THE EFFECTS OF SEX, AGE, TIME, HABITAT, AND MANAGEMENT ON BODY CONDITION OF WINTERING DUCK POPULATIONS ON THE TEXAS GULF COAST

A Thesis

by

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ABSTRACT

Waterfowl are of significant cultural, economic, and conservation importance along the Texas Gulf coast. Millions of ducks utilize this region as they move along the Central Flyway each winter. Understanding of body condition patterns for these birds and their relationships with habitat management techniques has important implications for recruitment, breeding success, and population regulation. This is especially true for females, which are typically the limiting sex in ducks, and juveniles, which are critical for recruitment. In this study, we collaborated with hunters over two years to salvage over 1800 of the most popularly hunted dabbling duck species along the Texas Gulf coast and interviewed managers to document habitat type and management techniques. Mass, linear measures, and fat scores were collected along with sex and age of each individual. We found that females were typically in better body condition than males, especially at the beginning of the hunting season. Body condition differed between immatures and adults, although the direction of that difference was year-dependent. Ducks generally declined in body condition across the winter hunting season and body condition was typically higher in the year 2017-18 than 2018-19. Body condition differences by habitat type and in relation to management intensity were species-dependent, but these factors were important predictors of body condition for the majority of species. Our results suggest that wintering female and immature dabbling ducks are doing well in comparison to their counterparts (i.e. males and adults), but that sex- and age-specific differences in relation to yearly precipitation patterns, habitat, and management intensity suggest differential responses to resource availability. Future research should explore sex- and age-specific foraging patterns and habitat usage on the wintering grounds.

DEDICATION

This thesis is dedicated to the many people that have supported me throughout my educational journey and all the birds who have contributed to my learning without whom this thesis would not exist.

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Contributors

This work was supervised by a thesis committee consisting of Dr. Jacquelyn K. Grace (advisor), Dr. Perry S. Barboza of the Wildlife and Fisheries Sciences Department, Dr. Russell A. Feagin of the Ecosystem Science and Management Department, and Dr. Michael T. Merendino of Ducks Unlimited.

All work for this thesis was completed by the student. Undergraduate assistants Anissa Magallan, J.J. Boles, Keith Andringa, Collin Chapman, Mariel Ortega, Maya Rasmussen and graduate assistant Viridiana Martinez assisted with a large portion of the field and lab work for this project.

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1. INTRODUCTION

For most of the 20th century, the majority of research on waterfowl biology has focused on breeding birds. This trend was sustained by the belief that factors that control population sizes and annual recruitment occur during the breeding period (Weller and Batt 1988).While breeding habitat availability, nesting and fledging success are inarguably critical in controlling waterfowl populations, factors on the wintering grounds are also vital for population regulation. In dabbling ducks, winter activities include replenishing reserves following fall migration, courtship and pair formation, and preparation for spring migration and the upcoming breeding season (e.g., Tamisier et al. 1995). Non-breeding (e.g., wintering) conditions correlate with duck recruitment rates and breeding success (Raveling and Heitmeyer 1989, Guillemain et al. 2008, reviewed in Davis et al. 2014). Even for small-bodied ducks such as teal, which are expected to obtain most energetic resources for reproduction on the breeding grounds, winter body condition is correlated with later reproductive success, probably due to carry-over effects (Guillemain et al. 2008). Moreover, body condition at the start of the winter season can control body condition at the end of the season, which is critical for migratory success (Tamisier et al. 1995). Thus, wintering body condition patterns and their relationships with habitat management techniques have important implications for recruitment, breeding success, and population regulation in dabbling ducks (Tamisier et al. 1995). This is especially true for females, which are typically the limiting sex in ducks (Bellrose et al. 1961), and juveniles, which are critical for recruitment.

Body condition is typically measured in nutrient stores (Brown 1996), such as body mass, fat, and protein, but is often poorly defined in the literature (Brown 1996, Clancey and Byers 2014). These condition measures are expected to reflect present and future fitness (Ringelman and Szymczak 1985; Owen and Cook 1977). Body condition in migratory ducks will typically increase during the fall arrival on the wintering grounds, then decrease towards the end of winter when energy is expended to find mates, deal with poor weather, and molt (e.g., Tamisier et al. 1995). This decline may also be due to the constant availability of resources reducing the need to store energy as costly extra mass (Haukos et al. 2001). Mass will increase, again, prior to spring migration (typically Feb-April) (Haukos et al. 2001). However, these trends are generalized and rarely broken down by species, sex, and age group.

Our understanding of wintering habitat selection and its influence on waterfowl health and body condition is limited by the high seasonal mobility of these species. Wintering waterfowl typically have high winter site fidelity, which generally exceeds that of the breeding grounds (Hestbeck 1993), however, fidelity varies greatly with species and study area size (Robertson and Cooke 1999). For example, blue-winged teal (*Spaula discors*) and northern shovelers (*Spatula clypeata*) have broad wetland habitat preferences, making habitat selection and mobility difficult to track (Baldassarre 2015). Green-winged teal (*Anas crecca*) have low between-year winter site fidelity and overlapping wintering and migration sites (Baldassarre 2015), while little information is known about winter movements and habitat selection in gadwall (*Mareca strepera*) (Baldassarre 2015). Finally, northern pintails (*Anas acuta*) have very high winter site fidelity with minimal movement, however the movements they do make are complex (Baldassarre 2015). This variation in winter movements both between and among species makes it difficult to establish causal relationships between winter habitat and fitness-related metrics. However, correlational studies can increase our understanding of potential relationships, especially for key demographic groups such as females and immatures.

Texas is heavily used by waterfowl during the fall migratory period (White and James 1978, Hestbeck 1993). In total, the Texas Gulf Coast hosts an estimated 1.9 million ducks per year (Texas Parks and Wildlife 2011) and is the top waterfowl harvest and wintering location in the Central Flyway (Pintail Action Group 2015; Texas Parks and Wildlife 2011). Following a steep decline in population size in the 1980's, population estimates for most ducks have met or exceeded population goals established by the North American Waterfowl Management Plan (NAWMP), including gadwall, green-winged teal, blue-winged teal, and northern shoveler. However, northern pintail populations remain below the NAWMP goals (Environment Canada and U.S. Department of the Interior 2012), although numbers have started to rebound (Bartzen and Dufour 2017). According to the USFWS, in 2018 northern pintail populations were still 40% below the long term average and 18% below the 2017 estimate, although there were about 1000 more breeding ponds in 2017 (U.S. Fish and Wildlife Service 2018). Research over the past few decades has suggested that the northern pintail, is not increasing in body condition throughout the winter as expected (Mora et al. 1987, Moon and Haukos 2009) and that management of their winter habitat is needed (Raveling and Heitmeyer 1989). Texas is a key wintering ground for this species, hosting up to 78% of northern pintails in the Central Flyway (Pintail Action Group 2015).

