Research Article

Lesser Scaup Winter Foraging and Nutrient Reserve Acquisition in East-Central Florida

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Abstract

*Lesser scaup (*Aythya affinis*) populations have been declining since the late 1970s. One of the explanations to account for this decline, the spring-condition hypothesis (SCH), is based on the premise that scaup are limited by their ability to acquire or maintain nutrient reserves during migration to the breeding grounds, leading to an impairment of their reproductive potential. Available evidence suggests that endogenous reserves required for reproduction are obtained at a later stage of migration or after arrival at the breeding grounds, not wintering sites. However, only one study has addressed body-condition levels on a southern wintering site in the last decade, with results limited to the wintering grounds on the Mississippi Flyway. We documented foraging behavior, nutrient levels, and body mass of lesser scaup in east-central Florida, USA, where 62% of the Atlantic Flyway population overwinters, during the winters of 2002 and 2003. Diurnal foraging did not increase seasonally. Nocturnal foraging increased seasonally by 76% or 43 minutes per night in females and by 478% or 1.9 hours per night in males. Measures of body condition did not change seasonally during 2002 for either sex. Between early and later winter in 2003 corrected body mass (CBM) and lipid reserves of male scaup increased 77 g and 39 g, respectively. Our results suggest that lesser scaup maintain or may slightly improve their physiological condition in east-central Florida during winter. Lower body mass and differences in nutrient levels in east-central Florida, compared to a wintering site in Louisiana, likely stem from geographic variation and lower thermal requirements associated with the warmer Florida environment. Lesser scaup depart Florida with sufficient reserves to initiate spring migration, but they maximize nutrient reserves used during reproduction elsewhere during migration or on the breeding grounds. These results suggest that maintaining the ecological integrity of this wintering ground is critical in minimizing winter mortality and preventing it from becoming an ancillary factor in current declines. Future research should address understanding survival rates during spring migration and at critical staging areas to provide new insight into the ramifications of scaup leaving wintering habitats such as MINWR with lower body condition than at other wintering sites in other flyways.* (JOURNAL OF WILDLIFE MANAGEMENT 70(6):1682–1689; 2006)

Key words

Aythya affinis, *body condition, Florida, lesser scaup, nutrient reserves, spring condition hypothesis, winter.*

Lesser scaup (hereafter scaup) populations have been declining steadily since the late 1970s (Austin et al. 2000, Afton and Anderson 2001, Wilkins and Otto 2003) and are currently below goals of the North American Waterfowl Management Plan (U.S. Fish and Wildlife Service 2005). One explanation for such decline was purported by the spring-condition hypothesis (SCH; Austin et al. 2000, Afton and Anderson 2001, Anteau and Afton 2004). The SCH states that reproductive success of scaup has declined in recent years because females arrive at the breeding grounds in poor body condition (smaller lipid, protein, and mineral reserves, and lower body mass) as compared to historical data, which leads to an impairment of their reproductive potential.

In testing the SCH, Anteau and Afton (2004) illustrated that historically scaup increased body mass on northern staging areas (e.g., Minn., USA), as compared to other locations along the Mississippi Flyway. Their results suggested that nutrient reserves (lipid, protein, and mineral) may not be maximized until scaup arrive on the breeding grounds. These researchers contend, with supporting evidence from several locales, that pervasive habitat degradation in northern stopovers could undermine the female's ability to meet prebreeding body-condition requirements with concomitant reductions in reproductive output (at least for females migrating in the Mississippi Flyway and breeding in Manit., Canada).

Measures of body condition can vary substantially across the species' winter range. For instance, data collected in 2001 revealed that scaup in east-central Florida had lower body mass than at other southern wintering sites (e.g., La., USA; Herring 2003). One interpretation of this discrepancy was that it reflected geographic variability that scaup may exhibit without discernable demographic impact (e.g., survival, Herring and Collazo 2004). Another was that lower body mass was indicative of habitat quality differences on the wintering grounds, which may influence body condition prior to migration, and ultimately, at the time of arrival on the breeding grounds.

