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STABLE-CARBON ISOTOPES SUPPORT USE OF ADVENTITIOUS COLOR TO DISCERN WINTER ORIGINS OF LESSER SNOW GEESE

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Abstract.—We scored adventitious color on the head plumage of Lesser Snow Geese (*Chen caerulescens caerulescens*) collected from four winter habitats, January–March, 1983–1984. Geese from brackish marshes in Louisiana were more rust-colored than those collected in agricultural habitats or in freshwater coastal marshes in Texas, where virtually no color was present. Stable-carbon isotope analyses of geese from a site where geese from southern winter areas mix with resident winter birds during spring migration, support conclusions that birds with rust color are from brackish marshes in Louisiana farther south.

ISÓTOPOS ESTABLES DE CARBÓN APOYAN EL USO DE COLORES ADVENTICIOS PARA DETERMINAR EL ORIGEN DE INDIVIDUOS DE *CHEN CAERULESCENS CAERULESCENS*

Sinopsis.—Colocalmos colores adventicios en el plumaje de la cabeza de individuos de *Chen caerulescens caerulescens* capturados durante los meses de enero a marzo de 1983–1984, en cuatro localidades diferentes. Los gansos de aguas salobres de Louisiana tenian un color más cobrizo que los capturados en habitats agricolas o de agua dulce en anegados de Texas, los cuales habian perdido virtualmente la coloración. El análisis de gansos marcados con isotopos estables de localidades en donde los migratorios que vienen del sur se mezclan con residentes invernales (durante la migración primaveral), apoya la conclusión de que las aves con color más cobrizo son de anegados salobres de localides del sur de Louisiana.

The plumage of many species of waterfowl is stained occasionally with rust coloration, and it has long been thought that this results from feeding in wetlands with deposits of iron oxides (Bales 1909, Kennard 1918, Höhn 1955). This staining could be used to infer geographic origin of migrating waterfowl (Baranyuk and Syroechkovsky 1994). Recently, the

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measurement of naturally occurring stable isotopes of carbon, nitrogen, and hydrogen in tissues of organisms also have been used to infer geographic origin (Cormie et al. 1994, van der Merwe et al. 1990, Vogel et al. 1990). This approach is based on the fact that stable isotope ratios in diets of consumers reflect those in their food (DeNiro and Epstein 1978, 1981), and that local food webs may have characteristic isotopic signatures (Alisauskas and Hobson 1993). Stable isotope ratios in the foods and tissues of wintering Snow Geese were used recently (Alisauskas and Hobson 1993) to infer winter origin and dependence on nutrients derived from agricultural and salt marsh habitats.

In this paper, we quantify variation in adventitious color on the head plumage of mid-continent Lesser Snow Geese. We argue that this natural marker allows inferences about origins of individual geese and movements of birds among winter habitats. We tested our assumptions for spring migrants by using stable-carbon isotope analysis of tissues from birds, with and without adventitious coloration, collected at a northern wintering area. To evaluate feeding origins of individuals, we chose samples of Snow Geese from a site in Iowa which serves as both a northern wintering area and spring staging area that supports birds with winter origins along the Gulf of Mexico coast (Davis et al. 1989).