Although much work has gone into managing and conserving land for waterfowl populations, the biological effectiveness of these techniques is rarely evaluated (Fleskes et al. 2016), and studies generally focus on quantity rather than quality of ducks (Elmberg et al. 2006). Waterfowl habitat on the Texas Gulf Coast varies from flooded crop fields to permanent marshes. Although some studies in this region suggest that natural wetlands support higher duck carrying capacities than agricultural wetlands (Rollo and Bolen 1969), others have found that anthropogenic wetlands provide important habitat for species such as the northern shoveler (Guillemain et al. 2000). Recent studies have predicted that duck population sizes are positively influenced by increasing habitat quality factors such as the level of connectivity (Mattsson et al. 2012) or the availability of food resources (Barboza and Jorde 2018).

Here, I investigate sex- and age-specific patterns in body condition and their relationships with wintering habitat and management techniques for dabbling ducks on the Texas Gulf Coast. I target green-winged teal, northern pintail, blue-winged teal, northern shoveler, and gadwall due to their abundance and hunting popularity in the study area, and because they share similar feeding behaviors. Although these five species feed in similar ways and coexist in the same locations, they represent a diversity of vegetation and water depth foraging preferences (White and James 1978). Closely related species such as the northern shoveler and blue-winged teal have very different foraging strategies both in time spent foraging, location of foraging, specialization, and forage content (Dubowy 1985). Specifically, the objectives of my study are to examine sex- and age-specific effects of time across the winter season (Nov-Jan), year (2017-18 & 2018-19), habitat type, and habitat management on body condition for five species of dabbling ducks. I predicted that:

1.) female ducks would be in lower body condition than male ducks, especially in early winter.
2.) immature ducks would be in lower body condition than adult ducks throughout winter.
3.) all ducks would decline in body condition from November to January, consistent with previous literature.
4.) habitat types and management tactics would be related to duck body condition, and those effects may be sex- and age-specific.

Species morphometric and mass norms for these species by age and sex are largely unknown, although many studies acknowledge that duck body condition and morphology are influenced by these variables (Dubowy 1985, Ringelman and Szymczak 1985, Heitmeyer 1995, Haukos et al. 2001, Elmberg et al. 2006, Deveries et al. 2008, Moon and Haukos 2009, Fleskes et al. 2016). Moreover, sex and age differences in size and mass are extremely important to density dependent processes and population dynamics (Elmberg et al. 2006). Thus, in addition to the above hypotheses, I also fill this knowledge gap by analyzing morphometric measurements of males, females, immatures, and adults of several species, which will provide baseline values upon which to compare future studies.

2. MATERIALS AND METHODS

All research reported here was permitted under U.S. Fish and Wildlife Service Permit No. MB66499C-0 and Texas Parks and Wildlife Department Scientific Research Permit No. SPR-0317-079 to J. Grace.

2.1 Field Methods

Data for this study was collected using hunter donated specimens. I salvaged the following species: green-winged teal, northern pintail, blue-winged teal, northern shoveler, and gadwall. Other species originally considered were eliminated from the study due to low harvest frequency in the study area.

Landowner permission was obtained to collect salvaged specimens from three private hunting clubs (Run-and-Gun Adventures, Thunderbird Hunting Club, Pierce Ranch) and one public Wildlife Management Area (Mad Island WMA) on the central Texas Gulf coast (Figure 1). These sites included marsh, pond, and moist soil habitat (Table 1). Samples were collected in the winter hunting seasons of year 1 (Dec 2017 - Jan 2018) and year 2 (Nov 2018 - Jan 2019), although collections were not made at every site on every date (Table 2). Specimens were collected at each site between 8:00 am and 3:00 pm.

Table 1: Breakdown of ducks sampled by habitat type, sex, and age. Note these numbers only reflect ducks for which habitat information was obtained.

Habitat Type	**Total Ducks**	**Males**	**Females**	**Adults**	**Immatures**	**Number of subsites**
Marsh	133	50%	50%	61%	39%	11
Moist Soil	387	58%	42%	72%	28%	26
Pond	193	54%	46%	68%	32%	3

Table 2: Ducks were salvaged from four major sites on 11 days across two years, “X” indicates a site was sampled on that date, “--” indicates a site was not sampled that date.

Collection Date	**Collection Site**			
	Run-and-Gun Adventures	**Thunderbird Hunting Club**	**Pierce Ranch**	**Mad Island WMA**
12/9/17	X	X	--	X
12/16/17	--	X	--	X
1/13/18	X	X	--	X
1/20/18	X	X	--	X
1/27/18	X	X	--	X
11/10/18	X	--	--	X
11/17/18	X	--	--	X
12/8/18	X	--	X	X
12/15/18	X	--	--	X
1/12/19	X	--	X	X
1/19/19	X	--	X	X