The conservation challenge posed by scaup underscores the importance of gaining a greater understanding of scaup body-condition dynamics throughout their annual cycle, including their wintering range. However, only one study has addressed body condition of scaup on a southern wintering site (Mississippi Flyway) in the last decade

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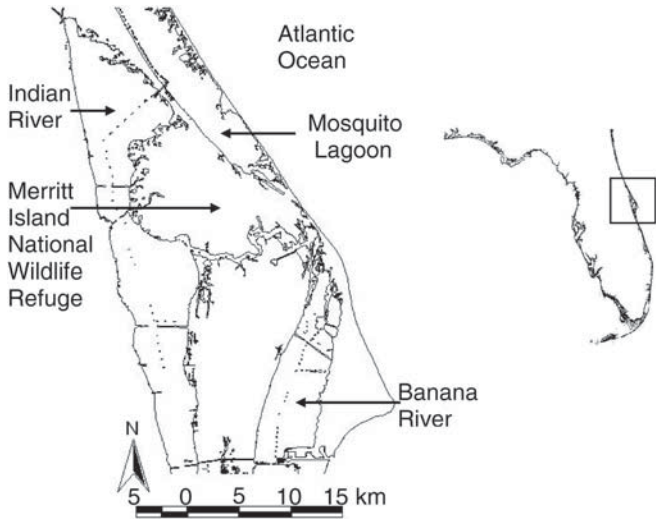


Figure 1. Location of the lesser scaup foraging and body-condition study site in the Indian River Lagoon, Florida, USA, in 2002 and 2003. Map shows the Merritt Island National Wildlife Refuge and the 3 lagoon systems: Indian River, Mosquito Lagoon, and Banana River.

(Anteau and Afton 2004). Our objectives were 1) to measure winter body condition of scaup in east-central Florida, where 62% of all the Atlantic Flyway scaup population winters, and 2) to determine if foraging behavior and body condition changed prior to spring migration. Examining the relationship between nutrient reserves and time spent foraging (Austin 1987) and duration of dives (Poulton et al. 2002) is essential to understand scaup winter body-condition dynamics. Finally, we placed our results in a broader geographic context by comparing them to data from the one other southern wintering site where body-condition research has been conducted, to facilitate assessments of across flyways and advance understanding of body condition of wintering scaup.

Study Area

We conducted our research at Merritt Island National Wildlife Refuge (MINWR) during the winters of 2002 and 2003. The refuge was located on the Atlantic Coast approximately 1 km east of Titusville, Florida, USA (28°40′N, 80°46′W; Fig. 1). The refuge enveloped the John F. Kennedy Space Center on Merritt Island, covering 55,039 ha of the National Aeronautical and Space Administration's (NASA) 57,000 ha in Brevard and Volusia counties. Our study area was part of the Indian River Lagoon (IRL) complex, including the waters of the Indian and Banana Rivers and the southern half of the Mosquito Lagoon. These areas provided the most valuable wintering habitat for scaup on the Atlantic Flyway (Bellrose 1980), harboring >15% of the continental population (Bellrose 1980, Austin et al. 1998).

Merritt Island proper is a barrier island complex separated from the mainland by the Indian River and from Cape Canaveral by the northern Banana River. The island was composed of sandy beaches, dune systems, hammocks, lagoons, and 72 salt marsh impoundments jointly managed by the Brevard Mosquito Control District, National Park Service, NASA, and United States Fish and Wildlife Service. Waters tend to be shallow, aeolian lagoons with average depths of 1.5 m and maximum depths of 9 m (dredged regions). Typical salinities ranged from 10 to 42 parts per trillion (Provancha and Sheidt 2000). Estuarine and impounded wetland habitats within our study site were approximately 400 km^2.

Methods

Time Budgets

We collected behavioral time activity budget (TAB) data in 2002 only, using diurnal scan sampling (Altman 1974, Baldassarre et al. 1988, Mitchell et al. 1992) and focal nocturnal radio telemetry techniques (Custer et al. 1996). Behavioral activities used during scan sampling were defined by Paulus (1988) and include feeding, resting, locomotion, alert, preening, social display, and threat displays. We based nocturnal time activity budgets on attenuation of telemetry signals and limited them to ascertaining whether birds were feeding. We defined winter periods as early and late, based on migration chronology (Bellrose 1980) and aerial survey data from winter 2000–2001 (G. Herring, United States Geological Survey, unpublished data). We defined early winter as mid-December through 10 February and late winter as 11 February–20 March, when the majority of scaup had departed from the area. We used these dates to define data collection periods for both behavioral observations and nutrient reserve collections.

