Research Note

Body Mass of Lesser Scaup during Fall and Winter in the Mississippi Flyway

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Key words

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The combined continental breeding population of greater and lesser scaup (*Aythya marila* and *A. affinis*, respectively) in North America has declined markedly since the mid-1980s (Afton and Anderson 2001). Annual breeding population estimates have been consistently below the North American Waterfowl Management Plan (NAWMP) goal of 6.3 million scaup (United States Fish and Wildlife Service and Canadian Wildlife Service 1986), and the 2005 estimate was 46% below the NAWMP goal and the lowest on record (Wilkins et al. 2005). Afton and Anderson (2001) reported the overall decline in scaup may be driven primarily by reductions in the lesser scaup population.

Multiple hypotheses have been posed to address the scaup population decline, which may be influenced by factors operating throughout the annual cycle and range of scaup (Austin et al. 2000, Afton and Anderson 2001). Anteau and Afton (2004) evaluated the spring condition hypothesis and reported nutrient reserves of female lesser scaup at spring stopover areas in the upper Mississippi Flyway and breeding areas in Manitoba, Canada, were lower in 2000 and 2001 than in the 1980s and reported that these nutrient reserves may impact female survival, breeding propensity, and reproductive success. However, body mass dynamics of fall migrating and wintering scaup have not been studied since the 1980s and early 1990s in the Mississippi Flyway, and investigations of body mass and nutrient reserves of lesser scaup are needed throughout the annual cycle and range of the species (Austin et al. 2000). Fall and winter body condition influences survival, physiological and behavioral events, and subsequent reproduction of waterfowl (Dubovsky and Kaminski 1994, Barboza and Jorde 2002). Nutrient reserves acquired from foods consumed on wintering and migrational areas can influence breeding propensity and reproductive performance of geese, some ducks, and other migratory birds (Ankney and MacInnes 1978, Alisauskas and Ankney 1992, Norris 2005), including lesser scaup that use lipids acquired during winter, spring migration, or on breeding areas for clutch formation (Esler et al. 2001).

We collected lesser scaup during fall 1999–2000 and winter 2000–2001 from Manitoba, Canada, southward within the Mississippi Flyway to Louisiana, USA. Our objectives were to 1) estimate body mass of lesser scaup and analyze sex-specific variation in mass in relation to location of scaup collection, age, body morphometrics, and date of collection, and 2) compare our contemporary estimates of scaup mass to those from previous studies conducted at similar locations.

Study Area

We collected lesser scaup from hunters in the following locations: 1) Manitoba, Canada (White Water Lake and Delta Marsh); 2) Minnesota, USA (near Agassiz National Wildlife Refuge [NWR] and Thief Lake Wildlife Management Area); 3) Ontario, Canada (Long Point on Lake Erie); 4) Michigan, USA (Anchor Bay on Lake St. Clair); 5) Wisconsin, USA (Shell Lake and Lake Michigan); 6) Keokuk Pool (Pool 19) on the Mississippi River between Illinois and Iowa, USA; 7) Mississippi, USA (catfish [*Ictalurus punctatus*] ponds near Morgan City); and 8) coastal Louisiana, USA (Sabine NWR, Rockefeller State Wildlife Refuge, and near Lake Arthur). These sites have been recognized as important migrational or wintering areas for scaup (Bellrose 1980, Dubovsky and Kaminski 1987, Bookhout et al. 1989, Korschgen 1989).

Methods

We obtained hunter-harvested lesser scaup (hereafter scaup unless specified) between mid-September 1999–2000 and late January 2000–2001. Hunter techniques used to collect scaup were not investigated and thus not analyzed. Although several studies have reported negatively biased body mass and condition for hunter-harvested ducks (Dufour et al. 1993, Pace and Afton 1999), we assumed our specimens provided conservative estimates of scaup mass, yet enabled comparisons among collection locations, age classes, and with previous estimates of scaup mass.

