawk nests with adults present at the time of the banding visit in late July, 958 (97.1%) successfully reared one or more young to banding age, with a mean of 2.02 young per successful nest. We lack exact figures on the percentage of pairs that attempted breeding and failed prior to this visit, but an early survey by Jean Harris (pers. comm.) in the eastern half of our study area showed that 11 of 60 pairs in 1987 and 19 of 39 pairs in 1988 failed and deserted their nests during June and the first half of July, prior to the banding visit.

All of the 40 unfrozen eggs examined in Saskatoon and 24 of the 67 frozen eggs (36%) examined in Ottawa showed advanced microbial decomposition, whereas in the remaining 37 frozen eggs there was little

TABLE 2. Organochlorine residue content in Swainson's Hawk eggs (expressed as ppb, net weight).

Location	Year	# eggs	DDE	Dieldrin	Oxy-chlordane	Heptachlor-epoxide	HCB	PCB
Saskatchewan (pooled, unhatched eggs)								
Nokomis	1984	2	515	69	25	105	4	263
Kindersley	1984	3	1020	23	33	104	5	101
Kindersley	1985	4	159	14	10	29	7	62
Kerrobert	1984	3	813	50	24	138	52	481
Kerrobert	1985	2	727	36	33	293	41	301
Beaufield	1985	2	83	197	36	165	24	22
Major	1985	3	460	48	20	83	36	378
Wartime	1985	5	326	106	29	248	129	157
Dakotas (Stendell et al. 1988)								
	1974–1979	16	80–960	20–710	20–40	0–180	0–790	0–900
Oregon and Washington (Henny and Kaiser 1979)								
	1976	10	190–713	220–730	NA	140–170	130	500
Washington (Bechard 1981)								
	1977–1978	8	140–2900	80–180	70–560	80–1550	100–5200	100
Oregon (Henny et al. 1984)								
	1978–1980	25	150–10,410	100–1340	110–310	100–2950	190–2620	NA

NA—not available.

evidence of microbial decomposition and 6 showed moderate microbial decomposition. Seven of the 40 unfrozen eggs candled in Saskatoon were firm and 33 "sloshed"; all 7 of the firm eggs and 8 of the 33 "sloshing" eggs had visible embryos. Of the 67 frozen eggs examined in Ottawa, 11 (16%) had visible embryos. Six of the 15 instances of embryo death occurred in 1988, the warmest year when temperatures reached 42 C.

Both the temporal variation in percent of nests with unhatched eggs ($r_s = 0.435$, $P < 0.05$) and the percentage of eggs that failed to hatch ($r_s = 0.450$, $P < 0.05$) were significantly correlated with the predicted grasshopper infestation in Rural Municipality 290, Kindersley-Elna (Mukerji and Braun 1985), where most of the nests in this study were concentrated.

The organochlorine residue content of unhatched eggs collected from nests in west-central Saskatchewan in 1984 and 1985 was low (Table 2).

DISCUSSION

This study provides long-term evidence of year-to-year variation in occurrence of unhatched eggs, but the various causes of this variation remain uncertain.

Both the temporal variation in percentage of nests with unhatched eggs and the percentage of eggs that failed to hatch are significantly correlated with predictions of grasshopper abundance for the study area. Such measures of association need not necessarily represent a cause-and-effect relationship, and the significance depends largely on one single high year, 1985. In Saskatchewan, grasshopper outbreaks are positively correlated with temperature and inversely correlated with rainfall in the previous year (Edwards 1960, Gage and Mukerji 1977). Hence, severe grasshopper outbreaks typically occur when precipitation is low and temperatures are above average. Such weather conditions are likely to have negative effects on small mammal populations and may affect incubation behavior of hawks. The economics of insect control have been discussed by Madder and Stemeroff (1988).

Our observations and those of Schmutz et al. (1980) suggest that grasshoppers are not a main food item for Swainson's Hawk nestlings, though Cameron (1913) considered that grasshoppers formed the "staple sustenance" of these hawks in Montana. We have observed large flocks of Swainson's Hawks feeding on grasshoppers only during their pre-migration gatherings in Saskatchewan in August. Johnson et al. (1987) observed nonbreeding Swainson's Hawks gathering in flocks to feed on grasshoppers in Idaho from late June through August, but hypothesized that mammals and birds are necessary to meet the dietary needs of breeding females and developing young.

Although this hawk migrates through Central and South America, where DDT is still widely used, the organochlorine residue and PCB content of unhatched eggs collected from nests in the Canadian Prairies in 1984 and 1985 were well below known levels for embryo or behavioral toxicity (Table 2). Levels are similar to those recorded in randomly collected eggs from the Dakotas (Stendell et al. 1988) and are generally

lower than those found in eggs from nests in Washington state, especially eggs that failed to hatch (Henny and Kaiser 1979). Organochlorine contamination, either local or on the Argentina "wintering" grounds, is not responsible for hatching failures.

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