BLUE-PHASE ROSS' GEESE AND OTHER BLUE-PHASE GEESE IN WESTERN NORTH AMERICA

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ABSTRACT.—The existence of wild, blue-phase Ross' Geese (*Chen rossii*) and blue-phase geese intermediate in size and other characteristics between Ross' and Lesser Snow Geese (*Chen caerulescens caerulescens*) was verified by collection. Winter populations of Ross' and Lesser Snow Geese in California contained less than 0.02% blue-phase birds. Of these blue-phase geese, 8% were Ross', 77% were Lesser Snow, and 15% were intermediate in size. Intermediate blue-phase geese are probably the result of hybridization. Blue-phase Ross' Geese could originate from backcrossing of hybrids and/or recurrent mutation. Genes for blue feather color were probably eliminated from ancestral populations of Ross' Geese and may presently be prevented from reestablishment in the gene pool by hunter and/or predator selection. *Received 16 October 1978, accepted 26 March 1979.*

THE Blue Goose is a polymorphic color phase of the Lesser Snow Goose (*Chen caerulescens caerulescens*) (Cooch 1961). In 1973, J. D. Heyland collected two blue-phase birds that matched Greater Snow Geese (*C. c. atlantica*) in all measurements (Palmer 1976: 129). Blue-phase Lesser Snow Geese have hybridized with Ross' Geese (*Chen rossii*) in captivity (Sibley 1938, Gray 1958: 53), and one wild hybrid was observed at McConnell River, Northwest Territories in 1970 by J. P. Prevett (Palmer 1976: 158). Dzubin (1979) has often observed blue-phase geese no larger than Ross' Geese at autumn migration staging areas in southwestern Saskatchewan. This paper reports on the collection, field observation, and possible genetic origin of wild, blue-phase Ross' Geese and blue-phase geese intermediate in size and form between Ross' Geese and Lesser Snow Geese.

METHODS

Measurements were taken from freshly killed birds and follow methods used for white geese by Trauger et al. (1971) with one exception: flat wing length was measured from tip of the longest primary to the proximal end of the pollex. This is approximately 10 mm less than the standard "flat wing" length from tip of longest primary to wrist. Color descriptions follow Palmer (1962). During a concurrent study of Ross' Geese, the number of blue-phase geese that we observed in California and Saskatchewan from 17 December 1975 to 22 April 1977 was recorded. Body size and bill morphology (Trauger et al. 1971) were examined with a 15–60× telescope and were used as criteria to classify blue-phase geese as Ross', Lesser Snow, or intermediate geese. Family relationships of blue-phase geese were recorded when behavior indicated such associations (see Raveling 1969). Ratios of blue-phase to white-phase geese were obtained from field observations of geese in California during the winter of 1976–77. Geese killed in California during the hunting seasons of 1975–76 and 1976–77 were examined at commercial picking plants at Tulelake in northeast California, and at state-managed hunting areas of state and federal wildlife refuges in the Sacramento and San Joaquin valleys.

RESULTS AND DISCUSSION

We observed three identifiable types of blue-phase geese in flocks of white geese in western North America: (1) typical blue-phase Lesser Snow Geese (hereafter called blue-Snows), (2) blue-phase Ross' Geese (blue-Ross'), and (3) blue-phase birds with characteristics intermediate between Ross' and Lesser Snow Geese (blue-interme-