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For analysis, we combined samples of scaup from similar latitudinal and physiographic locations. We combined data for birds from Manitoba and Minnesota because collection sites were freshwater, palustrine, emergent wetlands, or lacustrine wetlands of glacial origin within or near the Prairie-Parkland Region (Cowardin et al. 1979). Likewise, we combined scaup samples from collection sites in the Great Lakes Region (Ontario, Michigan, Wisconsin) because scaup were collected at similar latitudes and within the Great Lakes System. We analyzed scaup collected from Keokuk Pool, Mississippi, and Louisiana separately because these sites were disjunct geographically along a decreasing latitudinal gradient.

We placed each collected scaup in a labeled plastic bag and froze these specimens before shipment to Mississippi State University (Afton et al. 1989). We thawed scaup 24 hours before necropsy and dried each bird with paper towels to absorb surface moisture before weighing (Chappell 1982). We classified specimens as either adults or juveniles by examining rectrices, wing plumage, and cloacal characters (Hochbaum 1942, Carney 1992). We measured body mass (± 1 g) of thawed specimens (with ingesta) and length (± 1 mm) of body, wing chord, tarsometatarsus, and culmen (Afton and Ankney 1991, Carney 1992). Chappell (1982) reported body mass of thawed scaup rarely differed by >1 g of fresh mass. We did not subtract ingesta mass from total mass because previous authors reported body mass including ingesta (Hine et al. 1996, Austin et al. 1998). We used body mass as an index of body condition because Chappell and Titman (1983) reported a positive relationship ($r^2 = 0.81$) between body mass and lipids for spring and fall migrating lesser scaup.

We conducted separate but identical analyses of male and female body mass. We performed principal component analysis (PCA) of the correlation matrix for all morphometric measurements within sexes (PROC PRINCOMP; SAS Institute 1999). We used first principal component scores (PC1) to index body size (Afton and Ankney 1991, Anteau and Afton 2004), followed by analysis of covariance (ANCOVA) to test effects of collection location and age on variation in mass, with PC1 and collection date (CD) as covariates and year of collection as a random variable (PROC MIXED; SAS Institute 1999). Because body mass of individuals may vary through time at a location, we calculated CD to adjust for varying lengths of collection periods at each location (Anteau and Afton 2004). We calculated CD by subtracting the annual date of the first day of collections per location and year from the annual date when an individual was collected and then adding 1 (Anteau and Afton 2004). We used backward elimination of variables and interactions ($P > 0.05$), excluding the PC1 $\times$ collection-location interaction, to select final models (Zar 1999). We found no evidence of differential size migration in scaup (cf. Alexander 1983); PC1 did not vary by location for either sex ($F_{4,110–144} \leq 1.08$, $P \leq 0.37$). We excluded 3 males and 3 females from analysis because of missing morphological data ($n = 1$ M, $n = 2$ F) or because data were deemed outliers ($n = 2$ M, $n = 1$ F; Cook's D values $>4/n$; Freund and Littell 1991). We assumed unequal variances of body mass data, because Akaike's and Bayesian information criteria (Littell et al. 1996, Anderson et al. 2000) indicated our data fit a model with heterogeneous variances. We used restricted-residual maximum-likelihood estimation methods in all ANCOVAs (PROC MIXED; Littell et al. 1996, SAS Institute 1999). We tested for differences in mean body mass, adjusted for PC1 and CD, for each significant term ($P \leq 0.05$) by specifying the PDIFF option in the least-squares means statement (PROC MIXED; SAS Institute 1999).

We obtained body mass data from known previous studies in which lesser scaup were collected during fall migration or winter for comparison with our data. We used data from previous studies in which investigators collected scaup at similar locations and by similar methods to us and either provided estimates of mean mass and variation or data to calculate these statistics. For these comparisons, we computed means and standard errors (SEs) from our raw data and unpublished data sets, and we compiled means and SEs from published studies. We did not adjust our raw data for individual variation in structural size and CD because such data were not available for all previous studies. We did not statistically compare our data with previous data sets because sample sizes for some sex–age cohorts were small ($n < 20$), and we were primarily interested in general trends in body mass between previous and recent periods. We used overlap of SEs to assess similarity in mean mass between our and previous estimates.

