DOI: 10.17242/MVvK_3.10

FEATHER MINERAL CONTENT OF REDHEADS (*Aythya americana*) WINTERING ALONG THE GULF OF MEXICO

Steven B. Murden[1], Marc C. Woodin[2], Thomas C. Michot[3], Milton W. Weller[1], Joseph L. Moore[1], Stephen E. Adair[1] and Kenneth L. Risenhoover[1]

[1] Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, Texas 77843,
[2] National Biological Service, Southern Science Center, Texas Gulf Coast Field Station, Corpus Christi, Texas 78412,
[3] National Biological Service, Southern Science Center, Lafayette, Louisiana 70506.

ABSTRACT

To evaluate the potential use of mineral content as a marker for identifying origins of wintering Redhead ducks along the coast of the Gulf of Mexico, we determined concentrations (ppm) of calcium (Ca), copper (Cu), magnesium (Mg), manganese (Mn), potassium (K), sodium (Na), and zinc (Zn) in wing feathers by atomic absorption spectrophotometry (AAS). Samples available for study included pairs of whole wings from Texas saltwater habitat (n = 653 birds), Florida saltwater habitat (n = 287 birds), and South Dakota pond habitat (n = 34 birds), and pairs or single secondary feathers from Louisiana saltwater habitat (n = 287 birds) and Texas pond habitat (n = 2257 birds). We found no differences between secondary feathers from the left and right wings from the same individual, but secondary feathers did differ from primaries from the same individual in Mg and Zn. Concentrations of Ca were higher ($P \leq 0.05$) in flight feathers of juveniles (< 1 yr of age) than in those of adults. Feathers from females had higher ($P \leq 0.05$) Zn than those from males among both adults and juveniles. Concentrations of Ca and Zn in feathers of Texas pond birds were higher ($P \leq 0.05$) than concentrations in feathers from Redheads from other geographic areas sampled. Magnesium from feathers of birds taken in Texas ponds and Louisiana saltwater habitat was higher ($P \leq 0.05$) than in feathers of Redheads from the other three areas. Zinc concentrations in feathers of birds from Texas ponds were higher ($P \leq 0.05$) than those in feathers from Louisiana birds, and Zn in feathers from birds from both of those sites was higher ($P \leq 0.05$) than in feathers from

Redheads from the other three areas. Because of the extremely high variability in mineral concentrations of Redhead feathers as determined by atomic absorption spectrophotometry, use of this technique to identify geographic origins, if based on the elements used in this study, is too uncertain to be reliable.

INTRODUCTION

Knowing the origins of wintering populations of migratory waterfowl facilitates the design of strategies for population management and habitat conservation. Many species of North American waterfowl show relatively broad patterns of movement from extensive breeding areas throughout the prairies or tundra to equally dispersed wintering areas (see Bellrose 1980). Redhead ducks (*Aythya americana*) are unique because approximately 78% of all Redheads in North America winter on the lower Texas and upper Mexican coast and yet come from two strikingly different breeding areas: the prairie pothole region of the northern United States and Canada, and the Great Basin population of Utah and Nevada (Weller, 1964; **Figure 1**). Other smaller populations winter along the Gulf of Mexico in the shallow waters of Chandeleur Sound, Louisiana, and Apalachee Bay, Florida (**Figure 1**), and probably originate in the eastern prairie pothole region (Bellrose, 1980).

A traditional method of tracing waterfowl origins and migration routes is with banding (Nichols and Hines 1987) or the use of alternative methods of marking individuals, such as neckbands or nasal markers. Banding works efficiently, however, only when large numbers of birds from breeding or molting areas can be banded and then recovered in some proportionate manner on migration and wintering areas. Data depend on recovery of bands by hunting, which is virtually nonexistent in some wintering areas (e.g., Chandeleur Sound of Louisiana and the gulf coast of Florida), or which is temporally and spatially biased (Conroy and Blandin, 1984; Nichols *et al.*, 1991). Another method of determining bird origins is to identify populations by morphological differences (e.g., James, 1970; Haberman *et al.*, 1991). Disjunct wintering Redhead populations from Texas and Louisiana showed no significant morphometric differences (M.C. Woodin and T.C. Michot, unpubl. data).