METHODS

Winter study areas.—Adult plumage Snow Geese were collected during January–March from locations representing four winter landscapes (Fig. 1) named according to predominant habitat feature or diet of geese (Alisauskas et al. 1988). MARSH: (1) J. D. Murphree Wildlife Management Area, Port Arthur, Texas, 9–11 Jan. (n = 32), 11 Feb. (n = 32), 1983, 14 Jan. (n = 31), 14 Feb. (n = 31), 1984, (2) Sabine National Wildlife Refuge, Cameron Parish, Louisiana, 13 Jan. (n = 32), 16 Feb. (n = 30), 1983, 18 Jan. (n = 30), 15 Feb. (n = 31), 1984, (3) Rockefeller State Refuge, Grand Chenier, Cameron County, Louisiana, 14–27 Jan. (n = 25), 14–23 Feb. (n = 38), 1983, 9–13 Feb. (n = 15), 1984; RICE: (4) Garwood, Colorado County, Texas, 10–12 Jan. (n = 34), 9–10 Feb. (n = 34), 4–5 Mar. (n = 25), 1983, 11 Jan. (n = 28), 11 Feb. (n = 39), 3 Mar. (n = 31), 1984, (5) north of Lacassine National Wildlife Refuge, Jefferson Davis Parish, Louisiana, 21–24 Jan. (n = 38), 17–22 Feb. (n = 34), 1983; WHEAT: (6) Sequioyah National Wildlife Refuge, Muskogee County, Oklahoma, 31 Jan.–6 Feb. (n = 59), 1984; CORN: (7) a combination of three areas: (a) near Riverton, Fremont County, Iowa, 13–19 Jan. (n = 31), 1983, 16–17 Feb. (n = 31), 1994, (b) near Schell City, Vernon County, Missouri, 18–20 Jan. (n = 32), 1994 and (c) Boyle, Jefferson County, Kansas, 11–12 Feb. (n = 33), 1983. Further details about these areas were given by Alisauskas et al. (1988).

Spring migration study areas.—Spring collections, in both years, continued in areas that serve as both winter locations and also through which birds move from more southerly winter termini: (6) Muskogee County, Oklahoma, 8–14 Mar. (n = 47), 1983, and (7) Fremont County, Iowa, 2–

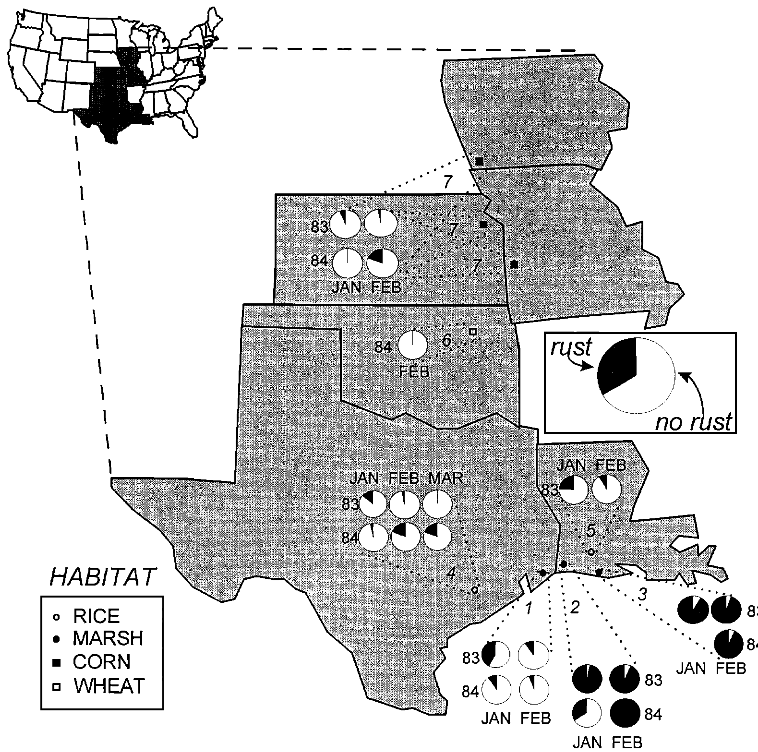

FIGURE 1. Prevalence in adventitious color on the head of Lesser Snow Geese collected on winter areas: (1) coastal freshwater marsh, Texas, (2) coastal brackish marsh, Louisiana, (3) coastal brackish marsh, Louisiana, (4) Garwood Prairie, Texas, (5) Calcasieu Prairie, Louisiana, (6) winter wheat habitat, Oklahoma (7) corn habitats near Missouri River valley.