Results

We analyzed body-mass and morphological data from 149 male and 114 female lesser scaup obtained from hunters. The PCA indicated correlations among morphometrics were positive for each sex, and PC1 accounted for 43% of the variation in morphometrics for males and 40% for females. Eigenvector weights of PC1 ranged from 0.428–0.601 for males and 0.348–0.599 for females.

Age of scaup did not influence variation in body mass, neither as a main effect nor as an interaction term for males ($0.03 \leq F_{1–4,126–131} \leq 1.87$, $0.12 \leq P \leq 0.85$) or females ($0.02 \leq F_{1–4,91–105} \leq 3.70$, $0.06 \leq P \leq 0.88$). Additionally, no interaction term including collection location was significant for males ($1.07 \leq F_{4,126–136} \leq 1.87$, $0.12 \leq P \leq 0.37$) or females ($0.50 \leq F_{4,91–100} \leq 2.22$, $0.07 \leq P \leq 0.74$).

We detected a significant effect of location on variation in body mass of males ($F_{4,141} = 9.62$, $P \leq 0.001$) and females ($F_{4,106} = 29.97$, $P \leq 0.001$). Generally, mean mass of both sexes declined with latitude of collection from north to south, except for an increase in male mass at Keokuk Pool (Fig. 1). Mean mass of male scaup was greatest in the Prairie-Parkland Region and Keokuk Pool ($-4.87 \leq t_{141} \leq 3.97$, $0.001 \leq P \leq 0.011$) but did not differ between these 2 locations ($t_{141} = 0.61$, $P = 0.54$). Mean mass of males collected in the Great Lakes Region, Mississippi catfish ponds, and coastal Louisiana was 74 g (9%), 88 g (10%),

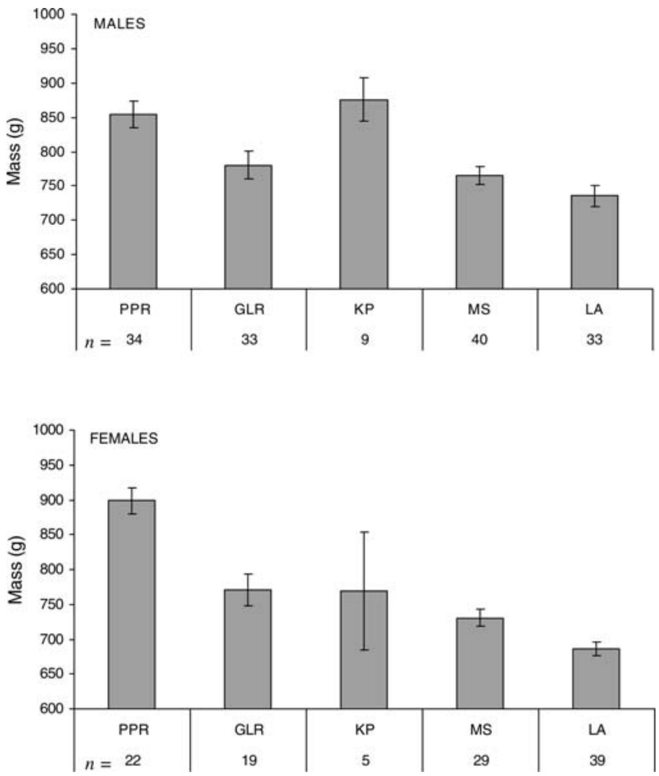

Figure 1. Least-squares mean body mass (±SE; g) of male and female lesser scaup collected at 5 locations (i.e., Prairie-Parkland Region [PPR]; Great Lakes Region [GLR]; Keokuk Pool along the Mississippi River between Illinois and Iowa, USA [KP]; Mississippi, USA [MS]; and Louisiana, USA [LA]; $n =$ number of scaup by location), fall and winter 1999–2001.

and 119 g (14%) lower, respectively, than mean mass of birds from the Prairie-Parkland Region. Mean mass of males collected in the Great Lakes Region, Mississippi catfish ponds, and coastal Louisiana was 95 g (11%), 110 g (13%), and 140 g (16%) lower, respectively, than mean mass of birds from Keokuk Pool. Mean mass of males from the Great Lakes Region, Mississippi, and Louisiana did not differ ($-1.53 \leq t_{141} \leq 1.77$, $0.08 \leq P \leq 0.12$).