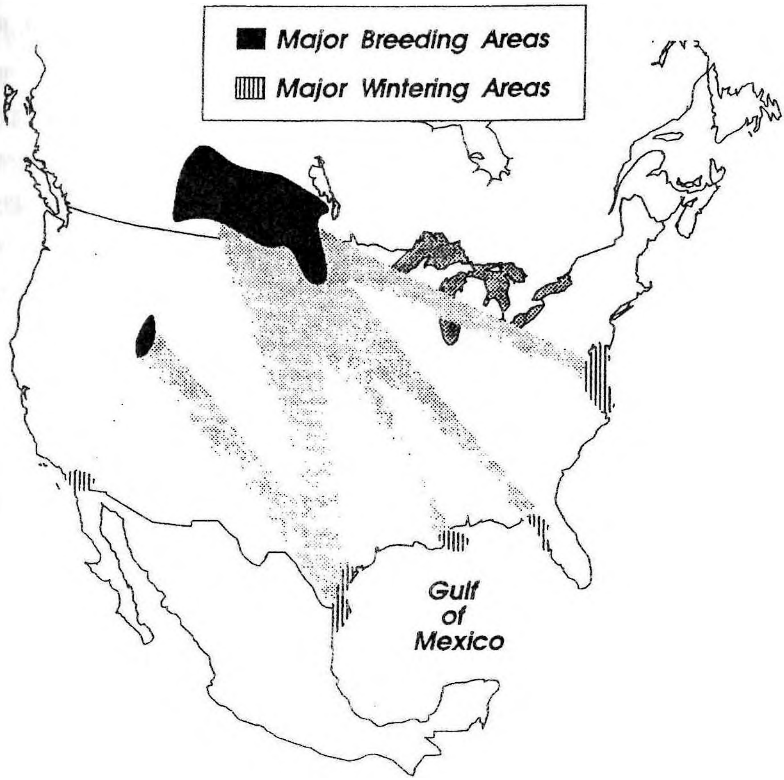

Figure. 1. Map showing general distribution of breeding and wintering areas of the Redhead duck (after Bellrose 1980).

Mineral composition of bird feathers has also been used to determine geographic origins of migratory birds. Hanson and Jones (1968, 1976) used optical emission spectrophotometry of feather minerals to trace origins of Snow Goose (*Chen caerulescens*) populations and subsequently validated the technique by experimental feeding of captive Canada Geese (*Branta canadensis*) (Jones *et al.*, 1987). Kelsall and Burton (1977, 1979), using x-ray emission spectrophotometry, demonstrated sexual differences in feather mineral content and indicated that a sample of at least 40 birds was necessary to represent a population of snow geese and eliminate bias of sex and perhaps age variability.

From 1986 until 1991, during cooperative and overlapping studies of Redheads wintering along the Gulf of Mexico, we had an opportunity to obtain feathers and wings from ducks trapped or collected from the three primary wintering areas along the gulf coast. Despite the possibility that these wintering populations might prove to be mixed pools impossible to identify and classify by origin, a sample of such size and distribution provided a unique opportunity to apply atomic absorption spectrophotometry (AAS) to investigate mineral composition among age, sex, and feather groups and to examine mineral composition patterns related to habitat use.

Objectives of the study were to (1.) Examine differences in feathers or feather groups that might influence accuracy of the AAS technique; (2.) Assess variability in mineral content of feathers of Redheads from different sex and age classes; (3.) Determine if Redheads from three different wintering populations (Texas, Louisiana, and Florida) could be separated based on feather mineral content; and (4.) Compare mineral content of feathers of Redheads according to wetland salinities on their respective ranges.