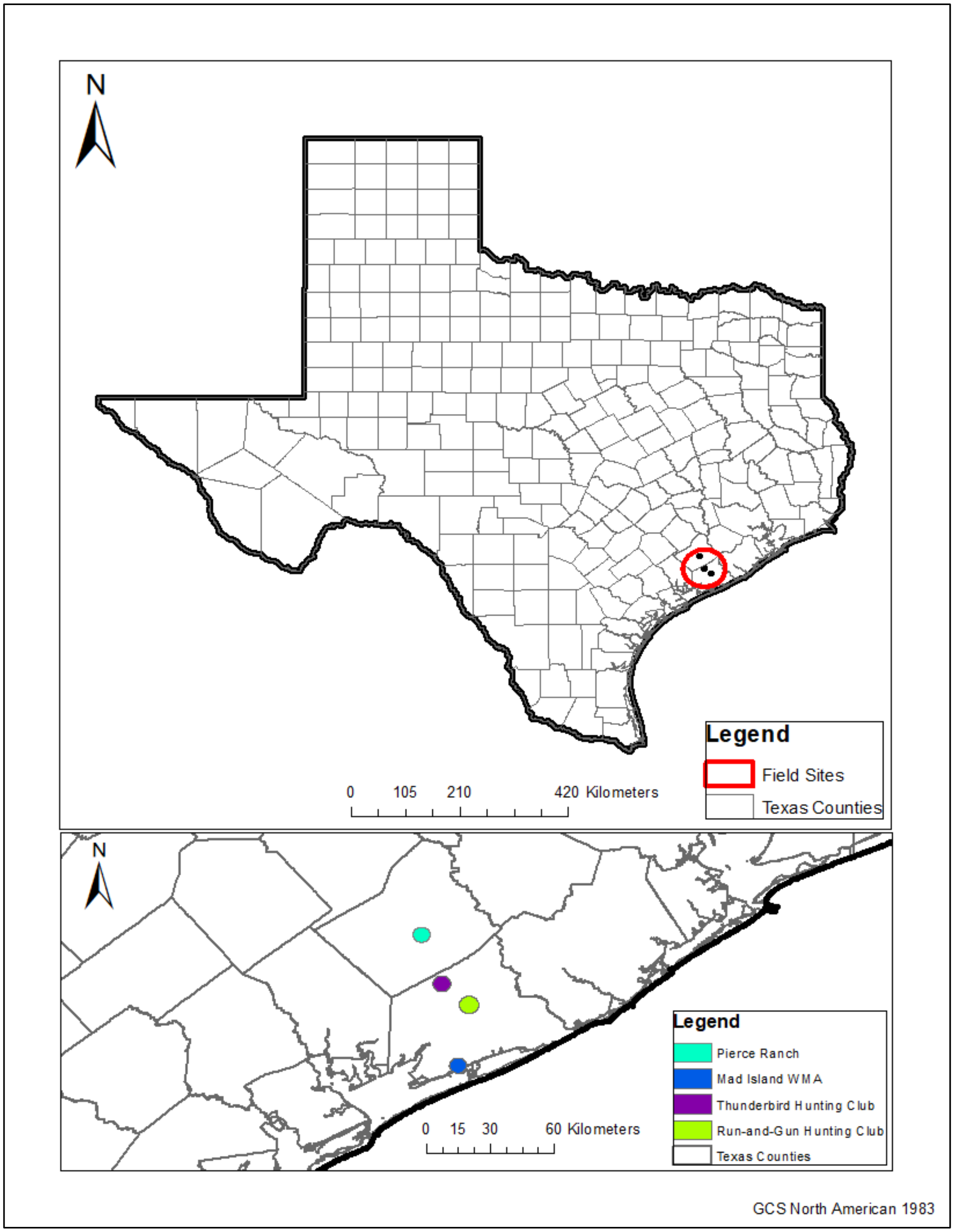

Figure 1: All collection sites were in the central Texas Gulf Coast region in Wharton and Matagorda Counties (based on maps provided by Texas Department of Transportation and Texas Natural Resources Information System).

At each collection event, every hunter completed a TPWD Wildlife Resource Document (Appendix A) and identified the subsite at which ducks were shot. Each duck was identified to species, weighed to the nearest gram, and clearly labeled with a unique identifier. We then removed the breast meat and one wing (required for legal transport) and returned this to the hunters. The remainder of the body was individually bagged in a plastic freezer bag and transported to Texas A&M University for storage between -20 and -80 °C.

2.2 Laboratory Methods

In the laboratory, specimens were thawed and each individual was re-identified to species, sexed, and aged (i.e., immature, adult) using the USFWS Wing Guide (Carney 1992), head and body plumage, internal anatomy (i.e., presence of ovary or testes for sexing), and tertial/tail molts (aging). Multiple methods were used to reduce misidentification. Next, each bird was measured thrice for tarsus length and bill length (from nostril to tip) to the nearest millimeter using a caliper, and the mean of these three measures was recorded. Flattened wing cord was measured to the nearest millimeter using a wing bar. Fat around the gizzard was also scored as present or absent (Appendix B). For all identification and measurements, ducks were assigned an "NA" value if they were too damaged to be confidently identified/measured. All measurements and identification were conducted by A. Guggenheimer to ensure consistency of data collection.

2.3 Habitat and Land Management Methods

To classify habitat types and land management techniques for the subsite at which each specimen was collected, I conducted structured interviews with three of the four land managers (Appendix C). If possible, each subsite listed on the TPWD Wildlife Resource Documents (Appendix A) was described by managers as one of the following habitat types: seasonal flooded cropland, moist soil (e.g., flooded pastures), semi-permanent (marsh), permanent (pond), forested wetland (green-tree), or other. Specific management techniques used at each subsite were identified by land managers as used or not, during both waterfowl season (Nov-Jan) and during off-waterfowl season (Feb-Oct), these were: water management, mechanical management (i.e. plowing/disking), and invasive species management (i.e., planting native plant species, removing invasive plant species, removing invasive animal species). Each subsite was scored within these categories by dividing the number of management techniques performed by the number of possible management techniques for that category. For example, a subsite with water control during waterfowl season, but not off-waterfowl season would get a water management score of 0.5. Management category scores were highly correlated and thus, could not be analyzed separately. Instead, the scores from each of these categories were summed to give an overall management intensity score out of 3. Scores were then associated with individual specimens. Additional survey information was not analyzed due to low variability in responses.

2.4 Statistical Methods

2.4.1 Data Handling

To reduce data entry mistakes two researchers independently translated paper copies of field and laboratory data into Microsoft Excel. These were compared to correct any errors. All field and lab data were merged for each specimen, and all further statistics were completed in R statistical software (R Core Team 2017).

2.4.2. Calculation of Scaled Mass Index

Body condition can be defined in several different ways (Clancey and Byers 2014). Here, I used a combination of linear morphometric measurements, mass, and fat scores. I measured multiple morphometric values as no linear index is definitely better than another when estimating body condition (Labocha and Hayes 2012). I used scaled mass index (SMI) as a proxy for body condition (Peig and Green 2009), because waterfowl body condition is best estimated by condition indicators that scale body mass for size (Brown 1996) rather than just body mass alone (Schamber et al. 2009). SMI equals $M_i(L_0/L_i)^b$, where M_i is individual mass, L_0 is the mean length of the linear measure that most highly correlates with mass, L_i is the individual length of this linear measure, and b is the slope of an Standardize Major Axis (SMA) regression of the natural log of mass on the natural log of each linear measure. SMI values were calculated separately for each species of interest. No significant interactions between linear measurements and sex or age were found for any of the five focal species ($p > 0.05$) as determined by an ANOVA of mass and each linear measure for each species, so a single scaling component was calculated for each species. For all species wing cord had the strongest relationship with mass ($r^2 > 0.2$ for all species); thus the slope of this regression line was used as the scaling component.

SMI values were used in place of mass and linear measures in further body condition analyses. Birds with gizzard fat present had higher SMI scores than those without, suggesting that SMI is related to nutrient stores (blue-winged teal: $t(159)=4.6$, $p < 0.001$; green-winged teal: $t(220)=7.8$, $p<0.001$; northern pintail: $t(27)=3.9$, $p=0.002$; gadwall $t(48)=4.4$, $p<0.001$; northern shoveler: $t(44)=2.1$, $p<0.001$). Fat score, however was not found to be significantly affected by any of our predictor variables, and thus not discussed, below (Appendix B). Because SMI is not frequently used in waterfowl studies, we also compared our results to those for which body condition was calculated as the residuals of an ordinary least squares (OLS) regression of body mass on a principle component analysis (PCA) score of tarsus, bill, and wing length. Results for these two body condition measures were similar (Appendix D), thus we only report results for SMI scores, here.