Female mean mass was highest in the Prairie-Parkland Region ($-10.54 \leq t_{106} \leq -5.13$, $P \leq 0.001$) and lowest in Louisiana ($-10.54 \leq t_{106} \leq 3.61$, $0.001 \leq P \leq 0.004$). Mean mass of females collected in the Great Lakes Region, Mississippi, and Louisiana was 127 g (14%), 168 g (19%), and 213 g (24%) lower, respectively, than mean mass of females from the Prairie-Parkland Region. Female mean mass in the Great Lakes Region did not differ ($t_{106} = 1.77$, $P = 0.08$) from those in Mississippi, but female mean mass in Louisiana was 85 g (11%) and 45 g (6%) less than those from the Great Lakes Region and Mississippi, respectively. Mean mass of females collected at Keokuk Pool did not differ from mean mass of females at other locations ($-1.50 \leq t_{106} \leq 0.98$, $0.14 \leq P \leq 0.98$).

We assembled estimates of mean mass and associated SEs for lesser scaup collected in 5 previous studies similar to ours in the Mississippi Flyway (Table 1). Three other studies provided estimates of scaup mass prior to the 1980s, but none reported estimates of variation; thus, our comparisons were limited to those from 1981 to 1991. Mean mass of all cohorts of scaup in our study generally was greater or similar to those from previous studies, except adult males in the Prairie-Parkland Region (Table 1).

Discussion

Body mass of male and female scaup generally declined during fall migration from the Prairie-Parkland Region to wintering habitats in Mississippi and Louisiana, similar to patterns of body mass dynamics in other North American waterfowl (Baldassarre and Bolen 2006). Declines in body mass and lipids may be influenced by endogenous mechanisms (Loesch et al. 1992), environmental conditions (e.g., food and weather; Owen and Cook 1977), physiological costs of annual cycle events (e.g., migration, molt, and pairing; Heitmeyer 1988), genetic set-points for fitness dependent upon risks of weather and predation (Gates et al. 2001, Barboza and Jorde 2002), or a combination of these and other factors (e.g., disturbance). Regardless, loss of mass and lipids during winter is a common pattern in waterfowl and may be adaptive (Gates et al. 2001) but could also have carry-over effects with negative or positive ramifications for migratory populations (Norris 2005).

Greater mass of male and female scaup in the Prairie-Parkland Region likely reflected increased foraging activities and lipid levels before and during fall migration (Austin et al. 1998) concurrent with increased abundance and biomass of amphipods (Austin 1983, Afton 1984, Wen 1992), an important food of lesser scaup (Afton and Ankney 1991, Afton et al. 1991). Declines in body mass from the Prairie-Parkland Region to the Great Lakes Region may have resulted from energetic cost of migration to this region (Berthold 1975), physiological responses to local environmental conditions (e.g., temperature; Owen and Cook 1977, Whyte and Bolen 1984), or a combination of these and other factors. Observed declines in body mass also may have reflected dietary shifts between regions. Zebra mussels (*Dreissena polymorpha*) and other mollusks are a common food of scaup in the Great Lakes Region (Hamilton et al. 1994, Petrie and Knapton 1999), and these mollusks may have less metabolizable energy compared to amphipods (Ballard et al. 2004).

Scaup migrating through the Great Lakes Region typically winter in the Atlantic Flyway while scaup using Keokuk Pool predominantly winter in the Mississippi Flyway (Bellrose 1980, Austin et al. 1998). Thus, scaup collected from midlatitude locations in the Great Lakes Region and Keokuk Pool may represent different migratory populations exposed to different environmental conditions (e.g., lacustrine vs. riverine systems), and these different conditions may influence variation in body mass between midlatitude locations. Alternatively, variation in estimates of scaup mass at Keokuk Pool also may have reflected variable habitat and foraging conditions at preceding migratory sites and Keokuk Pool (Anteau and Afton 2004). However, large variation in mean mass of male and female scaup at Keokuk Pool likely was influenced by small sample sizes at this location. Hence,

Table 1. Mean (±SE; g; *n* birds)[a] body mass of lesser scaup collected in fall and winter at similar locations during our study (1999–2001) and previous studies (1981–1991).