MATERIALS AND METHODS

Study Areas and Sampling of Populations

Redheads which had been collected for other studies were available from winter ranges in Texas, Louisiana, and Florida, and from within their breeding range in South Dakota. In Texas, Redheads were sampled from two types of wetlands in adjacent study areas (Adair, 1990). Redheads occupying coastal brackish ponds (3-13 ppt) near Corpus Christi were sampled, as were birds from nearby saltwater habitats. All Redheads which used coastal ponds also used saltwater habitats, traveling daily to the ponds after feeding in salt water (Woodin, 1994; Mitchell *et al.*, 1992). Saltwater habitats from which birds were available were the frequently hypersaline (39-48 ppt) Laguna Madre and the normally saline (22-41 ppt) Redfish Bay. Ducks in the ponds were live-trapped, banded, and released (Moore, 1991), and thus only secondary wing feathers could be removed. Birds taken in the Laguna Madre and Redfish Bay were shot for feeding ecology studies, and thus both wings were often available. In Louisiana, sampling likewise occurred in connection with food habits studies in the shallow brackish to saline waters (17-30 ppt) of Chandeleur Sound (Michot and Nault 1993, Michot *et al.* 1994), and secondaries were collected to match studies in Texas. In Florida, all birds were collected for food studies in brackish to saline waters (12-38 ppt, T. C. Michot, unpubl. data) of Apalachee Bay, and one or both wings were available for study. Collection of Redheads from mostly freshwater marshes (< 1-2 ppt) of Day County, South Dakota, was associated with studies by Woodin of other natural tracers; hence, wings were available. Thus, our five study sites comprised a wetland salinity gradient from low to high salinities, which we categorized as follows: (1.) South Dakota pond; (2.) Texas pond; (3.) Louisiana saltwater; (4.) Florida saltwater; and (5.) Texas saltwater habitats. According to Cowardin *et al.* (1979), these sites are classified respectively as (1.) palustrine fresh-mixosaline emergent wetlands; (2.) palustrine mixohaline emergent wetlands; (3.) estuarine polyhaline aquatic bed habitat; (4.) estuarine mixohaline-euhaline aquatic bed habitat; and (5.) estuarine hyperhaline aquatic bed habitat.

Samples available for study included pairs of whole wings from Texas saltwater habitat (n = 653 birds), Florida saltwater habitat (n = 287 birds), and South Dakota pond habitat (n = 34 birds), and pairs of secondary feathers from Louisiana saltwater habitat (n = 287 birds) and Texas pond habitat (n = 2257 birds). Based on plumage (Weller, 1957; Dane and Johnson, 1975) and cloacal characteristics (Kortright, 1943), feathers from ducks collected in fall and winter were classed as juveniles (young-of-the year) or adults, and those taken in spring in breeding areas (South Dakota) were classed as yearlings or adults.

Chemical Analysis

To evaluate the potential use of mineralization as a natural marker for identifying origins of wintering Redhead ducks along the Texas gulf coast, we determined the concentration (limit of detection = 0.01 ppm) of Ca, Cu, Mg, Mn, K, Na, and Zn in feathers of Redheads from Texas (n =40) and Louisiana (n = 40). Minerals chosen for analysis were based on those used successfully in published studies (e.g., Jones *et al.*, 1987), configuration of available AAS equipment, and preliminary testing with feathers. Initial testing of Redhead feathers revealed that Cu and Mn concentrations were too low to be reliably detected;

concentrations of Cu and Mn were <0.01 ppm in all 80 samples tested. We consequently removed Cu and Mn from the list of minerals to be analyzed. Secondary feathers or whole wings were randomly selected from the pool of samples available from each geographical site for the different sex and age classes. Feathers were identified by sample number, primary or secondary, left or right wing, and sex and age. Samples were cut at the shaft into 2- to 3-cm lengths (calamus discarded; see Altmeyer *et al.*, 1991) and placed in an ultrasonic cleaner (Model SF-9, Fisher Scientific, Pittsburgh, PA) designed to hold eight 30-ml beakers. Successive 5-minute washes were used on all feathers as follows: 1:1 acetone:carbon tetrachloride solution, ultrapure water, and acetone.