We randomly chose locations, flocks, and time of day for diurnal sampling. We divided the diurnal period into 2 approximately even blocks of time: sunrise until 1200 hours and 1200 hours until sunset, and we conducted near-equal numbers of scans in each period. We scanned flocks only once (ensuring independence of observations) at each site. We minimized the chances of underestimating time spent foraging (e.g., submerged scaup; Baldassarre et al. 1988) by scanning flocks slowly. Water depths were also generally shallow (1.5 m) and there was no emergent vegetation to obscure scan observations.

We did not record sex during diurnal sampling bouts because preliminary behavioral observations from 2001 indicated that female and male scaup behaved similarly during the day (Wilcoxon tests: feed $P = 0.95$, rest $P = 0.80$, locomotion $P = 0.74$, preen $P = 0.98$; $n = 321$; Herring 2003). We did not include the 2001 estimates of behavior in our analyses because they were conducted with the use of focal observations rather than the scan sampling method used in 2002. Differences in sampling methods could result in bias in estimates if we pooled data. However, biases aside, the focal observations provided detailed observations of both sexes, and similarities in diurnal behaviors were reflective of the larger population of scaup at MINWR. We assumed that diurnal behavior between males and females was also similar during 2002. Other studies observed similar foraging times between sexes for scaup (Christopher and Hill 1988,

Gammonley and Heitmeyer 1990) and for other waterfowl species (Paulus 1984, Bergman et al. 1989, Mitchell et al. 1992). Finally, we recorded time of observation and location.

We captured scaup used for nocturnal monitoring with quick-catch corral traps over baited locations (Joanen 1964, Haramis et al. 1986). We used 9 separate trap locations within MINWR to minimize group-dependent behaviors among radioed birds. We trapped 60 scaup (34 F, 26 M) between 4 and 7 January 2002. We sexed birds using wing plumage characteristics (Carney 1992). We surgically implanted a radiotransmitter in each bird (Korschgen et al. 1984, Olsen et al. 1992). We used intra-abdominal radiotransmitters with an external whip antenna, rather than traditional back-mounted units, to minimize behavioral effects (Woakes and Butler 1975, Perry 1981, Olsen et al. 1992). Radiotransmitters were implantable model A2310 (Advanced Telemetry Systems, Isanti, Minnesota) and had a minimum lifespan of 6 months. Mean mass of transmitters was 18 g, which was $\leq$2.91% of our lightest bird. We used isoflurane as the anesthetic (Aerane, Ananquest, Madison, Wisconsin), delivered into the bird via an Isotec 3 vaporizer (Ohmeda, Madison, Wisconsin). All other surgical procedures followed that of Olsen et al. (1992). Prior to release, we gave all birds fluids and monitored them for >1 hour after surgery. In addition, we banded all birds with United States Fish and Wildlife Service aluminum bands. We released birds at their capture site.

Prior to establishing data collection procedures, we visually monitored the activity patterns of 8 radiomarked scaup for >6 hours. Implanted scaup behaved in the same manner as adjacent unmarked scaup, feeding in regular rhythmic patterns and performing other activities (e.g., resting, preening). Additionally, we confirmed that we were able to use attenuation of radio signal strength to discern feeding activity (i.e., signal strength either weak or nonexistent during dives) or nonfeeding (i.e., signal strength normal). We used a 30-minute sampling bout after determining that time between foraging bouts averaged 21.9 $\pm$ 2.4 minutes ($n = 13$ implanted scaup). The 30-minute period increased the likelihood of detecting foraging activity during sampling. We randomly selected the time and location where surveys started each evening. We used a truck-mounted 6-element dual Yagi antenna (Cushcraft, Manchester, New Hampshire) setup with a null system to determine if radioed scaup were present at sites. When we located radioed scaup, we monitored up to 2 radioed birds whose locations could be determined via triangulation and whose radio signal was sufficiently strong to enable monitoring of foraging behavior. We only recorded the behavior of 2 radioed scaup at each site to maximize areas sampled. Radiomarked scaup were usually >250 m apart, so we assumed observational data were independent.