2.4.3. Effects of Date, Sex, Year, and Age Class on Body Condition

For each species the effects of collection day and year, sex, age class, and two-way interactions on SMI were evaluated using a global model: *SMI~ Sex*Age + Sex*Day + Sex*Year + Age*Day + Age*Year + Day*Year*. Linear models (LM) were performed for each species then Q-q plots of residuals for each LM were examined for outliers, and these were removed for each species (3 for blue-winged teal, green-winged teal, northern pintail, and gadwall, and 4 for northern shoveler). Linear models were run twice, once with all the data and once with a data subset that excluded periods of the hunting season that were not represented in both years. Year one lacked November sampling, which was conducted in year two, and year two did not continue as far into January as year one (Table 2). There were no differences in the direction of important effects between this sub-set data set and the full data set (Appendix E), thus we only report results using the full data set, below. Top models were determined using a multimodal inference framework with Akaike's Information Criterion correction for small sample size (AICc) via the package MuMIn in R (Barton 2018). Only models within $\Delta 2$ AICc of the top model were considered to be within the top model set (Appendix F). Within this set, the top model was determined to be the model with the smallest degrees of freedom. Thus, our model selection was highly conservative. In one case there were two models that met these criteria; we chose the model with the lowest AICc of the two as the top model (Table 3).

Table 3: Top models for the effects of demographics on SMI for each species.

Species	Model	df	logLik	AICc	delta
Blue-winged teal	Day + Sex + Year	5	-2116.588	4243.300	0.870
Green-winged teal	Day + Sex * Year	6	-1940.281	3892.800	1.420
Northern shoveler	Day * Sex	5	-918.350	1847.100	1.100
Northern pintail	Day + Age * Year	6	-536.905	1086.800	0.000
Gadwall	Sex + Age * Year	6	-920.273	1853.100	0.000

2.4.4. The Effects of Habitat and Management on Body Condition

Preliminary analysis suggested that main hunting site (Thunderbird Hunting Club, Run-and-Gun Hunting Club, Pierce Ranch, and Mad Island WMA) was not an important predictor of SMI (Appendix G), and thus was not included in subsequent analyses.

Only moist soil, marsh, and pond habitat had large enough sample sizes for analysis, thus ducks harvested from other habitats were removed from the dataset for this analysis. For each species the significant effects of previous models (i.e. collection day and year, sex, age class, and two-way interactions), habitat type, management score, and relevant two-way interactions on SMI were evaluated using a global model. For example, the blue-winged teal global model was: *SMI~ Management*Age + Management*Sex + Habitat*Age + Habitat*Sex + Day + Year*. As above, models were evaluated using Akaike's Information Criterion correction for small sample size (AICc) and models within Δ2 AICc of the top model were considered to be within the top model set (Appendix H). The model with the lowest degrees of freedom within this set was the top model (Table 4).

Table 4: Top models used to evaluate effects of habitat and management on SMI for each species. Green-winged teal was the only species for which the top model did not include an effect of habitat and/or management. “df” is degrees of freedom, “logLik” is log likelihood, and delta indicates the difference in AICc value between the model in question and the model with the lowest AICc.

Species	Model	df	logLik	AICc	delta
Blue-winged teal	Habitat+Management+Sex+Year	7	-1151.465	2317.400	0.590
Green-winged teal	Sex*Year	5	-1154.857	2320.000	1.330
Northern shoveler	Day*Sex+Age*Management	8	-534.195	1085.900	1.680
Northern pintail	Management	3	-204.120	415.000	1.860
Gadwall	Habitat+Management+Sex+Year	7	-575.709	1166.600	0.210

3. RESULTS

3.1 Sample Sizes

From 2017 to 2019 a total of 1804 specimens were salvaged in the field and 1747 were analyzed in the lab (see Appendix I for descriptive statistics). We calculated SMI for 434 blue-winged teal, 393 green-winged teal, 168 gadwall, 179 northern shoveler, and 97 northern pintail. Habitat data was collected for 240 blue-winged teal, 234 green-winged teal, 106 gadwall, 108 northern shoveler, and 36 northern pintail. Samples were obtained from over 11 marshes, 3 ponds, and 26 moist soil subsites within the four larger sites. Descriptive statistics of body measurements and whole mass for each species by age and sex are reported in (Appendix I).

3.2 Sex Differences in Body Condition

Sex had a significant effect on SMI for blue-winged teal ($p<0.001$), green-winged teal ($p<0.001$), northern shoveler ($p=0.001$), and gadwall ($p<0.001$, Table 5). For all these species females had a higher SMI than males (Figure 2). For green-winged teal, the effect of sex on SMI was moderated by year ($p= 0.036$, Table 5), such that the difference in SMI by sex in 2018-19 was less than in 2017-18 (Figure 3).

Table 5: Effects of sex (and two-way interactions with sex) on scaled mass index. A ":" indicates an interaction and "*" indicates a significant effect. "Year" indicates winter 2017/18 (year 1) or winter 2018/19 (year 2). The non-reference category can be found in parenthesis.

Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Sex (male)	-20.273	3.203	-6.328	<0.001 *
Green-winged teal	Sex (male)	-23.889	5.239	-4.559	<0.001 *
Green-winged teal	Sex (male):Year	15.102	7.169	2.107	0.036 *
Northern shoveler	Sex (male)	-61.771	18.470	-3.344	0.001 *
Northern shoveler	Sex (male):Day	0.518	0.296	1.747	0.082
Gadwall	Sex (male)	-41.680	10.230	-4.076	<0.001 *