Mineral concentrations (ppm) were determined in feather samples by flame AAS (Varian, SpectrAA-20, Palo Alto, CA). Samples were prepared for analysis by using a dry-wet-dry ashing procedure (Helrich, 1990). Laundered samples were weighed in dry porcelain crucibles and oven-dried (120^0 C) for 2 hours. Dry matter was determined, and crucibles with dried samples were burned in a muffle furnace (550^0 C) for 2 hours, removed, and allowed to cool. Samples were moistened with ultrapure water, then nitric acid (9 *N*), and gently heated on an electric hotplate to evaporate the liquid until only residual moisture remained. Crucibles were returned to the muffle furnace for an additional 1 hour, removed, and allowed to cool. Ashed samples were solubilized in 6 *N* hydrochloric acid and brought to volume with ultrapure water to obtain a ratio of 1:5 acid:water. Appropriate dilutions were prepared to bring mineral concentrations to reading ranges within AAS standards. We employed quantitative minimum acceptable performance criteria for the AAS based on regression analysis of calibration standards by using least-squares regression analysis ($R^2 > 0.95$) (Sokal and Rohlf, 1981).

Test of Precision

To evaluate the precision of our procedures, we performed three repeated measurements of each of 11 Redhead feather samples. We analyzed samples for concentrations of Ca, K, Mg, and Na on three separate occasions during an 8-hour period, and calculated coefficients of variation (CV) for each element. Only elements with a CV of < 40% were used in subsequent analyses to evaluate differences among Redhead groups.

Test of volume

To determine whether the amount (g) of our sample material was too small (i.e., one secondary feather), we combined 10 secondary feathers from the same wing of adult males to form pooled samples. We then analyzed and compared 20 pooled samples and 20 nonpooled (i.e., one secondary feather) samples from the same location.

Variation in Mineral Concentrations Within and Among Birds

To examine patterns of mineralization in Redhead feathers from the same individual, we compared mineral concentrations between fifth secondary feathers (20 from right and 20 from left wings) of individual birds, and between 20 primary and 20 secondary feathers selected from 20 wings of different birds. We postulated that adults would differ from juvenile birds because adult males generally molt at different geographic locations than juveniles and females (Hochbaum, 1944; Mitchell, 1993). To test this hypothesis, we compared Ca, Mg, and Zn concentrations among sex and age classes of 80 Redheads (20 from each sex and age class) from Texas.

Geographical and Habitat Comparisons

Concentrations of Ca, Mg, and Zn in feathers were compared among 175 adult male Redheads collected from Louisiana, Texas, and Florida saltwater habitats, from Texas pond habitat, and for yearling males from South Dakota pond habitat. Only males were used in the analysis to minimize potential variation produced by sex differences (e.g., Kelsall and Burton 1979, this study).

Statistical Analysis

A two-sample t-test (SAS Institute Inc. 1987) was used to detect differences in mineral concentrations between feathers on right and left wings and differences in mineral concentrations between primary and secondary feathers. Feather mineral concentrations within different sex and age classes were analyzed by using a 2 X 2 factorial design and selected *a priori* contrasts (SAS Institute Inc. 1987). Comparison of mineral concentrations between geographical areas was analyzed by using analysis of variance (ANOVA); separation among means was determined by the Tukey's HSD test (SAS Institute Inc. 1987). Random effect models were used for all ANOVAs.

Validation

To assess the utility of feather mineralization as a natural marker, we conducted a blind-sample test. We used Ca, Mg, and Zn concentrations from adult males collected in Texas saltwater, Texas pond, and Louisiana saltwater habitats to determine the accuracy with which unknown samples could be properly assigned to their respective geographic origin. Ten secondary feather samples from adult males from each geographic area were selected by an assistant and each sample was randomly assigned a number. The number key was placed into an envelope and sealed until all unknown mineral concentrations were assigned to a geographical area based on Z-tests (Sokal and Rohlf, 1981). The z-probabilities were derived by comparing unknown samples with known mineral concentrations of Redhead duck feathers ($n = 29$) from Texas pond habitat and saltwater habitats of Texas and Louisiana. When a sample's P-value from the Z-test fell below 0.05, the hypothesis that the samples came from the same population was rejected.