We located radiomarked scaup from 2 separate points and we took a compass bearing to triangulate (handheld Global Positioning System [GPS] coordinates at each site using a Garmin, model 12CX GPS [Garmin, Olathe, Kansas]). We attempted to take both bearings <15 minutes apart, minimizing movement and subsequent error in the birds' location and depth of the foraging site. Once we established the birds' location, we recorded 30 minutes of audio data from the radiotelemetry receiver. Additionally, we noted the radiofrequency, date, time, and location of data collection. We later determined the duration of foraging dives from audiotapes, which served as an indicator of foraging conditions. We defined the duration of dives as the length of time a radio signal was lost when scaup were under water. We used Program Locate II (Pacer, Truro, Nova Scotia, Canada) to calculate positions of radioed scaup. We visited nocturnal feeding sites based on our triangulated locations and measured water depth. Because distinct attenuation occurred in waters >55 cm deep, we did not include data from sites <55 cm deep in the analyses to avoid underestimating nocturnal foraging. The IRL system was very shallow and sloped gently from the shoreline out to the deepest points, resulting in homogeneous depths. Subsequently, we were confident that depths taken at triangulated nocturnal foraging sites were similar to adjacent areas.

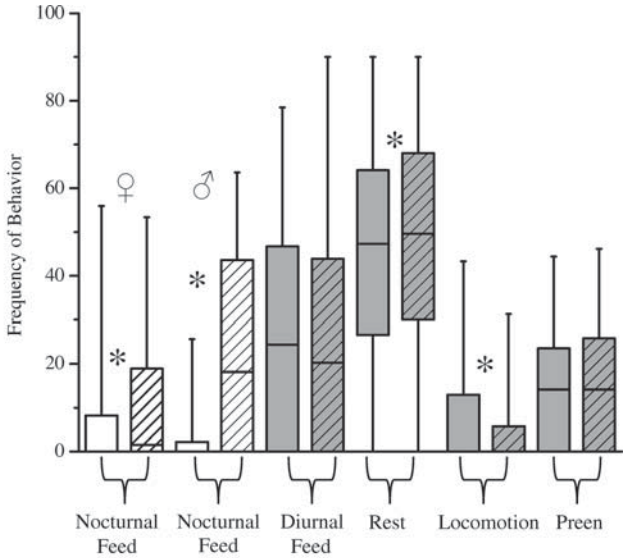
We evaluated radiolocation angle errors by taking 13 triangulated readings (26 bearings) from different locations from a distance of 1 km prior to initiating tracking. We compared triangulated locations to the known position determined by GPS. The mean angle error was 2° $\pm$ 0.09. Mean distance error between triangulated locations and actual locations was 53 m $\pm$ 2.5. The mean error polygon for all subsequent scaup locations was 232 m^2 $\pm$ 5.5 ($N =$ 546).

We divided the nocturnal period into 2 approximately equal periods: sunset to 2400 hours, and 2400 hours to sunrise. We attempted to collect equal amounts of data within both periods during early and late winter. We collected data 2–3 nights per week, from 14 January to 19 March 2002. We summarized data as percent time spent feeding per 30-minute period and then used this mean to estimate the proportion of time spent feeding per night after controlling for seasonal changes in the length of the nocturnal period. We did not record diurnal dive lengths and assumed nocturnal length of dives was equivalent. Water clarity was frequently poor (G. Herring, personal observation), most likely requiring scaup to use tactile foraging during diurnal and nocturnal dives.

Body Condition

We collected scaup at MINWR with a shotgun using a combination of jump and pass shooting to avoid bias associated with collecting decoyed birds (Pace and Afton 1999). In 2002, we collected 73 scaup between 18 and 21 January (16 F, 23 M) and 27 February and 1 March (19 F, 15 M); in 2003, we collected 85 scaup between 27 and 29 January (9 F, 7 M) and 26 and 28 February (39 F, 30 M). We recorded fresh body mass ($\pm$ 1 g) within 1 hour of collecting. We sexed birds as described earlier. We labeled the collected birds, sealed them in double bags, froze them, and later transported them to the laboratory at North Carolina State University.

