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INHERITANCE OF COLOR PHASES OF FERRUGINOUS HAWKS

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Color polymorphism occurs quite commonly among birds (Huxley 1955, Paulson 1973). In the Snow Goose (*Anser caerulescens*) color is thought to be determined by one gene, the dark, or blue allele being dominant (Cooke and Cooch 1968). As part of an ecological study of buteos in southeastern Alberta (Schmutz et al. 1980), we recorded the color phase of adult and nestling Ferruginous Hawks (*Buteo regalis*). Two phases were observed on our study area: a light phase with predominantly white undersides and rufous thighs, and a dark phase, appearing black in flight except for the white undersides of the remiges and the rectrices (Godfrey 1966). The nestlings are very similar to the adults and were easily categorized as light or dark phase. We recorded the color phase of each adult in 1976 and 1977 in all cases where both members of a pair were seen (85 of 97 pairs), and the color phase of each nestling for 48 pairs.

Since light- and dark-phased birds are so distinctive, we considered it unlikely that color phase is polygenically determined. The simplest hypothesis is that one gene determines color phase. Table 1 summarizes the color phases of offspring born to parents of known

phase. Our hypothesis is that the dark phase is produced by a dominant allele for melanism. The occurrence of one dark nestling born to a pair of light colored parents contradicts this hypothesis. However, this could be an anomalous case resulting from fertilization by a dark male who did not stay mated to this light female, a new mutation, or an error in recording data. For example, we once saw a female carrying nest material and displaying to a male with whom she did not copulate at that time. Then she flew approximately 1 km to a location where she copulated with another male before rejoining her original "mate." Possibly we

TABLE 1. The number of light and dark nestlings produced in 1976 and 1977 where phase of all offspring was recorded.

Year	No. nests	No. nestlings	
		Light	Dark
Light × light matings			
1976	15	37	0
1977	21	54	1
Light × dark matings			
1976	4	4	5
1977	6	8	5
Dark × dark matings			
1976	1	2	2
1977	1	1	0

TABLE 2. Color phases of offspring born to pairs in which the male was light phase and the female dark phase in 1977.

Pair no.	Offspring			
	Female		Male	
	Light	Dark	Light	Dark
1	0	0	0	0
2	1	0	1	1
3	0	2	1	0
4	0	1	1	0

erred in recording because we transferred nestlings to and from this nest in another experiment.

An alternative hypothesis is that the allele for melanism is recessive. In this case no light-phased nestlings would be produced when both parents are dark. However, light nestlings (in nests of dark adults) occurred three times, which is very unlikely to have been the result of mutation or an error in recording. Since light nestlings were present in two nests of dark adults, "extra-pair" copulation would have had to occur at least twice. We would also predict more dark nestlings when both parents were light since by chance alone both members of eight pairs should have been heterozygous. Therefore, we believe that there is evidence to suggest the allele for melanism is dominant.

To determine whether the gene for color phase is sex-linked, we analyzed the color phases of offspring born to pairs in which the male was light-phased and the female dark-phased. We included only those pairs in which at least one of the adults was trapped (Hamerstrom 1963). We determined sex by weight, nestlings near fledging that were under 1,300 g being classified as males and those over 1,300 g as females; adults under 1,500 g were classified as males and those over as females (Schmutz 1977). Since the female is the heterogametic sex in birds and the melanistic allele is assumed to be dominant, we would expect only light-phased daughters and dark-phased sons. Since daughters and sons of both phases were produced (Table 2), we conclude that color phase is not sex-linked.

Assuming that dark phase is dominant, the frequency of the allele for melanism was 0.056 as calculated from the numbers of offspring of each phase over two years (Table 1). The breeding population consisted of 8 dark- and 78 light-phase birds in 1976 and 8 dark- and 76 light-phase birds in 1977. If the population were in Hardy-Weinberg equilibrium, we expected 10 heterozygous dark-phased birds in both years and the remainder to be light-phased, which did not differ from the observed (1976, $\chi^2 = 0.248$, $P > 0.05$; 1977, $\chi^2 = 0.249$, $P > 0.05$).