RESULTS

For the precision test, repeated AAS readings taken from the same samples varied considerably for Na (CV = 59%) and K (CV = 48%), whereas Ca (CV = 29%) and Mg (CV =

8%) were less variable. Because of the high variability in Na and K, we eliminated these minerals from further testing. We did not perform repeated measurements for Zn; the readings among feather groups were very consistent (Note the low SE for Zn in Table 1.). For the volume test, we found that the concentration of Zn was greater (ANOVA; 39 df, $P < 0.001$) in the pooled sample than in the single-feather samples, but Ca and Mg concentrations in the pooled sample did not differ (ANOVA; 39 df, $P > 0.05$) from single-feather concentrations.

Mean concentrations of minerals by wings and feather types are shown in **Table 1**.

Table 1: Mean (±1 SE) concentrations (ppm) of calcium, magnesium, and zinc in flight feathers from different wings and of different types from Redheads wintering along the gulf coast. Means in a column with the same uppercase letter for minerals within wings and within feather types are not significantly different (Analysis of variance; $P > 0.05$).

	Calcium	Magnesium	Zinc
Wing*			
Left	0.39 (0.03) A	0.35 (0.03) A	0.07 (0.03) A
Right	0.39 (0.03) A	0.36 (0.03) A	0.07 (0.03) A
Feather type*			
Primary	0.44 (0.03) A	0.59 (0.03) A	0.10 (0.004) A
Secondary	0.39 (0.03) A	0.36 (0.03) B	0.07 (0.003) A

*Feather samples (n=20) collected from Florida

Concentrations of Ca, Mg, and Zn in the fifth secondary feathers did not differ between left and right wings (t-test, 19 df, $P > 0.05$). Concentrations of Ca, Mg, and Zn, however, did vary between primary and secondary feathers from the same wing. Primary feathers contained significantly (19 df, $P < 0.01$) higher concentrations of Mg and Zn than did secondary feathers. Calcium concentrations were higher in primary feathers than in secondary feathers, although the difference was not statistically significant (19 df, $P>0.25$). Juveniles had higher concentrations of Ca (2 X 2 factorial ANOVA; 39 df, $P<0.05$) in feathers regardless of sex (**Table 2**). Juvenile males possessed greater concentrations of Mg in their feathers than did adult males ($P=0.01$), but adult and juvenile females showed no difference ($P= 0.98$). Adult and juvenile females had higher ($P<0.05$) Zn concentrations than males from the same age class (**Table 2**).

Table 2: Mean (± 1 SE) concentrations (ppm) of calcium, magnesium, and zinc in feathers of different ages and sexes of Redhead ducks from Laguna Madre, Texas, 1988-90. Means within a column with the same letter are not different (ANOVA; P < 0.05).

Age and Sex	n	Calcium		Magnesium		Zinc	
		x	(SE)	x	(SE)	x	(SE)
Ault female	20	0.65	(0.07) A	0.66	(0.07) AB	0.09	(0.004) A
Adult male	20	0.61	(0.06) A	0.55	(0.07) A	0.07	(0.005) B
Juv. female (0.005) C	20	0.90	(0.09) B	0.65	(0.05) AB	0.11	(0.005) C
Jiv. male	20	0.87	(0.06) B	0.81	(0.08) B	0.08	(0.004) A

Feathers of Redhead ducks collected from Texas pond habitat contained higher concentrations of Ca and Zn than feathers from ducks collected from all other areas and contained higher Mg concentrations than all sites except Louisiana (ANOVA, P < 0.05) (**Figure 2**). Feathers from Redheads in Louisiana saltwater habitats differed from those collected in saltwater habitats in Florida and Texas by containing higher (P < 0.05) concentrations of Mg and Zn, although those three sites showed no differences in Ca concentrations. Mineral concentrations in feathers of yearlings from pond habitat in South Dakota were similar to concentrations in Redheads from Florida and Texas saltwater habitats for all minerals, but differed significantly from Louisiana saltwater habitats for Mg and Zn.