In the laboratory, we recorded the following morpholog-



* Significant difference at $P \leq 0.05$.

Figure 2. Box plots of seasonal diel behavior patterns of lesser scaup at Merritt Island National Wildlife Refuge, Florida, early (solid box) and late winter (hatched box) 2002. White boxes are females and males, and light grey boxes are combined sexes. We determined significant differences ($P \leq 0.05$) by Wilcoxon tests. We determined combined sexes' diurnal patterns by scan sampling and nocturnal samples by radiotelemetry. Box plots are 25–75% quartiles and bars mark 95–5% intervals. Medians are solid black lines.

ical measurements: culmen length, head, rectrix, tarsus, total length, and wing chord. Afterwards, we plucked carcasses; removed the contents from their esophageal, proventricular, gizzard, and gastrointestinal tract; and reweighed the carcasses with all internal organs included (± 1 g) to estimate corrected body mass (CBM). We obtained a carcass homogenate by continually passing samples through a Hobart meat grinder (Troy, Ohio), using first a 10-mm grinding plate followed by a 3-mm plate. We mixed samples, removed a 200-g subsample, weighed the subsample, and then dried the subsample at 80° C, and reweighed it. We then reground the dry subsample with the use of an industrial grade blender (Waring model 36BL23, Torrington, Connecticut) until all the subsample passed through a 2-mm sieve (Anteau 2002). Finally, we took 2 samples of 10 g from each bird homogenate and extracted lipids with the use of a Goldfisch apparatus for 8 hours with petroleum ether (Dobush et al. 1985). We determined ash content by burning lean samples in a muffle furnace at 600° C for 12 hours. We assumed protein to be ash-free lean mass. We conducted all nutrient reserve assessment work at the Department of Poultry Science's nutritional laboratory at North Carolina State University.

We conducted all research under U.S. Fish and Wildlife Service Research Permit 773137, Florida Fish and Wildlife Conservation Commission Scientific Collecting Permit WXO1671, and North Carolina State University Institutional Animal Care and Use Committee Protocol 01-144-0.

Statistical Analyses

Time budgets.—Diurnal TAB data were expressed as percent time spent per activity. Because data did not meet assumptions of normality and equal variance (Levene's test, Shapiro–Wilks test; JMP 2001) even after attempts to transform data, we used Wilcoxon nonparametric tests for analyses comparing differences between seasons for time spent in feed, rest, locomotion, and preening activities. Nocturnal data by season (percent time spent feeding/night), as well as duration of dives, were also analyzed with Wilcoxon tests for the same reasons.

Body condition.—We used a 2-tier approach to examine the influence of sex, season, and year on each of the response variables (i.e., CBM, protein, lipids, minerals). We began with a full-model, a 3-way analysis of variance (ANOVA) whose terms were year, season, season × year, sex, and remaining interaction terms (JMP 2001). We included an index of body size as a covariate in the model to determine if it significantly accounted for some of the variance in the analysis, possibly influencing main-effect contrasts. The body-size index consisted of the standardized scores of the first principal component (PC1) obtained from a principal-component analysis on 6 morphometric measurements taken from each scaup (Afton and Ankney 1991, Esler et al. 2001). PC1 explained 42% of the overall variation among morphometric measurements; all factor loadings were positive and ranged from 0.31 to 0.54. Analysis-of-variance models yielded significant interactions (see Results). Therefore, to focus on the question of interest and facilitate interpretation of results, we conducted analysis of covariance (ANCOVA) to examine the effects of season on each of the response variables for each sex and year separately. In the models, winter period was the treatment and PC1 the covariate to adjust contrasts between season by size of birds (Afton and Ankney 1991, Esler et al. 2001). All body-condition data met assumptions of normality and homoscedascity (Levene's test, Shapiro–Wilks test; JMP 2001), and all ANCOVA tests met the requirement of parallelism (i.e., $P > 0.40$ for PC1 × winter-period term). All tests were considered significant at $P \leq 0.05$. We report untransformed mean values and SE, except in the case of ANCOVA, where we report the adjusted mean and SE.