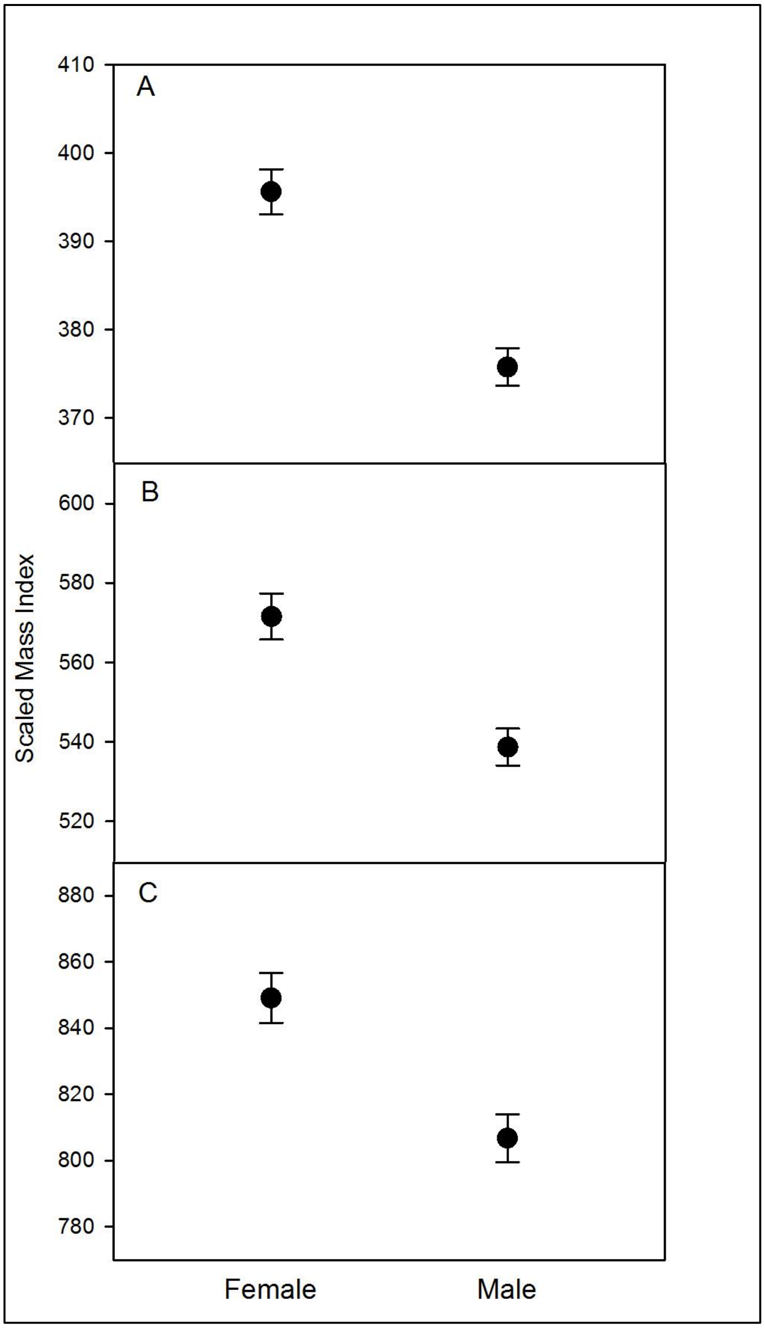

Figure 2: The effect of sex on scaled mass index (SMI) for blue-winged teal (A), northern shoveler (B), and gadwall (C). Females have higher SMI than males for all species. Note different y-axis scales. Dots represent means and bars represent standard error.

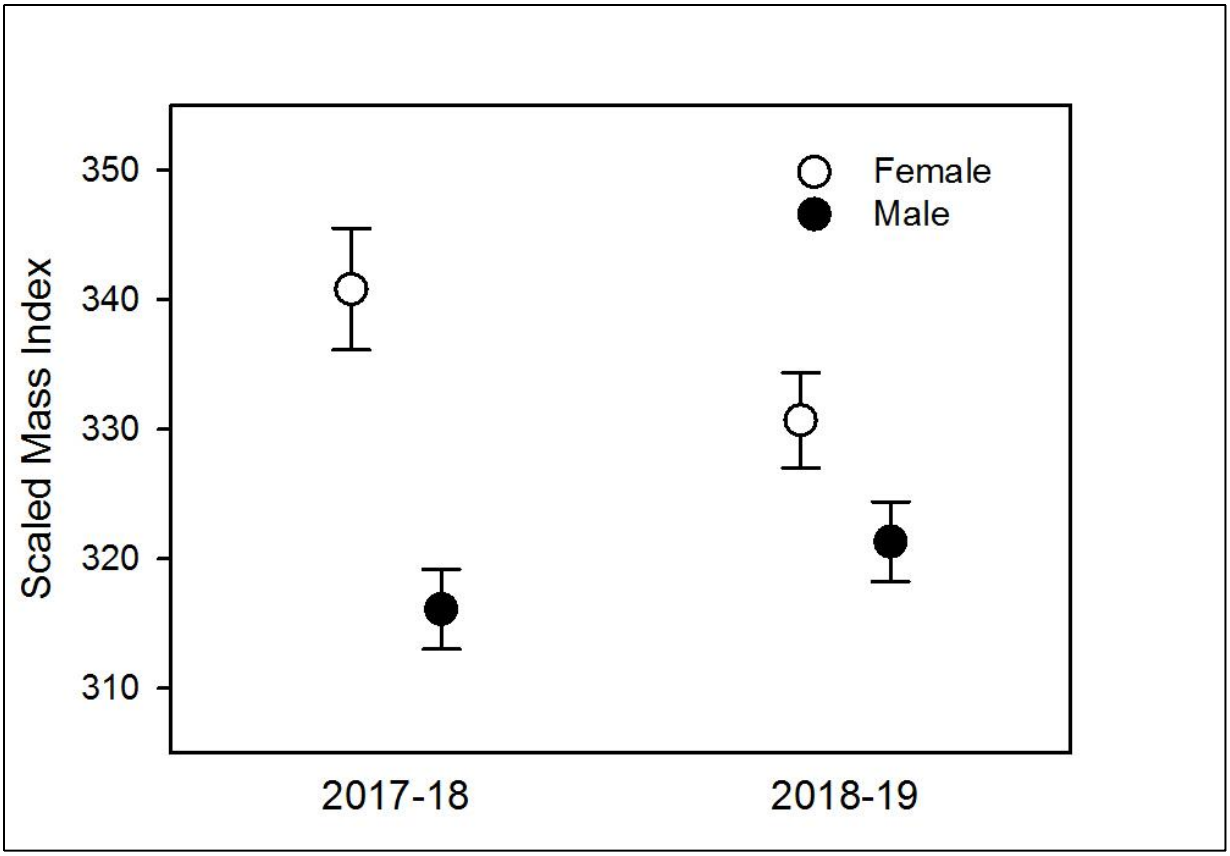

Figure 3: The effect of sex and year on scaled mass index for green-winged teal. Females have higher body condition than males for both years, but the effect is less in 2018-19. Females also have higher body condition in 2017-18 than 2018-19, while there is no difference between years for males. Dots represent means and bars represent standard error.

3.3 Collection Day and Body Condition

Day of collection significantly affected SMI for blue-winged teal (p= 0.011), green-winged teal (p= 0.011), northern shoveler (p=0.001), and northern pintail (p<0.001) (Table 6). For all of these species, SMI decreased across time (Figure 4). There were no significant interactions between collection day and age or sex for any species, indicating a consistent effect of day for all age and sex classes.

Table 6: Effects of collection day (1=November 1, 92=January 31) and two-way interactions with day on scaled mass index. A"*" indicates a significant effect. The non-reference category can be found in parenthesis.

Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Day	-0.157	0.061	-2.560	0.011 *
Green-winged teal	Day	-0.196	0.077	-2.543	0.011 *
Northern shoveler	Day	-0.775	0.219	-3.544	0.001 *
Northern pintail	Day	-1.539	0.412	-3.733	<0.001 *

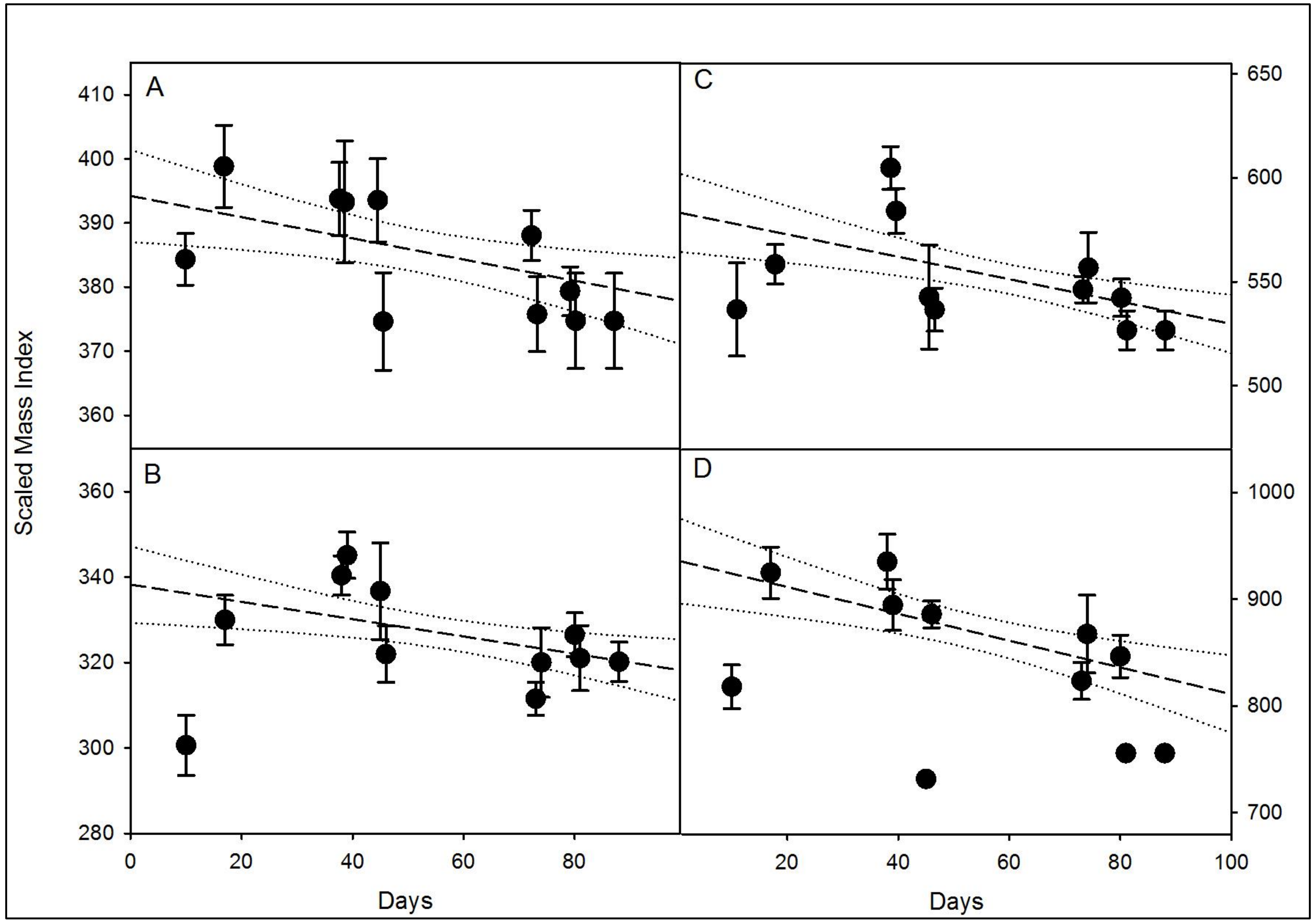

Figure 4: Effect of collection day (Days, 1=Nov to 92=Jan 31) on scaled mass index (SMI) for blue-winged teal (A), green-wing teal (B), northern shoveler (C), and northern pintail (D). Dots represent means, bars represent standard error, dashed lines are regression lines, and dotted lines are confidence intervals of the regression. Note different y-axis scales.

3.4 Age Differences in Body Condition

There was an effect of age on SMI for northern pintail and gadwall, but that effect was moderated by year (age x year: p=0.001 and p=0.011, respectively, Table 7) in a species-dependent manner. Adult pintail had lower SMI than immatures in 2017-18 (Figure 5a), while immature gadwall had lower SMI than adults in 2018-19 (Figure 5b). These results appear to be primarily driven by very high SMI values for immature pintail in the first year, and adult gadwall in the second year (Figure 5). There were no other age effects for any species.

Table 7: Effects of age and year (winters 2017-18 and 2018-19) on scaled mass index. Only significant results and trends are shown. A "*" indicates a significant effect. The non-reference category can be found in parenthesis.

Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Year (2018-19)	10.345	3.808	2.717	0.007 *
Green-winged teal	Year (2018-19)	-13.759	5.400	-2.548	0.011 *
Green-winged teal	Sex (male):Year	15.102	7.169	2.107	0.036 *
Northern pintail	Year (2018-19)	-20.832	18.438	-1.130	0.262
Northern pintail	Age (immature)	42.7882	27.873	1.535	0.128
Northern pintail	Age (immature):Year	-126.726	38.008	-3.334	0.001 *
Gadwall	Year (2018-19)	-60.510	17.560	-3.446	<0.001 *
Gadwall	Age (immature)	-59.980	23.020	-2.605	0.010 *
Gadwall	Age (immature):Year	65.670	25.650	2.561	0.011 *