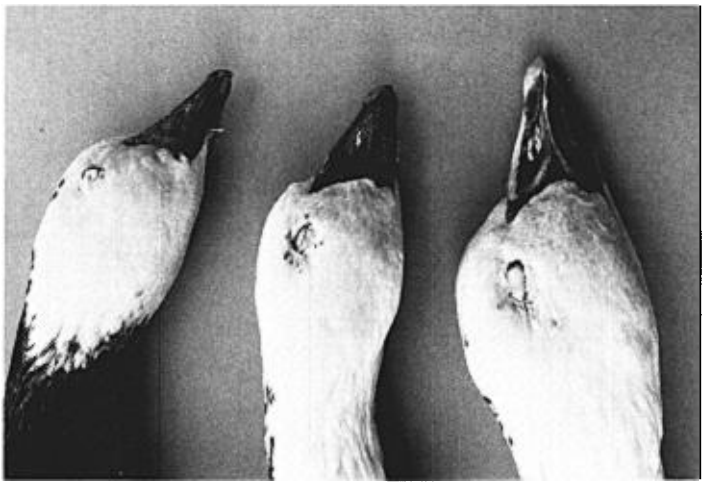

Fig. 1. Heads and bills of blue-phase geese (left to right: Ross', intermediate, and Lesser Snow).

diates). Two blue-Ross', four blue-intermediates, and one 2-day-old gosling of a blue-intermediate × Ross' Goose pair were collected in 1976 and 1977. These specimens are presently in the Wildlife and Fisheries Biology Museum at the University of California, Davis. Measurements were obtained from an additional two blue-intermediate geese shot by hunters.

Description of blue-Ross' Geese.—All mensural characteristics of the two blue-Ross' Geese (an adult and an immature, Table 1) are well within the range of comparable measurements for Ross' Geese (cf. Trauger et al. 1971). The "smile patch," evident on bills of intermediate white geese (Trauger et al. 1971: 861) and blue-intermediates, is not present on blue-Ross' Geese (Fig. 1). Slight swellings are evident at the base of the upper mandible of the adult blue-Ross', not unlike many adult Ross' Geese (Palmer 1976). Color pattern of the adult (Fig. 2) corresponds to the "White-Bellied Blue" (category 4) described by Palmer (1976: 122). Color of neck, upper back, and scapular feathers, however, approaches black rather than "dark slaty brown or fuscous" of Palmer's (1976: 123) White-Bellied Blues. Pigmented feathers cover the entire neck and terminate just beneath gular and malar regions of the head. A broad band of black feathers extends along the dorsal side of the neck and head, decreases in width, and ends in a triangular patch on the crown. The remainder of the head is white. The distal margins of blackish-brown contour feathers of the upper breast are fuscous. Lower breast, flanks, sides, and underwing coverts show different degrees of gray or grayish-fuscous. Abdomen, crissum, rump, and axillar feathers are white. Light, silvery-gray alular feathers, primary coverts, and lesser coverts have black rachises. Middle and greater coverts vary from almost white to light silvery-gray. Primaries are black. Secondaries, tertials, and scapulars are black with varying amounts of white along the vane edges. Tail feathers are white with a central area of grayish-fuscous color. Other adult blue-Ross' seen during the study had nearly identical plumage.

The pattern of pigmented feathers on the immature blue-Ross' is similar to that of the adult except on the head and neck (Fig. 2). The head of the immature is speckled with fuscous-colored feather tips, and the generally blackish-brown neck contains interspersed white feathers. Pigmented feathers of the immature are gen-