Results

Time Budgets

We made 1,587 scans between 28 December 2001 and 20 March 2002 on 69,427 scaup at >50 locations within MINWR. Mean flock size of scanned scaup was 43 ± 1 (range = 6–762). Of all activities, only time spent resting ($T = 2.14$, $P = 0.03$, df = 1) and in locomotion ($T = 20.20$, $P = < 0.001$, df = 1) changed between winter periods (Fig. 2) for male and female scaup. During late winter, the amount of time spent resting increased by 6% or 20 minutes/day, whereas the time spent in locomotion decreased by 33% or 21 minutes/day. Time spent feeding during the day (diurnal period) did not differ by winter period for scaup ($T = -1.82$, $P = 0.07$, df = 1).

Table 1. Analyses of covariance model results for each response variable (corrected body mass, lipid, protein, and mineral) by sex and year. The covariate was the first principal component 1, obtained from 6 morphometric variables measured from lesser scaup collected during early and late winter in east-central Florida during 2002 and 2003.

		CBM[a]		Lipid		Protein		Mineral	
Effect	**df**	***F***	***P***	***F***	***P***	***F***	***P***	***F***	***P***
F									
Winter period by year									
2002 early vs. late	1,32	2.16	0.15	2.26	0.14	0.43	0.52	0.82	0.37
2003 early vs. late	1,43	3.53	0.06	2.73	0.10	0.36	0.55	0.01	0.91
PC1[b] (2003)	1,43	26.20	<0.001	21.00	<0.001		6.91		0.01
M									
Winter period by year									
2002 early vs. late	1,31	0.51	0.48	0.43	0.61	2.64	0.11	1.94	0.17
2003 early vs. late	1,37	10.78	0.002	3.99	0.05	2.72	0.11	4.41	0.04
PC1 (2003)	1,37	7.73		0.008					

[a] Corrected body mass.
[b] Principal component 1.

We sampled nocturnal feeding activities over 98 hours between 14 January and 19 March 2002. We collected activity data on 43 of 60 radiotagged scaup for a mean number of 4.5 ± 1.2 budgets per scaup. Out of a total of 196 bouts, there were 44 (early winter) and 41 (late winter) bouts for males and 47 (early) and 64 (late) for females. Female scaup increased nocturnal foraging from early to late winter period by 76% or 43 minutes/night ($T = -2.06$, $P = 0.003$, df = 1, $n = 110$), whereas males increased it by 478% or 1.9 hours/night ($T = 3.49$, $P < 0.001$, df = 1, $n = 85$) (Fig. 2).

Over the winter, male dives were 13% longer than those of females ($T = 8.41$, $P < 0.001$, df = 1, $n = 2{,}896$). Length of dives increased from early to late winter in males by 25% ($T = 7.68$, $P < 0.001$, df = 985). Males spent 12 ± 0.3 seconds (early winter) and 16 ± 0.3 seconds (late winter) under water per dive. Females spent 13 ± 0.2 seconds under water per dive and did not change with winter period ($T = 1.81$, $P = 0.06$, df = 1, $n = 1{,}911$).

Nutrient Reserves

The comprehensive ANOVA models indicated that CBM and lipid levels varied significantly by sex and year (i.e., interaction, $P \leq 0.01$). Protein levels varied significantly by sex, year, and winter period ($P = 0.02$). There were no significant interaction terms in the ANOVA model for mineral reserves. Mineral levels were higher for males than females ($P = 0.01$) and higher during the late winter period than earlier in the winter ($P = 0.04$). PC1, or body-size index, was not a significant term in any of the models. On the basis of these results, we ran ANCOVA models, by sex and year, to examine patterns of CBM and nutrient levels by winter period (treatment) after adjusting data by body size (covariate).

Female and male body condition (CBM, lipid, protein, mineral) did not change seasonally in 2002 (Tables 1, 2). Between early and late winter in 2003, average CBM increased 77 g for males ($P = 0.002$) and 40 g for females ($P = 0.06$, Tables 1, 2). Males in 2003 also increased mean lipid reserves by 39 g ($P = 0.05$) and ash content by approximately 4 g ($P = 0.04$) by late winter (Tables 1, 2). Protein levels did not differ significantly with winter period for either sex in 2003 (Tables 1, 2). Female lipids and mineral reserves were also similar between winter periods in 2003 (Table 2). Body size still accounted for some of the increase in some nutrient levels in 2003 as suggested by significant covariate terms in some models (Table 1). Corrected body mass increased (parallel, but positive slopes) with body size within each winter period for males and females in 2003. The same was the case for protein and mineral levels for males in 2003.