In order to investigate the geographical variation in the proportion of birds of each color phase, we sum-

marized the color-phase reported in the literature (Table 3). We combined our data for both years since this approach was followed by previous authors. There was no significant difference among the color-phase ratios (a 2×4 chi-square test omitting Olendorff's data; $\chi^2 = 7.65$, $P > 0.05$).

We calculated the expected frequencies of each type of pair bond for 1977 data. We used only one year's data because, based on two color-marked, dark-phased individuals, it is likely that Ferruginous Hawks tend to return to the same territory. If this is the case, data on color phases for successive years would not be independent. We expected 34.4 light-light matings, 7.2 light-dark matings, and 0.4 dark-dark matings if individuals in the population mate randomly. We observed 34, 7, and 1, respectively ($\chi^2 = 0.26$, $P > 0.05$). This provides no evidence for departure from random mating.

Payne (1967) and Paulson (1973) suggested that polymorphism among raptors may be explained by apostatic selection. They postulated that the rare morph should be at a selective advantage because the prey are less likely to recognize it as a predator. This reasoning could be extended to predict that members of different morphs would be able to obtain more prey than pairs of the same morph and hence such pairs should be capable of raising more young (Paulson 1973). We compared the number of young raised to near fledging for light-light ($\bar{x} = 2.56$, $n = 36$) and light-dark pairs ($\bar{x} = 2.20$, $n = 10$), combining 1976 and 1977 data, and found no significant difference ($T = 0.94$, $df = 44$, $P > 0.05$). This indicates that pairs of different morphs did not experience increased reproductive success.

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TABLE 3. Numbers of light and dark phase Ferruginous Hawks reported in the literature among geographical locations.

Number		Percent dark	Location	Reference
Light	Dark			
154	16	9.4	Alberta	This study
61	1	1.6	South Dakota	Lokemoen and Duebbert (1976)
100	4	3.9	Idaho	Howard (1975)
—	—	3.0	Colorado	Olendorff (1973)
41	1	2.4	Utah	Weston (1969)

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RECENT PUBLICATIONS

Pheasants in Asia 1979.—Edited by Christopher Savage. 1979. World Pheasant Association. 116 p. Paper cover. £8.50. Source: W.P.A., Daws Hall, Lamarsh, Bures, Suffolk CO8 5EX, England. These are the proceedings of the First International Pheasant Symposium, held in Kathmandu, Nepal. They include reports on the status of pheasants; papers on field study techniques, captive breeding, and conservation management; and remarks attending the opening and closing of the conference. Illustrated, index.

Handbook of the Birds of India and Pakistan. Vol. 2. Second edition.—Salim Ali and S. Dillon Ripley. 1980. Oxford University Press, Delhi. 347. p. \$34.00. Continuing the revision of this series (noted in *Condor* 78:574, 81:416), this volume incorporates information about movements and ranges of species that has accumulated since 1969, when the first edition was published. It covers the Galliformes, Gruiformes, and Charadriiformes through the Crab Plover. A few taxonomic changes have been made and four new color plates have been painted by John Henry Dick to replace those in the first edition.

The California Islands: Proceedings of a Multidisciplinary Symposium.—Edited by Dennis M. Power. 1980. Santa Barbara Museum of Natural History, Santa Barbara, CA. 787 p. Paper cover. Spanning approximately 1,360 km along the coast of California and Baja California, the California Islands have long been studied by scientists. The Santa Barbara Museum of Natural History organized a symposium, held in 1978, for bringing together and advancing research on these islands and surrounding waters. The 43 papers in this book stem from that meeting. They are grouped by topic: geologic history and paleontology, prehispanic man, vegetation changes and the impact of feral animals, and the biogeography, evolution, and ecology of—in turn—land plants, marine organisms, and land animals. Power has edited the collection, contributed a paper, and written a useful introduction and a summary. The volume itself has been well produced and it includes two fold-out vegetation maps in color. Ornithologists who are interested in island avifaunas should not confine themselves to the eight papers about birds. Otherwise, they will miss the book's general theme: "that the physical and biological components of both land and sea are interwoven in often complex, cause-and-effect relationships."