For Ca, only 12 of the 29 blind test samples were assigned to their proper origin (**Table 3**). On average, only 30% of the classifications of feathers using Mg concentrations were correct for the three areas. The most successful (66%) classifications were for the Louisiana and Texas saltwater samples using Zn feather concentrations.

Table 3: Number and percent of unknown feather samples (n = 29) from blind-sample test that were correctly classified as to geographical origin using a 2-tailed Z-test probability (P < 0.05).

Collection Site	Calcium		Magnesium		Zinc	
	N. correct	%	N. correct	%	N. correct	%
Texas ponds	10	34	9	31	9	31
Louisiana saltwater	12	41	8	28	19	66
Texas saltwater	10	34	9	31	19	66

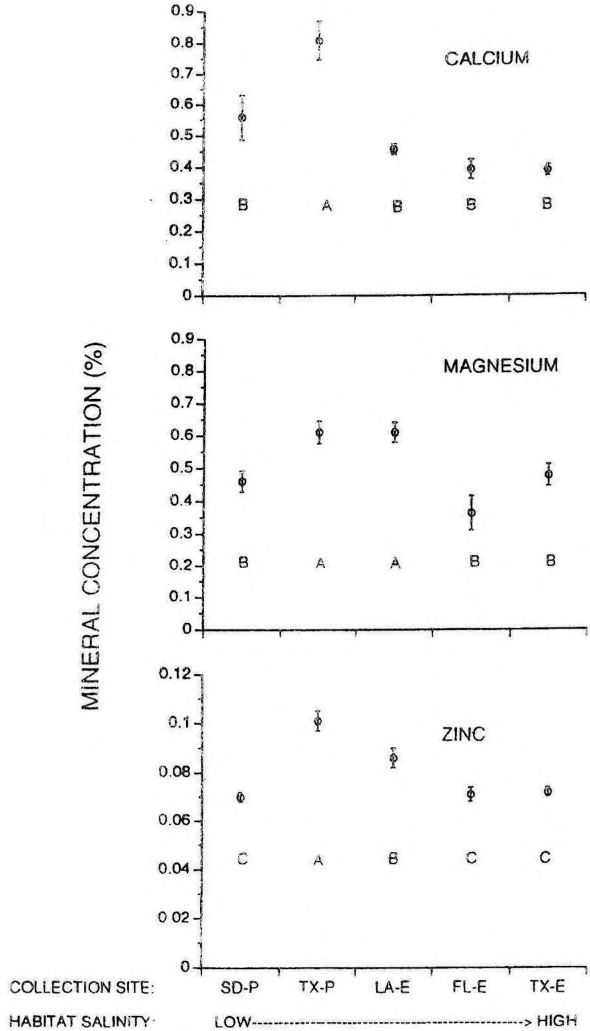

Figure 2: A comparison of the calcium, magnesium, and zinc concentrations in secondary feathers of adult male redhead ducks collected from saltwater habitat of Florida (FL-E; n = 30), Texas (TX-E; n = 40), and Lousiana (LA-E; n = 40) and pond habitat of Texas (TX-P; n = 40), and of yearlings from pon habitat in South Dakota (SD-P; n = 25). Means within a mineral class showing the same letter are not significantly different (P > 0.05, Tukey's HSD mean separation test).

DISCUSSION

No differences were found in wings from the same individual, but secondary feathers differed from primaries in Mg, Zn, and possibly Ca; this pattern was also shown for other elements in predaceous birds by Altmeyer *et al.* (1991) and in shorebirds by Goede (1991). Differences were detected between age and sex groups for some elements, a pattern also demonstrated in snow geese by Kelsall and Burton (1977, 1979). Consequently, we recommend that future studies make comparisons only within sex and age groups.