Discussion

Measures of body condition did not change with winter period for female scaup, although differences in CBM were nearly significant in 2003. Conversely, CBM, lipid and mineral levels increased during late winter for males, but only in 2003, and the increase in reserves was not large. Interannual variability of nutrient levels in waterfowl is not unusual and was observed by Chappell (1982), Miller

Table 2. Winter period means and SE of corrected body mass, lipids, mineral, and protein reserves for female and male lesser scaup collected during early and late winters of 2002 and 2003 in east-central Florida. We obtained means from ANCOVA after adjusting for body-size differences.

	F estimate (g)				M estimate (g)			
Variable	**Early**	**SE**	**Late**	**SE**	**Early**	**SE**	**Late**	**SE**
CBM[a] 2002	635.2	19.2	673.8	17.5	749.3	16.6	731.2	18.7
CBM[a] 2003	632.1	19.6	672.3	8.2	650.0	20.6	727.1	9.8*
Lipid 2002	68.9	7.7	84.9	7.1	120.0	12.5	105.1	14.1
Lipid 2003	63.8	18.1	96.4	7.6	59.6	17.4	98.5	8.3*
Mineral 2002	20.0	1.3	21.6	1.2	22.4	1.5	25.6	1.7
Mineral 2003	20.0	1.3	20.2	0.5	20.2	1.4	23.7	0.7*
Protein 2002	130.7	4.1	134.4	3.7	151.4	4.1	141.4	4.6
Protein 2003	127.4	3.5	125.1	1.5	129.9	4.1	137.5	1.9

[a] Corrected body mass.
* Significant difference at $P \leq 0.05$.

(1986), Thompson and Baldassarre (1990), and Alisauskas (2002).

Overall, positive changes in male and female body and lipid mass were recorded as the winter progressed, although most increases were not significant. These patterns suggested that scaup were able at least to maintain or slightly improve their body condition throughout the winter. Our results were consistent with the findings of Anteau and Afton (2004) in that we found no evidence to suggest that scaup substantially increase nutrient reserves or body mass prior to departing a wintering site. Our findings, however, are in sharp contrast to those reported for wintering male and female ring-necked ducks (*Aythya collaris*) in Florida, where measures of body condition increased more distinctly during winter (Hohman and Weller 1994). Differences in ring-necked duck timing of migration (departing earlier) and reproduction (earlier onset; Bellrose 1980, Hohman and Eberhardt 1998) may be at the core of the differences.

Geographic variation in overwinter body condition of avian species has been previously noted (Pienkowski et al. 1975, Nolan and Ketterson 1983, Thompson and Baldassarre 1990). In this vein, we found that body condition of scaup in Florida was considerably lower than for scaup wintering in Louisiana in the 2000s, but it was more similar to those from the 1980s (Afton et al. 1989, Anteau and Afton 2004). Both male and female scaup in Florida had approximately 40% lower lipid reserves, 25% lower mineral reserves, and 10% lower fresh body mass than scaup from Louisiana in the 2000s. Part of the difference in body mass may be because Anteau and Afton (2004) did not subtract ingesta from body mass. However, in our study ingesta mass was usually 36 g for both sexes and would not account for the total difference between studies.

We believe that interannual variation in body condition recorded at MINWR (this study) and Louisiana (Anteau and Afton 2004) likely result from annual differences in temperature and food abundance. Some of the differences between areas might be accounted by milder temperatures in east-central Florida, where mean daily winter temperature was 7° C warmer relative to Louisiana (National Oceanic and Atmospheric Administration 2004). Such a benign environment may lead to lower metabolic requirements, and hence, differences in body masses and lipid reserves (Kendeigh et al. 1977, Lima 1986). Benign weather conditions may have also contributed to the lack of striking variation in most reserve levels and CBM between winter periods during our study.