		Our study			Previous studies					
Location[b]	Age–sex	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	Location	Yr	Reference
PPR	Ad M	872	28	16	959	18	38	Minn.	1984–1985	Austin et al. (1998)
	Juv M	922	26	18	868	17	36	Minn.	1984–1985	Austin et al. (1998)
	Ad F	923	27	10	861	14	41	Minn.	1984–1985	Austin et al. (1998)
					842	29	32	Manit.	1981–1982	Austin and Fredrickson (1987)
	Juv F	931	18	12	828	18	34	Minn.	1984–1985	Austin et al. (1998)
GLR	Ad M	820	28	16	764	24	23	Ont.	1982–1983	F. P. Kehoe (unpublished data)[c]
	Juv M	832	27	18	744	15	23	Ont.	1982–1983	F. P. Kehoe (unpublished data)
	Ad F	771	43	9	701	18	16	Ont.	1982–1983	F. P. Kehoe (unpublished data)
	Juv F	800	22	11	706	15	22	Ont.	1982–1983	F. P. Kehoe (unpublished data)
KP	Ad M	889	37	6	893	6	96	KP, ILRV	1985, 1989–1991	Hine et al. (1996)
	Juv M	983	38	5	809	6	86	KP, ILRV	1985, 1989–1991	Hine et al. (1996)
	Ad F	894	4	2	842	11	43	KP, ILRV	1985, 1989–1991	Hine et al. (1996)
	Juv F	780	157	4	744	10	74	KP, ILRV	1985, 1989–1991	Hine et al. (1996)
La.	Ad M	753	22	20	721	9	28	La.	1986	Afton et al. (1989)
	Juv M	710	20	13	727	17	11	La.	1986	Afton et al. (1989)
	Ad F	703	10	23	680	10	22	La.	1986	Afton et al. (1989)
	Juv F	662	12	16	669	13	11	La.	1986	Afton et al. (1989)

[a] Means and SEs were calculated from raw data and not adjusted for any covariates or weighted for sample size.
[b] PPR = Prairie-Parkland Region; GLR = Great Lakes Region; KP = Keokuk Pool, Mississippi, USA; ILRV = Illinois River Valley.
[c] F. P. Kehoe, Ducks Unlimited Canada.

patterns in scaup body mass for this location should be interpreted in light of this variation.

Aquaculture ponds constitute a significant area in Mississippi (>37,000 ha; Dean et al. 2003) and Arkansas, USA (>25,000 ha; United States Department of Agriculture 2004, Wooten and Werner 2004), and these habitats may provide adequate resources for migrating and wintering scaup in the Lower Mississippi Alluvial Valley (Dubovsky and Kaminski 1987, Christopher et al. 1988, Wooten and Werner 2004). Indeed, body mass of scaup collected from Mississippi catfish ponds was similar to or greater than that for scaup collected from natural wetlands in Louisiana. However, greater body mass of scaup wintering in Mississippi compared to Louisiana also may have been a function of birds maintaining larger nutrient reserves at higher latitudes (Gates et al. 2001), although scaup were collected at similar times (i.e., Dec–Jan) in these regions.