We found that feather mineral content differed by habitat and geographic sites, but there was no clear pattern along a salinity gradient. Habitat differences have been shown to influence feather mineralization during growth (Bortolotti *et al.* 1989), but surface adsorption also seems to be a problem which can, at least in some situations, affect stability of feather mineral profiles (Edwards and Smith, 1984; Cosson *et al.*, 1988a, 1988b). Whatever the cause, mineral concentrations in feathers collected from birds using ponds in southern Texas differed significantly from feathers collected from other sampling areas, including the adjacent Laguna Madre. This is counterintuitive given that at least one third of the Redheads on the Laguna Madre use the ponds every day (Adair, 1990; Moore, 1991).

We cannot recommend use of this technnique to identify geographic origins of birds because of (1.) high variability within samples, and (2.) failure of the unknown-sample test to provide confidence in prediction. Studies using birds from known molting areas are needed to establish baseline mineral concentrations for these areas. Concentrations from feathers of wintering birds could then be compared to the baseline values to ascertain whether birds on the various wintering sites come from separate post-breeding areas.

ACKNOWLEDGMENTS

This project was funded by the U. S. Fish and Wildlife Service National Wetlands Research Center through Cooperative Agreement number 14-16-0009-91-989 with Texas A&M University. We are most appreciative of the careful and dedicated work of three laboratory assistants without whom this work could not have been done: C. Cain, S. Lerich, and M. Seymour. Drs. E. Taylor and J. Matis contributed greatly to the statistical analyses. Dr. D. Gatlin made available equipment and space, and provided excellent counsel. D. Hyatt of the TAMU Poultry Science Center provided chickens for preliminary studies. We were assisted in the collection of Redhead duck specimens by B. Benedict, M.K. Skoruppa, T. Mason, T. Healy, J. Ramos, P. Chadwick, D. Mackey, A. Nault, W. Norling, and D. Rave. The mention of trade names of commercial products in this report does not constitute endorsement or recommendation for use by the National Biological Service, U.S. Department of the Interior.

REFERENCES

Adair, S. E. (1990). Factors influencing wintering diving duck use of coastal ponds in South Texas. M.S. Thesis, Texas A&M Univ., College Station. 201pp.

Altmeyer, M., J. Dittmann, K. Dmowski, G. Wagner, and P. Muller (1991). Distribution of elements in flight feathers of a white-tailed eagle. Sci. Total Environ. 105:157-164.

Bellrose, F. C. (1980). Ducks, geese & swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 540pp.

Bortolotti, G. R., K. J. Szuba, B. J. Naylor, and J. F. Bendell (1989). Mineral profiles of spruce grouse feathers show habitat affinities. J. Wildl. Manage. 53:811-817.

Conroy, M. J., and W. W. Blandin (1984). Geographic and temporal differences in band-reporting rates for American black ducks. J. Wildl. Manage. 48:23-36.

Cosson, R. P., J. C. Amiard, and C. Amiard-Triquet (1988a). Trace elements in little egrets and flamingos of Camargue, France. Ecotoxicol. Environ. Saf. 15:107-115.

C. Amiard-Triquet, and J. C. Amiard (1988b). Utilisation des plumes dons le recherche des sources de contamination des oiseaux par des elements traces: Cd, Cu, Hg, Pb, Se, et Zn chez les flamants de Camargue, France. Wat. Air and Soil Pollut. 42:103-115.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe (1979). Classification of wetlands and deepwater habitats of the United States. U.S. Fish Wildl. Serv. FWS/OBS 79/31. 108pp.

Dane, C. W., and D. H. Johnson (1975). Age determination of female redhead ducks. J. Wildl. Manage. 39:256-263.

Edwards, W. R., and K. E. Smith (1984). Exploratory experiments on the stability of mineral profiles of feathers. J. Wildl. Manage. 48:853-866.

Goede, A. A. (1991). The variability and significance of selenium concentrations in shorebird feathers. Environ. Monit. Assess. 18:203-210.

Haberman, K., D. I. MacKenzie, and J. D. Rising (1991). Geographic variation in the gray kingbird. J. Field Ornithol. 62:117-131.