3 Mar. (n = 32), 22 Mar. (n = 28), 1983, 6 Mar. (n = 38), 21 Mar. (n = 41), 1984.

Stable isotope analysis.—Before dissection, each goose was scored as either 0 (no rust) or 1 (rust on its head). About 10 ± 3 g of dried ground pectoral muscle was placed in cellulose extraction thimbles, and lipids extracted using a Soxhlet apparatus with petroleum ether solvent. Samples were then powdered and analyzed for stable-carbon isotope ratios ($^{13}C/^{12}C$, expressed in δ-notation as parts per thousand) for birds collected from Iowa in March 1983 (see Alisauskas and Hobson 1993 for details of sampling and stable isotope analysis). We tested the hypothesis that there was a mixture of birds that wintered locally (eating mostly milo and corn, Alisauskas et al. 1988) and immigrants from both rice prairie and marsh habitats in Texas and Louisiana (where corn is absent from the diet from midwinter onwards, Alisauskas et al. 1988). Corn, a C-4 plant, is readily distinguishable isotopically in diets of consumers feeding otherwise on C-3 based foodwebs (see Alisauskas and Hobson 1993). Precision of isotopic measurements was ±0.1‰.

Statistical analysis.—To test for differences in prevalence of geese with adventitious color, we used contingency analyses on two classes of rust using the likelihood ratio χ^2 (PROC FREQ, SAS 1990). Most Snow Geese pair for life (Cooke et al. 1995), but not all adult plumage geese are paired, nor is it likely that samples included more than one member from families. Thus we assume independence of most individuals in our statistical tests.

RESULTS

Acquisition of adventitious color.—A higher proportion of geese collected from MARSH had adventitious color than did those from RICE in 1983 (73% vs. 12%, χ^2 = 145, df = 1, $P < 0.001$) and in 1984 (42% vs. 7%, χ^2 = 36.5, df = 1, $P < 0.001$) (Fig. 1). No geese collected during winter from Oklahoma WHEAT habitats had adventitious color, and only 5% and 11% of geese collected from CORN study areas in 1983 and 1984, respectively, had any rust.

Not all geese from MARSH habitats had staining, and some geese in RICE and CORN had staining. The proportion of Snow Geese collected in MARSH with rust varied among MARSH sites in 1983 (χ^2 = 114, df = 2, $P < 0.001$) and 1984 (χ^2 = 65.9, df = 2, $P < 0.001$), because a lower percentage (25% and 8%) of Snow Geese from Murphree were stained compared to those from Sabine (98% and 64%) and Rockefeller (94% and 93%) in 1983 and 1984, respectively (Fig. 1).

Apparent movements among winter habitats.—The percentage of birds with rust was greater in January 1983 than in January 1984 at both Murphree (44% vs. 10%, χ^2 = 9.89, df = 1, $P < 0.002$) and Sabine (97% vs. 33%, respectively, χ^2 = 32.3, df = 1, $P < 0.001$). At Garwood (RICE), percentage of rusty geese was low and did not differ between 1983 and 1984 in January (15% vs. 4%, χ^2 = 2.40, df = 1, $P = 0.12$), or in February (3% and 3%, χ^2 = 0.01, df = 1, $P = 0.92$). This suggests that there was an influx of birds from RICE, CORN or WHEAT habitats onto MARSH sites in January 1984, with no apparent movement of geese from MARSH to RICE habitats.

Adventitious color during spring migration.—During winter, percentage of geese from CORN habitats with adventitious color was 5% and 11% in 1983 and 1984, respectively (Fig. 1). During March, these percentages increased to 18% and 35%, in respective years (year effect: χ^2 = 2.88, P = 0.09; season effect: χ^2 = 12.26, P = 0.0005; interaction effect: χ^2 = 0.01, P = 0.9), suggesting immigration of geese from marshes along the Gulf of Mexico and their subsequent mixing with local birds in Iowa.

Stable-carbon isotope analyses.—Carbon isotope ratios ($\delta^{13}C$) from a random subset of 29 geese collected in Iowa, March 1984, showed a bi-modal distribution (Fig. 2). We inferred that these two groups represented birds consuming diets composed mainly of corn or milo (95% CL: −13.04 to −9.76‰) throughout the winter in Iowa, Missouri or Kansas, versus those