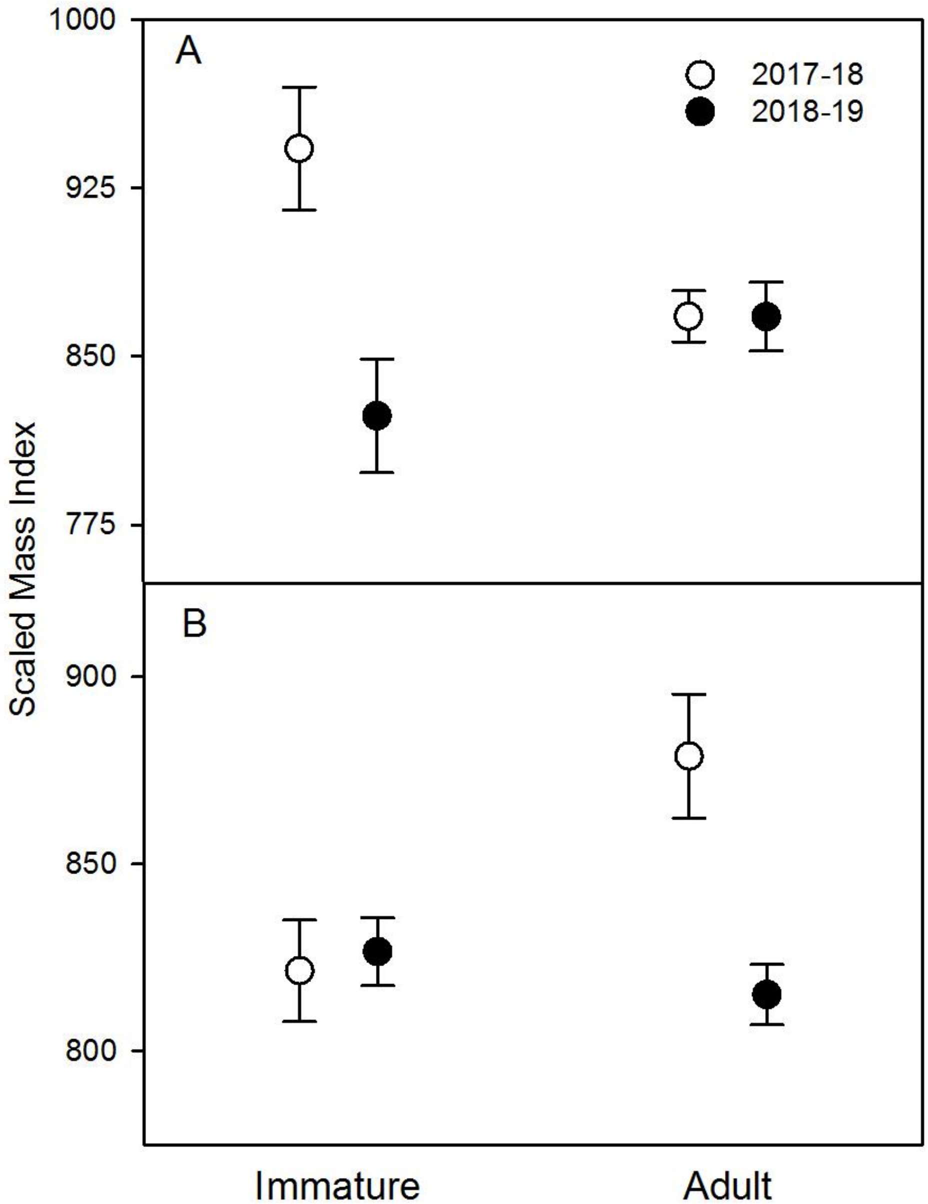

Figure 5: Effect of year on immature and adult scaled mass index (SMI) for northern pintail (A) and gadwall (B). Note different y-axis scales. Dots represent means and bars represent standard error.

3.5 Habitat and Land Management Differences in Body Condition

Habitat type and/or management intensity had a significant effect on body condition for blue-winged teal, northern shoveler, and gadwall. Management intensity was also in the top model predicting SMI for northern pintail, but the p-value in this case was 0.06, and thus not below our probability cut-off. Blue-winged teal had significantly lower SMI in moist soil ($p<0.001$) habitat when compared to marsh habitat (Table 8, Figure 6A), while gadwall had significantly higher SMI in pond ($p<0.001$) and moist soil ($p=0.001$) habitat compared to marsh habitat (Table 8, Figure 6B). SMI was also significantly lower in pond habitat for blue-winged teal ($p=0.005$), however the typically high management scores of this habitat type ameliorated that effect (Figure 6A). Management intensity was positively associated with SMI for blue-winged teal ($p<0.001$, Figure 7A), but negatively associated with SMI for gadwall ($p=0.001$, Table 8, Figure 7B). The effect of management was moderated by age for northern shoveler (age x management: $p=0.030$), such that management had a negative association with SMI for immatures (Figure 8A) with no significant effect in adults ($p=0.229$, Table 8, Figure 8B). There were no other interactions between sex/age and management/habitat intensity for any species, indicating consistent effects across all age and sex classes

Table 8: Effects of habitat (marsh, pond, moist soil), management intensity score, and relevant interactions on scaled mass index. A ":" indicates an interaction, a "*" indicates a significant effect, and "." indicates a strong effect. The non-reference category can be found in parenthesis.

Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Habitat (pond)	-37.493	13.356	-2.807	0.005 *
Blue-winged teal	Habitat (moist soil)	-57.347	15.222	-3.767	<0.001 *
Gadwall	Habitat (pond)	155.610	44.030	3.534	<0.001 *
Gadwall	Habitat (moist soil)	160.480	48.51	3.309	0.001 *
Blue-winged teal	Management Score	26.382	7.135	3.698	<0.001 *
Northern shoveler	Management Score	7.918	6.542	1.210	0.229
Northern pintail	Management Score	25.430	13.110	1.940	0.061 .
Gadwall	Management Score	-76.710	22.750	-3.373	0.001 *
Northern shoveler	Age (immature): Management Score	-21.336	9.676	-2.205	0.030 *