Hanson, H. C., and R. L. Jones (1968). Use of feather minerals as biological tracers to determine the breeding and molting grounds of wild geese. Ill. Nat. Hist. Surv. Biol. Notes No. 60, Urbana. 8pp.

Hanson, H. C. and R. L. Jones (1976). The biogeochemistry of blue, snow, and Ross' geese. Ill. Nat. Hist. Surv. Spec. Publ. No. 1, Urbana. 281pp.

Helrich, K. (ed.) (1990). Official methods of analysis. 15th ed. Assoc. Off. Anal. Chem. Arlington, Virginia. 1298pp.

Hochbaum, H. A. (1944). The canvasback on a prairie marsh. Am. Wildl. Inst., Washington, D.C. 201pp.

James, F. (1970). Geographic variation in birds and its relationship to climate. Ecology 51:365-390.

Jones, R. L, E. L. Ziegler, and H. C. Hanson (1987). Mineral composition of feathers from Canada geese (*Branta canadensis*) fed experimental diets. Ill. Nat. Hist. Surv. Biol. Notes No. 128, Urbana. 6pp.

Kelsall, J. P., and R. Burton. 1977. Identification of origins of lesser snow geese by X-ray spectrometry. Can. J. Zool. 55:718-732.

Kelsall, J. P. and R. Burton (1979). Some problems in identification of origins of lesser snow geese by chemical profiles. Can. J. Zool. 57:2292-2302.

Kortright, F. H. (1943). The ducks, geese, and swans of North America. Am. Wildl. Inst., Washington. D.C. 476pp.

Michot, T. C., E. B. Moser, and W. Norling (1994). Effects of weather and tides on feeding and flock positions of wintering redheads in the Chandeleur Sound, Louisiana. *In*: J. Kerekes and B. Pollard (eds.), Aquatic Birds in the Trophic Web of Lakes. (Dev. Hydrobiol. 96. 524 p.) Hydrobiol. 279/280:263-278.

Michot, T. C., and A. J. Nault (1993). Diet differences in redheads from nearshore and offshore zones in Louisiana. J. Wildl. Manage. 57:238-244.

Mitchell, C. A. (1993). Life history traits and habitat needs of the redhead. Fish Wildl. Leaflet 13.1.11. 7pp.

Mitchell, C. A. T. W. Custer, and P. J. Zwank. (1992). Redhead duck behavior on lower Laguna Madre and adjacent ponds of southern Texas. Southwest. Nat. 37:65-72.

Moore, J. L. (1991). Habitat-related activities and body mass of wintering redhead ducks on coastal ponds in South Texas. M.S. Thesis, Texas A&M Univ., College Station. 97pp.

Nichols, J. D., R. J. Blohm, R. E. Reynolds, R. E. Trost, J. E. Hines, and J. P. Bladen. 1991. Band reporting rates for mallards with reward bands of different dollar values. J. Wildl. Manage. 55:119-126.

Nichols, J. D., and J. E. Hines (1987). Population ecology of the mallard. VIII. Winter distribution patterns and survival rates of winter-banded mallards. U.S. Fish Wildl. Serv. Resour. Publ. No. 162. 154pp.

SAS Institute, Inc. (1987). SAS/STAT guide for personal computers, Version 6. Cary, NC: SAS Institute, Inc. 1028pp.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry: the practice of statistics in biological research. 2nd ed. W. H. Freeman and Co., New York, New York. 859pp.

Weller, M. W. (1957). Growth, weights, and plumages of the redhead, *Aythya americana*. Wilson Bull. 69:4-38.

Weller, M. W. (1964). Distribution and migration of the redhead. J. Wildl. Manage. 28:64-103.

Woodin, M. C. (1994). Use of saltwater and freshwater habitats by wintering redheads in southern Texas. *In*: J. Kerekes and B. Pollard (eds.), Aquatic Birds in the Trophic Web of Lakes. (Dev. Hydrobiol. 96. 524 p.) Hydrobiol. 279/280:279-287.