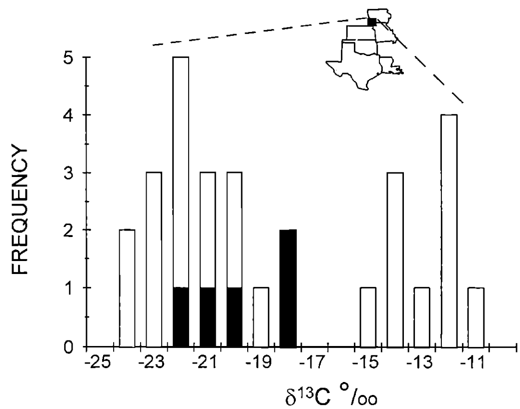

FIGURE 2. Frequency distributions of $\delta^{13}C$ values in muscle of Lesser Snow Geese collected during early spring migration near the Missouri River valley, showing inferred winter residents (right side), and immigrants (left side) including birds with marsh stain (shaded).

consuming foods from RICE (95% CL: −30.02 to −18.88‰) and MARSH (95% CL: −26.40 to −24.57‰, Alisauskas and Hobson 1993:51) along the Gulf of Mexico coast. All birds in this sample with adventitious color were within the distribution of carbon isotope ratios characteristic of geese wintering in MARSH or RICE habitats.

DISCUSSION

Lesser Snow Geese that overwinter in RICE, WHEAT, or CORN habitats subsist almost entirely on grasses and seeds of terrestrial plants (Alisauskas et al. 1988); those in brackish MARSH consume primarily tubers (*Scirpus* spp.), and rhizomes of *Spartina patens* and *Distichlis spicata* that grow in chronically water-logged soils (Alisauskas et al. 1988). Adventitious rust color on MARSH geese results largely from excavating and manipulating foods that are encrusted with, or are growing in anaerobic soils containing oxides of iron (Gambrell and Patrick 1978). Such iron oxide deposits were especially obvious in brackish areas of Louisiana MARSH where senescent stands of *Spartina* had been burned (RTA pers. obs.; such deposits were never seen on feeding areas in RICE or CORN habitats). Consequently, geese that spent at least part of the winter excavating *Spartina* rhizomes growing in these conditions acquired "marsh stain," as it is known locally. Kennard (1918:126) reported that "the deposit seems to be rapidly acquired," but as we observed no marked birds repeatedly, we were unable to quantify acquisition rate. Adventitious color on Snow Geese collected from two areas of brackish marsh (Sabine, Rockefeller) was more prevalent in January and February 1983 than on geese from freshwater marsh at Murphree. Although Snow Geese collected at Murphree were observed eating *S. patens* rhizomes, iron deposits were not obvious in the soil at Murphree as they were at Sabine or Rockefeller.

The same pattern of stained Snow Geese in Louisiana marshes and unstained ones in Texas marshes was documented by Kennard (1918) who attributed the difference to iron deposits from the Mississippi River.

Inferences about winter movements among habitats.—During both winters, rust scores were higher for geese collected in MARSH habitats than they were in the other three landscapes, but the magnitude of these differences varied between years. Within- and between-year differences occurred in the distribution of rust scores for some habitats. Apparently, this was due to movements of Snow Geese from one habitat to another. For example, numbers of Snow Geese on the Garwood and Calcasieu Prairies appeared to be declining in January 1984 (RTA, pers. obs.) while large numbers of unstained geese appeared in MARSH habitats (Fig. 1). We suspect that these unstained geese were those that normally would have remained in RICE habitats grazing green vegetation (Alisauskas et al. 1988), as they had in 1983 when conditions were favorable for growth of such vegetation. However, in December 1983, frosts and drought killed much emerging green vegetation, at least on the Garwood rice prairie and possibly in burned stands of *Spartina* in coastal marshes (Alisauskas et al. 1988). These findings indicate that in some years, marshes along the Gulf Coast may be important even to Snow Geese that normally would not winter there. This should be incentive for conservation and management of brackish and salt marsh habitats formely used exclusively by wintering Snow Geese (McIlhenny 1932) even though the number using them has declined since (Bateman et al. 1988).

