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LITERATURE CITED

ALSAGER, D. E., J. B. STENRUE, AND R. L. BOYLES. 1972. Capturing Black-billed Magpies with circular live traps. J. Wildl. Manage. 36:981–983.

BROCKWAY, B. F. 1965. Stimulation of ovarian development and egg laying by male courtship vocalization in budgerigars (*Melopsittacus undulatus*). Anim. Behav. 13:575–578.

DEWOLFE, B. D. 1968. *Zonotrichia leucophrys gambelii* (Nuttall): Gambel's White-crowned Sparrow. U.S. Natl. Mus. Bull. 237:1324–1344.

DHONDT, A. A., AND R. EYCKERMAN. 1979. Temperature and date of laying by tits *Parus* ssp. Ibis 121:329–331.

ERPINO, M. J. 1968a. Age determination in the Black-billed Magpie. Condor 70:91–92.

ERPINO, M. J. 1968b. Nest-related activities of Black-billed Magpies. Condor 70:154–165.

FARNER, D. S. 1959. Photoperiodic control of annual gonadal cycles in birds, p. 717–750. *In* R. B. Withrow [ed.], Photoperiodism and related phenomena in plants and animals. AAAS, Washington, DC.

FARNER, D. S., AND E. GWINNER. 1980. Photoperiodicity, circannual and reproductive cycles, p. 331–336. *In* A. Epple and M. H. Stetson [eds.], Avian endocrinology. Academic Press, New York.

FARNER, D. S., AND L. R. MEWALDT. 1952. The relative roles of photoperiod and temperature in gonadal recrudescence in male *Zonotrichia leucophrys gambelii*. Anat. Rec. 113:612–613.

FARNER, D. S., AND A. C. WILSON. 1957. A quantitative examination of testicular growth in the White-crowned Sparrow. Biol. Bull. 113:254–267.

GOODACRE, M. J., AND D. LACK. 1959. Early breeding in 1957. Br. Birds 52:74–83.

HOLYOAK, D. 1967. Breeding biology of the Corvidae. Bird Study 14:153–168.

LACK, D. 1950. The breeding seasons of European birds. Ibis 92:288–316.

LEHRMAN, D. S. 1965. Interaction between internal and external environments in the regulation of the reproductive cycle of the Ring Dove, p. 335–380. *In* F. A. Beach [ed.], Sex and behavior. Wiley, New York.

LEWIS, R. A., AND D. S. FARNER. 1973. Temperature modulation of photoperiodically induced vernal phenomena in White-crowned Sparrows (*Zonotrichia leucophrys*). Condor 75:279–286.

LINSDALE, J. M. 1937. The natural history of magpies. Pacific Coast Avifauna No. 25.

MORTON, M. L., M. E. PEREYRA, AND L. F. BAPTISTA. 1985. Photoperiodically induced ovarian growth in the White-crowned Sparrow (*Zonotrichia leucophrys gambelii*) and its augmentation by song. Comp. Biochem. Physiol. A Comp. Physiol. 80:93–97.

MUGAAS, J. N., AND J. R. KING. 1981. Annual variation of the daily energy expenditure by the Black-billed Magpie. Studies in Avian Biology No. 5.

MURTON, R. K., AND N. J. WESTWOOD. 1977. Avian breeding cycles. Clarendon Press, Oxford.

O'CONNER, R. J. 1978. Nest-box insulation and the timing of laying in the Wytham Woods population of Great Tits *Parus major*. Ibis 120:534–537.

PERRINS, C. M. 1970. The timing of birds' breeding seasons. Ibis 112:242–255.

RISSER, A. C. 1971. A technique for performing laparotomy on small birds. Condor 73:376–379.

SLAGSVOLD, T. 1976. Annual and geographic variation in the time of breeding of the Great Tit *Parus major* and the Pied Flycatcher *Ficedula hypoleuca* in relation to environmental phenology and spring temperature. Ornis Scand. 7:127–145.

WINGFIELD, J. C., AND D. S. FARNER. 1980. Control of seasonal reproduction in temperate-zone birds. Prog. Reprod. Biol. 5:62–101.

WINGFIELD, J. C., M. L. MOORE, AND D. S. FARNER. 1983. Endocrine responses to inclement weather in naturally breeding populations of White-crowned Sparrows (*Zonotrichia leucophrys pugetensis*). Auk 100: 56–62.

WINGFIELD, J. C., J. P. SMITH, AND D. S. FARNER. 1982. Endocrine responses of White-crowned Sparrows to environmental stress. Condor 84:399–409.

ZAR, J. H. 1974. Biostatistical analysis. Prentice Hall, Englewood Cliffs, NJ.

The Condor 88:93–94

PREDATORY BIRD BEHAVIOR AND TILLAGE OPERATIONS[1]

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Key words: Hunting success; prey abundance; predator-machinery association; American Kestrel; Red-tailed Hawk; Loggerhead Shrike.