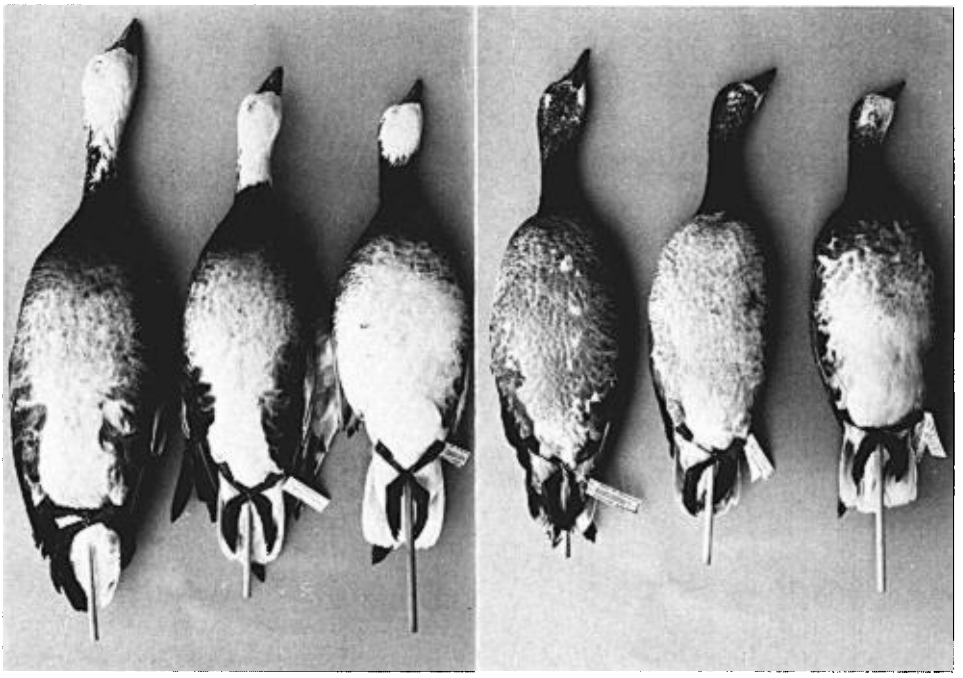

Fig. 2. Blue-phase geese. Left panel: adults (left to right: Lesser Snow, intermediate, and Ross'); right panel: immatures (left to right: Lesser Snow, intermediate, and Ross').

erally lighter in color and more tinged with fuscous than on the adult. Black and silvery-gray feathers of the adult are respectively blackish-brown and light grayish-fuscous on the immature bird.

Description of blue-intermediate geese.—Apart from color, blue-intermediate geese are similar to the intermediate white geese described by Trauger et al. (1971) (Table 1, Note: middle toe, flat wing, and total length of the adult male and culmen of an adult female are less than minimum values recorded for intermediate white geese). Coloration of adult blue-intermediates shows characteristics of both the "White-Bellied Blue Goose" of Palmer (1976: 122) and the blue-Ross' Goose. Feathers of the neck and upper back are black, as in the blue-Ross', whereas feathers of the head and upper portion of neck are predominantly white, as in blue-Snow Geese

TABLE 1. Measurements (mm) of blue-Ross' and blue-intermediate geese.

Age, sex, type	Exposed culmen	Total tarsus	Middle toe	Flat wing	Total length	Weight (kg)
Adult male						
Blue-Ross' (n = 1)	41.1	86.3	53.5	380	596	1.38
Blue-intermediate (n = 1)	46.0	87.3	52.1	380	635	1.75
Adult female						
Blue-intermediate (n = 3)	46.0	86.6	54.7	379	639	1.85
Range	44–47	83–89	52–56	373–382	615–660	1.70–2.10
Immature female						
Blue-Ross' (n = 1)	40.2	82.3	49.7	357	545	1.45
Blue-intermediate (n = 2)	43.5	84.5	55.4	360 (n = 1)	600 (n = 1)	1.61
Range	42–45	84–85	53–58	—	—	1.60–1.62

(Fig. 2). The amount of black on the back of neck and hind head varies among individuals, but all specimens exhibit some black extending to the occipital region. Dark gray flecking is evident around the eyes of two geese. The color tone of other pigmented feathers varies among birds from grayish-fuscous to fuscous. Rump, crissum, and abdomen may be almost white or pale gray. Blue-intermediate geese were observed in the field that had considerably more white than dead geese examined and that more closely resembled "Extreme White-Bellied Blue Geese" (category 2) of Palmer (1976: 122).

Color and pattern of immature blue-intermediates are much like those of the immature blue-Ross' Goose (Fig. 2). Their heads, however, show considerably less white than the blue-Ross' (blackish-gray is the predominant color, except for a conspicuously white gular region).

The newly hatched gosling of a male blue-intermediate and female Ross' Goose from a nesting colony at Karrak Lake, Northwest Territories (67°15'N, 100°15'W), was uniformly blackish-gray except for a white gular patch. The bird was considerably darker than any young Ross' observed but had a Ross'-like light yellow-colored sibling. Blue-Snow Geese are similar in color to this gosling, but gular regions are often pale yellow (Palmer 1976). The gosling weighed 70 g, whereas three captive young Ross' of the same age weighed 55–65 g.