Spring migration.—Alisauskas and Hobson (1993) demonstrated the utility of the stable-isotope approach for delineating the origin of birds feeding in areas where diets differed in isotope composition. We have further shown that, in combination with other techniques such as natural markers on plumage, stable isotope analysis can help to segregate mid-continent Snow Geese during spring migration. In particular, the isotope technique is useful for segregating individuals with significant contributions of corn to their winter diets. Differential use of corn resulted in a distinct bimodal distribution of $\delta^{13}C$ values in the spring sample of Iowa birds. As expected, geese with adventitious color fell entirely in the isotopic group associated with areas where C-3 diets were prevalent. The time required for isotopic signatures of immigrant and local geese to converge is unknown, but would depend on turnover rates of isotopes that, in turn, depend on metabolic rate (Hobson and Clark 1992).

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LITERATURE CITED

ALISAUSKAS, R. T. 1988. Nutrient reserves of Lesser Snow Geese during winter and spring migration. Ph.D. diss. Univ. Western Ontario, London, Ontario.

———, C. D. ANKNEY, AND E. E. KLAAS. 1988. Winter diets and nutrition of midcontinental Lesser Snow Geese. J. Wildl. Manage. 52:403–414.

———, AND K. A. HOBSON. 1993. Determination of Lesser Snow Goose diets and winter distribution using stable isotope analysis. J. Wildl. Manage. 57:49–54.

BALES, B. R. 1909. The brown stain occasionally seen on the feathers of wild ducks. Wilson Bull. 21:221–223.

BARANYUK, V. V., AND E. V. SYROECHKOVSKY. 1994. The usage of the natural marks in Wrangel Island Snow Geese for the population studies. (Russian with English summary). Ornithologia 26:45–49.

BATEMAN, H. A., T. JOANNEN, AND C. D. STUTZENBAKER. 1988. History and status of midcontinent Snow Geese on their Gulf Coast Winter Range. Pp. 495–515, *in* M. W. Weller, ed. Waterfowl in winter. Univ. Minnesota Press, Minneapolis, Minnesota.

COOKE, F., R. F. ROCKWELL, AND D. B. LANK. 1995. The Snow Geese of La Pérouse Bay: natural selection in the wild. Oxford University Press, New York. 257 pp.

CORMIE, A. B., H. P. SHWARCZ, AND J. GRAY. 1994. Relation between hydrogen isotopic ratios of bone collagen and rain. Geochim. et Cosmochem. Acta 58:377–391.

DAVIS, S. E., E. E. KLAAS, AND K. J. KOEHLER. 1989. Diurnal time-activity budgets and habitat use of Lesser Snow Geese *Anser caerulescens* in the middle Missouri River valley during winter and spring. Wildfowl 40:45–54.

DENIRO, M. J., AND S. EPSTEIN. 1978. Influence of diet on the distribution of carbon isotopes in animals. Geochim. et Cosmochim. Acta 42:495–506.

———, AND ———. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. Geochim. et Cosmochim. Acta 45:341–351.

GAMBRELL, R. P., AND W. H. PATRICK. 1978. Chemical and microbiological properties of anaerobic soils and sediments. Pp. 375–423, *in* D. D. Hook and R. M. M. Crawford, eds. Plant life in anaerobic environments. Ann Arbor Science Publications, Ann Arbor, Michigan.

HOBSON, K. A., AND R. G. CLARK. 1992. Assessing avian diets using stable isotopes I: turnover of ^{13}C in tissues. Concor 94:181–188.

HÖHN, E. O. 1955. Evidence for iron staining as the cause of rusty discoloration of normally white feathers in Anserine birds. Auk 72:414.

KENNARD, F. H. 1918. Ferruginous stains on waterfowl. Auk 35:123–132.

MCILHENNY, E. A. 1932. The blue goose in its winter home. Auk 49:279–306.

SAS (STATISTICAL ANALYSIS SYSTEMS). 1990. SAS User's guide: statistics. SAS Institute Incorporated, Carey, North Carolina.

VAN DER MERWE, N. J., J. A. LEE-THORPE, J. F. THACKERAY, A. HULL-MARTIN, F. J. KRUGER, H. COETZEES, R. H. V. BELL, AND M. LINDEQUE. 1990. Source-area determination of elephant ivory by isotopic analysis. Nature 346:744–746.

VOGEL, J. C., B. EGLINGTON, AND J. M. AURET. 1990. Isotope fingerprints in elephant bone and ivory. Nature 346:747–749.

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