Comparison of our estimates of scaup body mass with previous studies suggested body masses of scaup at important migrational and wintering habitats have not declined during fall and winter as they have during spring at some locations in the Mississippi Flyway (Anteau and Afton 2004). In our study, scaup were hunter-harvested and not randomly collected samples, which may partially explain the decreased mass we reported for adult males from the Prairie-Parkland Region (e.g., Pace and Afton 1999). Anteau and Afton (2004) reported declines in spring body condition of scaup in the Prairie-Parkland Region between the late 1970s and early 2000s may be influenced by reduced availability and quality of amphipods and other invertebrates in some portions of the Prairie-Parkland Region and upper Midwest. Our ability to detect possible lower body mass of scaup in fall due to reduced amphipod abundance in the Prairie-Parkland Region (e.g., cohorts other than adult males) may have been masked by forage conditions and endogenous reserves acquired by scaup prior to arrival in the Prairie-Parkland Region (e.g., the boreal forest). Nonetheless, we collected scaup at similar time periods to previous studies in this region (i.e., Sep–Oct) and therefore believe our and previous estimates are comparable.

Zebra mussel populations have increased since their introduction into the Great Lakes in the mid-1980s, and scaup remain in the Great Lakes Region for longer periods during fall and winter than before the mussel invasion (Wormington and Leach 1992, Hamilton et al. 1994, Petrie and Knapton 1999). We speculate the increase in mean mass of hunter-harvested scaup between the early 1980s and our study may be linked to increased availability of zebra mussels and other exotic invertebrates (Petrie and Knapton 1999, Ross et al. 2005).

Although our sample sizes were small at Keokuk Pool, our findings were consistent with results showing increased mass and lipids in spring collected scaup during the 2000s compared to the 1980s at this location (Anteau and Afton 2004). Bellrose and Hawkins (1947) reported mean weights of hunter-harvested lesser scaup from the Mississippi and Illinois river valleys during 1938–1940; their estimates generally were lower than ours or those of hunter-harvested scaup reported by Hine et al. (1996) at Keokuk Pool and the Illinois River Valley during 1985–1991. Abundance of fingernail clams (Sphaeriidae), another important food of scaup (Thompson 1973, Afton et al. 1991), declined considerably in the upper Mississippi River in the late 1980s (Wilson et al. 1995) but generally was high during our study (Sauer 2004). Additionally, zebra mussels have increased in abundance since the mid-1990s after introduction in the upper Mississippi River (Cope et al. 1997, Sauer 2004). Thus, increased abundance of fingernail clams and zebra mussels may be associated with stable or increased body mass of scaup at Keokuk Pool during our study (cf. Anteau and Afton 2004).

Afton et al. (1989) reported body weights of scaup collected in southern Louisiana were lower in 1986 than in the 1960s and suggested poor winter condition may negatively influence survival and subsequent reproductive performance of scaup. However, scaup mass in Louisiana during our study generally was similar or greater than mass of scaup collected by Afton et al. (1989) despite potential negative condition bias caused by using hunter-harvested birds in our study. Similarly, Anteau and Afton (2004) also reported nutrient reserves of scaup in Louisiana in late winter were greater in the 2000s than in the 1980s. Although mean mass of scaup wintering in Louisiana may have declined between the 1960s and the 1980s, mean mass of scaup in our and Anteau and Afton's (2004) studies suggest declines in scaup condition have stabilized since the mid-1980s.

We believe fall and winter body mass of scaup should reflect fall and winter habitat and food resources in the Mississippi Flyway; thus, we suggest these seasonal factors are not contributing to the continental scaup decline. However, other factors may influence scaup survival, habitat use, and nutrient acquisition during fall or spring migration and winter, such as forage availability and quality (Anteau and Afton 2004), disease (Goldberg et al. 1995), parasites (Vest 2002, Haukos and Neaville 2003), contaminants (Takekawa et al. 2002, Custer et al. 2003), and human disturbance (Austin et al. 1998).

Management Implications

Our study indicated that declines in scaup body mass during fall at important migrational and wintering areas in the Mississippi Flyway may not significantly contribute to the scaup population decline. Waterfowl managers should therefore focus research efforts on other potential causes of scaup declines (e.g., spring condition hypothesis) and continue to provide quality habitats for fall migrating and wintering scaup in the Mississippi Flyway. Furthermore, estimation of primary scaup foods and scaup energetic requirements at important migrational and wintering areas is needed to assess foraging carrying capacity and facilitate habitat conservation planning and management (e.g., Reinecke et al. 1989).

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