From these regional contrasts we surmised that scaup at MINWR were not necessarily at a disadvantage as compared to scaup wintering at selected locations in Louisiana (cf. Afton et al. 1989, Anteau and Afton 2004). Scaup appeared to be able to meet their maintenance energy and nutritional budgets as reflected by high survival rates (93%; Herring and Collazo 2004). Other indications of habitat suitability were the maintenance of small home ranges for both sexes (Herring and Collazo 2005) and the fact that scaup were not required to move elsewhere to secure sufficient forage (see Poulton et al. 2002).

The underlying cause behind the seasonal increase in nocturnal foraging behavior, particularly among males in our study, was not readily apparent. One possibility is that food resources declined seasonally, as reported for other wintering sites (e.g., Poulton et al. 2002). However, males in 2003 were able to increase their CBM, lipid, and mineral reserves, suggesting that food limitation cannot fully account for all patterns of foraging behavior. Moreover, as stated above, the home ranges of scaup were small and scaup were mostly sedentary (Herring and Collazo 2005). We speculate that an alternative possibility is that birds, males in this case, were compensating for time spent in diurnal courtship and agonistic behavior. Previous studies have reported that scaup increase courtship behavior in late winter (Weller 1965, Adair 1990). It is possible, then, that increased foraging activity at night helped them meet their daily nutritional requirements.

Maximization of nutrient reserves likely occurs when scaup arrive on the breeding grounds, as observed by Anteau and Afton (2004) in the Mississippi Flyway. We agree with Anteau and Afton (2004) that the constraints imposed by the relatively small body size and high wing-loading of scaup, coupled with adaptations for diving (Hendenstrom and Alerstam 1992, Lovvorn and Jones 1994), probably prevent scaup from carrying large amounts of nutrient reserves needed for reproduction during the early period of migration. Although recent experimental work on cockatiels (*Nyphicus hollandicus*) and red knots (*Calidris canutus*) in wind tunnels suggested that carrying large fuel loads during flights is not as energetically demanding as previously believed (Kvist et al. 2001, Hambley et al. 2004), these species are probably not the best biological models for waterfowl. Diving ducks have relatively higher wing loading (Lovvorn and Jones 1994), so their ability to efficiently carry large fuel loads long distances is likely impaired. Additionally, because they have a rather protracted migration (Bellrose 1980, Austin et al. 1998), they may not carry reserves beyond what is required to make each leg of their migration.

Merritt Island National Wildlife Refuge and adjacent estuaries provide suitable habitat for wintering scaup (Herring and Collazo 2004, 2005). Use of impounded wetlands at MINWR complements available estuarine systems and increases the likelihood of continued habitat availability on the wintering grounds (Herring and Collazo 2005). Although maximizing nutrient reserves on the wintering grounds does not appear to be a critical requirement for scaup beyond basic maintenance and perhaps to prepare for short migratory flights, these areas are an integral part of their yearly cycle complementing the costs of spring migration (Hohman and Weller 1994).

Degradation of wintering habitat could result in lowered adult female survival (Afton and Ankney 1991, Pace and Afton 1999), which may have a far greater impact on populations than poor body condition at the start of the

breeding season. Apparent high survival at MINWR reflects the importance of high-quality wintering habitats for scaup. Prominent wintering areas, such as Florida and Louisiana, are susceptible to both natural and human-induced habitat changes, and overwinter survival and physiological condition of lesser scaup in these areas should be monitored. Future research should address understanding female survival rates during spring migration and at critical staging areas (e.g., lower Great Lakes) to provide new insight into the ramifications of scaup leaving wintering habitats such as MINWR with lower body condition than at other wintering sites in other flyways.

Management Implications

The IRL is a major wintering site for scaup in North America. Its importance during this portion of the scaup's annual cycle is a compelling reason advocating for maintaining the ecological integrity of the system. Wintering scaup make extensive use of the John F. Kennedy Space Center, specifically the interior portion of MINWR. We encourage managers to continue monitoring wintering scaup to develop a better understanding of their habitat use, foraging behavior, and physiological condition throughout the entire IRL system. Our results depicted a best-case scenario for winter foraging and physiological condition of scaup in the IRL. Increased stressors on the IRL (Sime 2006) could result in changes in the abundance of prey resources for wintering scaup, and may impair their physiological condition, with concomitant decreases in overwinter survival.

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