Population estimates.—Sample counts in California revealed that, in the winter of 1976–77 only 12 (0.02%) of 59,009 individually examined Lesser Snow Geese and 3 (0.008%) of 38,825 Ross' Geese were blue-phase (all 3 blue-phase birds with Ross' were intermediate geese). In January 1977, an estimate of 507,347 white geese was obtained on the Mid-winter Inventory in the Pacific Flyway (U.S. Fish and Wildlife Service 1977). Application of the ratios of blue-phase geese we observed to this population estimate indicates that a maximum of less than 100 blue-phase birds were present in this population (cf. Dzubin 1979).

In California, 23% of the sightings of blue-phase geese during the winter of 1976–77 were blue-Ross' and blue-intermediate geese (Table 2). Although these data in-

TABLE 2. Sightings of blue-phase geese at migration and wintering areas.

Location and dates	*n*	% of blue-phase geese		
		Ross'	Inter-mediate	Snow
California				
17 Dec. 1975–28 Feb. 1976				
Sacramento Valley	37	19	16	65
San Joaquin Valley	33	64	9	27
6 Mar.–20 Apr. 1976				
Tule Lake Nat'l. Wildl. Ref.	244	23	11	66
Saskatchewan				
11 Sept.–25 Oct. 1976				
Kindersley area	205	3	5	92
California				
3 Nov.–2 Dec. 1976				
Tule Lake Nat'l. Wildl. Ref.	86	12	7	81
8 Dec. 1976–22 Feb. 1977				
Sacramento Valley	62	8	5	87
San Joaquin Valley	35	0	26	74
5 Mar.–22 Apr. 1977				
Tule Lake Nat'l. Wildl. Ref.	142	9	20	71

clude repeated observations of the same individuals, this proportion of observations should approximate the actual occurrence of blue-Ross' and blue-intermediate geese among blue-phase geese in California. We obtained a higher figure (38%) for seemingly comparable data during the winter of 1975–76. Attempts to locate blue-Ross' for collection, however, may have resulted in a disproportionate sighting rate for these birds.

Blue-Ross' and blue-intermediate geese made up only 8% of observations of blue-phase geese in southwestern Saskatchewan. Most blue-phase geese in this area probably came from the Ross' Goose breeding grounds in the central Canadian Arctic (Dzubin 1979). Lesser Snow Geese and Ross' Geese nest in mixed colonies in this area (Ryder 1971). This central Arctic population of Lesser Snow Geese contains a substantially higher proportion of blue-phase birds than the Lesser Snow Goose colonies of the western Canadian Arctic and Wrangel Island, U.S.S.R. (Cooch 1963, Cooke et al. 1975). The wintering grounds of central Arctic Lesser Snows are in Texas and Mexico, while most Ross' Geese and western Arctic and Wrangel Island Lesser Snow Geese spend the winter in California (see Kerbes 1975 for review). Birds from the central and western Arctic populations mix during migration through Saskatchewan. Differential migration (see Dzubin 1979) would explain the difference in proportions of types of blue-phase geese observed in Saskatchewan and California.

Differential mortality.—A sample of 3,355 Lesser Snow and Ross' Geese killed by hunters in California during the winters of 1975–76 and 1976–77 included 10 (0.3%) blue-phase geese. Blue-phase birds were killed more often by hunters during the latter year (8 of 1,743 birds, 0.5%) than could be explained by random selection from the population judged from sample counts of Lesser Snow Geese ($t_s = 4.406$; $P < 0.001$) or Ross' Geese ($t_s = 4.820$; $P < 0.001$) (test of proportions, Sokal and Rohlf 1969: 607). Hunters interviewed often stated that they had selected blue-phase birds from flocks of white geese in attempts to kill dark species of geese. Hunting regulations in California specify white goose limits independent of limits of dark geese.