Predatory birds occasionally take the prey flushed by moving machinery and thereby increase their hunting success. For example, Peregrine Falcons (*Falco peregrinus*) followed a refuge patrol boat to hunt Horned Grebes (*Podiceps auritus*) in South Carolina (Andre 1978). In Minnesota, Flugum (1975) noted that his farm tractor, being used in tillage work, would flush mice and improve the hunting success of Red-tailed Hawks (*Buteo jamaicensis*) and, rarely, American Kestrels (*F. sparverius*). During field work in Isabella County, central Michigan, between 1973 and the summer of 1985, I witnessed other examples of this association between avian predators and farm machinery. This paper further documents the avian predator-machinery association and provides new data on hunting success of avian predators that forage around working farm machinery.

Relative abundance of predator and prey was recorded by summing the number of sightings of each and relating these sightings to the daylight hours spent preparing a field for planting. Capture attempts by avian predators consisted of either a swooping descent from a perch or a rapid

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TABLE 1. Hunting success of American Kestrels around moving machinery.

Capture-frequency cohort number	0	1	2	3	4	5	6	7	8	9	10	11	12
Number of cohort observations	5	16	3	1	0	0	0	1	0	0	0	0	1
Number of capture attempts within cohort	5	18	7	3	0	0	0	8	0	0	0	0	13
Number of captures within cohort	5	16	6	3	0	0	0	7	0	0	0	0	12
Success rate (percent)	100	89	86	100	0	0	0	88	0	0	0	0	92

descent from a hovering flight. Observation distances were estimated within known field boundaries.

I spent 850 hr working at preplanting tillage and saw 104 mouse-sized mammals. In order of relative abundance, the prey consisted predominately of deer mice (*Peromyscus maniculatus*) followed by meadow voles (*Microtus pennsylvanicus*) and shorttail shrews (*Blarina brevicauda*).

I made 54 observations of the prey-capture success of American Kestrels, one of a Red-tailed Hawk, and two of Loggerhead Shrikes (*Lanius ludovicianus*) as they hunted from the borders of fields under tillage. The success of kestrels is presented in Table 1. The 54 stoops by kestrels resulted in 49 captures with a success rate of 81%. The 7 and 12 capture-frequency cohorts occurred in fields of unusually large populations of deer mice and meadow voles respectively and did not seem to differ in success rate from the lesser capture categories. There were 1.6 captures per successful observation period. The array of capture frequencies (0, 1, and >1) was compared with a Poisson distribution. There was a tendency for zero and single captures to be lower and higher than expected, respectively, but the trend was not significant ($\chi^2 = 3.22$, $df = 1$, $P > 0.08$). I estimated that the majority of kestrels remained only 15 min before leaving a field being tilled, especially if they were not successful in locating and attacking prey. During the two most successful observation periods (19 mice captured in 4.5 hr), it was 40 min before I saw a mouse not yet being attacked by a kestrel, whereas the kestrels averaged only 13 min between stoops. By contrast, at the low extreme in predator abunance, I saw three mice in one observation period of 3 hr without sighting a predator. Frequent sightings of prey were undoubtedly important in holding the interest of a kestrel to a field being tilled.

I saw avian predators, as well as their small mammal prey, most frequently during the early phases of tillage work (plowing and discing). Twice I saw predators (kestrels) perching and watching a bare field that was ready for planting. The prey were rarely seen during the latter stages of seed bed preparation because of lack of suitable habitat.

Ten of the 16 kestrels that captured only one mouse left the field and did not return. Those that captured one or more mice and remained at the field to hunt became more aggressive in their efforts; a few even went aloft in response to a shifting clod of earth. In three of the six sets of observations with sequential captures of prey, kestrels began stooping for prey much closer to the machinery as time progressed. However, some of their flight patterns were not as direct in approaching prey because of my working activity, this activity probably decreased their success ratio. In two cases, a close approach (20 m) by the tractor caused the stoop to be unsuccessful.

Kestrels sometimes responded to moving mice at distances of 100 m. On one day an individual caught three mice detected at distances beyond 200 m, confirming the visual acuity noted by Fox et al. (1976). On two occasions an individiual that had hunted successfully in one field followed the tillage operation up to 1.2 km into another field. The most successful effort occurred in October in the discing of a spring-plowed hay field that had been left idle for the summer. During 90 min I saw three voles; a kestrel caught 12 others and was still hunting when I left the field. Many kestrels appeared to be interested in the disturbance caused by tillage, but hunting success was the attraction that drew the individual closer and kept it occupied.

Only one of the nine Red-tailed Hawks that I sighted swooped down from its hunting perch and captured a mouse during my field work, even though this predator was a common summer resident. The birds in these nine sightings were on station and alert but were prone to leave the field rather than just shift perches when approached by machinery. Thus their opportunities for success were more limited than those for kestrels. My observations differed from Flugum (1975) in Minnesota, where the Red-tailed Hawk was more successful. He reported seeing an individual catch 32 mice, as well as other small mammals, in one day in a field of cornstalks being disced.

Loggerhead Shrikes were successful on the two occasions when I observed them pursue flushed mice. They were the boldest of the predators in pursuing mice near machinery.

LITERATURE CITED

ANDRE, J. B. 1978. Peregrine Falcons and boats: an example of symbiosis? Chat 43:62.

FLUGUM, C. T. 1975. Birding from a tractor seat. Crowell Company, New York.

FOX, R., S. W. LEHMKULE, AND D. H. WESTENDORF. 1976. Falcon visual acuity. Science 192:263–265.