Predators may also select extremely rare dark individuals from flocks of white geese. Lesser Snow and Ross' Geese were usually congregated in enormous flocks at migration staging areas and on the wintering grounds. Golden Eagles (*Aquila chrysaetos*) and Bald Eagles (*Haliaeetus leucocephalus*) were often abundant near these concentrations. On all occasions ($n = 118$) when an eagle was recorded flying overhead, both species of white geese took flight. Flocks maintained unity during evasive maneuvers. Lesser Snow Geese were attacked on three occasions. One goose, pursued by a Bald Eagle, had an obvious broken leg and two other geese, each chased by Golden Eagles, had become separated from other white geese. Thus, it appears that eagles selected abnormal geese. Individuals conspicuously different from the majority of prey in either behavior, location, or color are often selected by predators (Salt 1967).

Genetic origin of blue-Ross' Geese.—Cooke and Ryder (1971) proposed the existence of a modifying gene suppressing the adult phenotype in Ross' Geese to explain the polymorphism of goslings. The blue-intermediate × Ross' gosling, however, was considerably darker than any young Ross', and only blue-phase immature birds were observed with adult blue-Ross' parents (Table 3). Therefore, we suggest that blue coloration in Ross' Geese is determined by a dominant allele(s) similar to that of Lesser Snow Geese (Cooke and Cooch 1968, Cooke and Mirsky 1972).

Observations of pairs of geese and adults with young suggest that blue-interme-

TABLE 3. Observed associations of blue-Ross' and blue-intermediate geese from 1975 to 1977.

Adult pair		Associated immature(s)	Number of observations
Blue-Ross'	White-Ross'	2 Blue-Ross' (6) or none (2)	8
Blue-Ross'	Not seen	1 Blue-Ross'	2
White-Ross'	Not seen	1 Blue-Ross' + 1 White-Ross'	1
White-Ross'	Blue-intermediate	1 Blue-intermediate + 1 White-intermediate (1) or none (2)	3
White-Ross'	Blue-Snow	None	1
Blue-intermediate	White-intermediate	None	1
Blue-intermediate	Blue-intermediate	None	1
Blue-intermediate	White-Snow	1 Blue-Snow + 1 White-Snow	1
Blue-intermediate	Blue-Snow	None	1
Blue-intermediate	Not seen	1 Blue-Ross'	2
Blue-intermediate	Not seen	1 Blue-Snow	1
Blue-Snow	Not seen	2 Blue-intermediate	1

diates may be the result of hybridization (Table 3), as suggested for white-phase intermediates by Trauger et al. (1971). Blue-intermediate geese were seen paired with white-phase geese of both species. Backcrossing or interbreeding of blue-phase hybrids could produce blue geese with morphological characteristics of Ross' Geese.

Another possible source of blue-Ross' Geese is recurrent mutation of the gene(s) controlling feather color. The increasing population of Ross' Geese (Dzubin 1965, Ryder 1967, McLandress 1979) may only recently have reached a level sufficient for the production of detectable numbers of blue-Ross' Geese. Perhaps both mutation and hybridization constantly reintroduce the allele for blue feather color to the Ross' Goose gene pool. Comparative investigation of eastern Canadian Arctic Ross' Geese, which often show signs of hybrid origin (Prevett and MacInnes 1972), might clarify understanding of the genetic origin of the blue phenotype.

The existence of blue-Ross' Geese appears to support the hypothesis that the ancestral form common to both the Ross' and the Lesser Snow Goose was polymorphic (Cooke and Ryder 1971). Climatic conditions may differentially favor the color phases of Lesser Snow Geese (Cooch 1963). Perhaps environmental conditions during the evolution of the Ross' Goose all but eliminated the allele for blue feather color from the gene pool. The proposal of a monomorphic white ancestor (Ploeger 1968) is based on the assumption that the blue phenotype of Lesser Snow Geese evolved from a population of white geese. If predators selected against the expression of rare, abnormal, conspicuous plumage, the recessive allele for white is more likely to have successfully spread through the gene pool by the production of heterozygotes within an ancestral population of blue-phase geese than the alternative suggested by Ploeger's hypothesis.

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