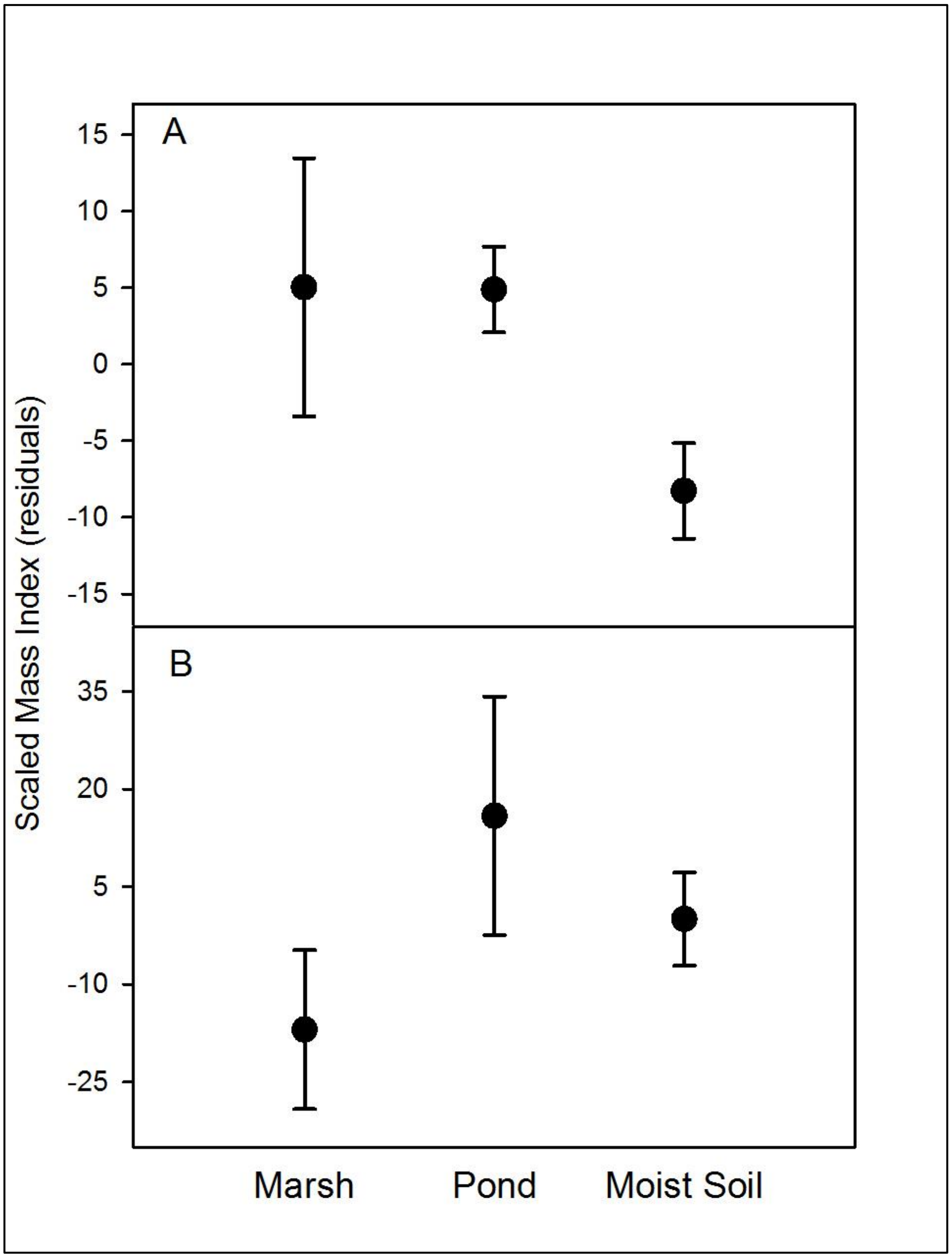

Figure 6: The effect of marsh, pond, and moist soil habitat types on scaled mass index (SMI) for blue-winged teal (A) and gadwall (B). Dots represent means, bars represent standard error. The y-axis represents the residuals of a regression of management, sex, and year on SMI for blue-winged teal as well as gadwall, which were the other variables in the top model predicting SMI.

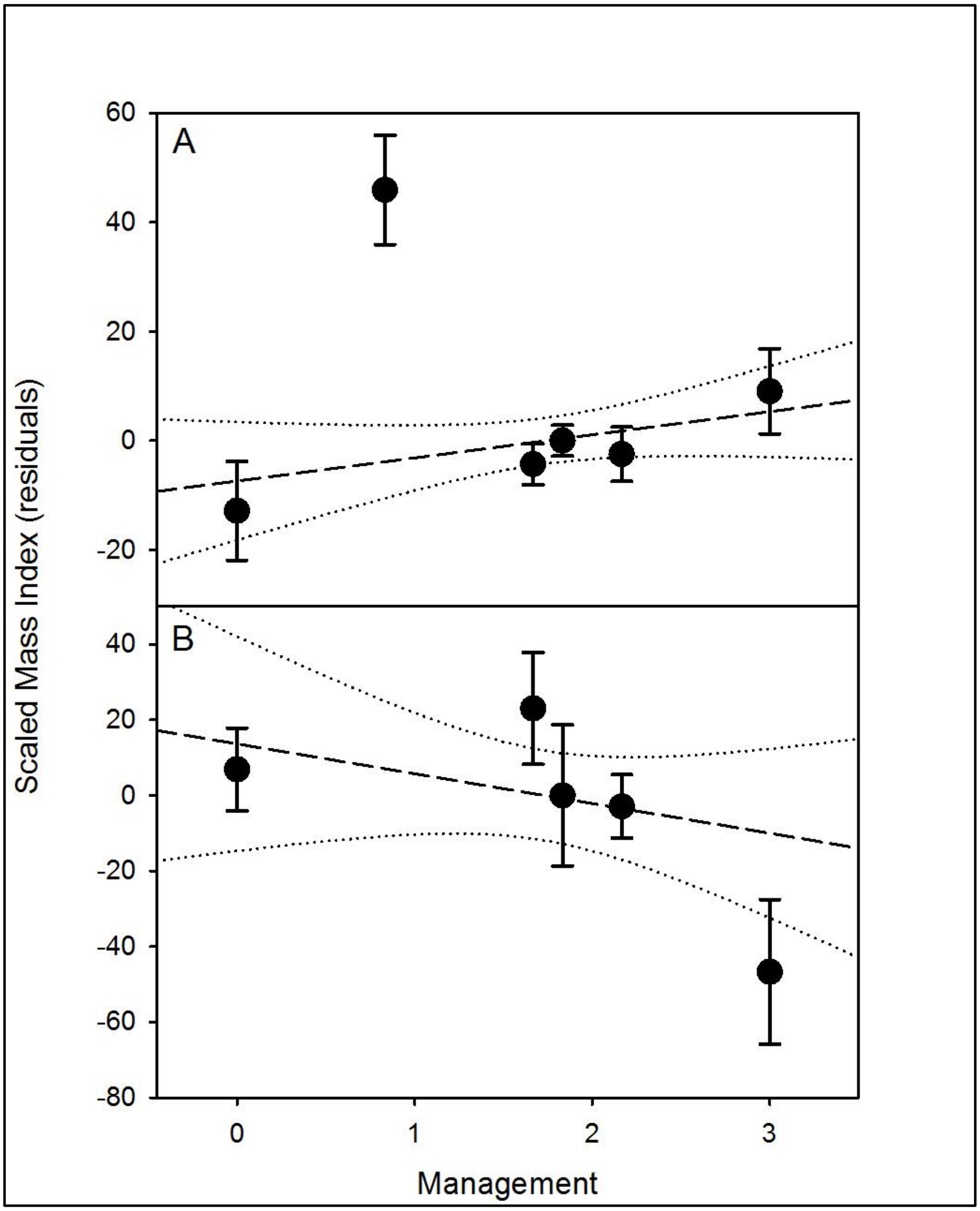

Figure 7: Effects of management intensity score (1-3) on SMI for blue-winged teal (A) and gadwall (B). Dots represent means, bars represent standard error, dashed lines are regression lines, and dotted lines are confidence intervals of the regression. The y-axis represents the residuals of a regression of habitat, sex, and year on SMI for blue-winged teal as well as gadwall, which were the variables in the top model other than management.

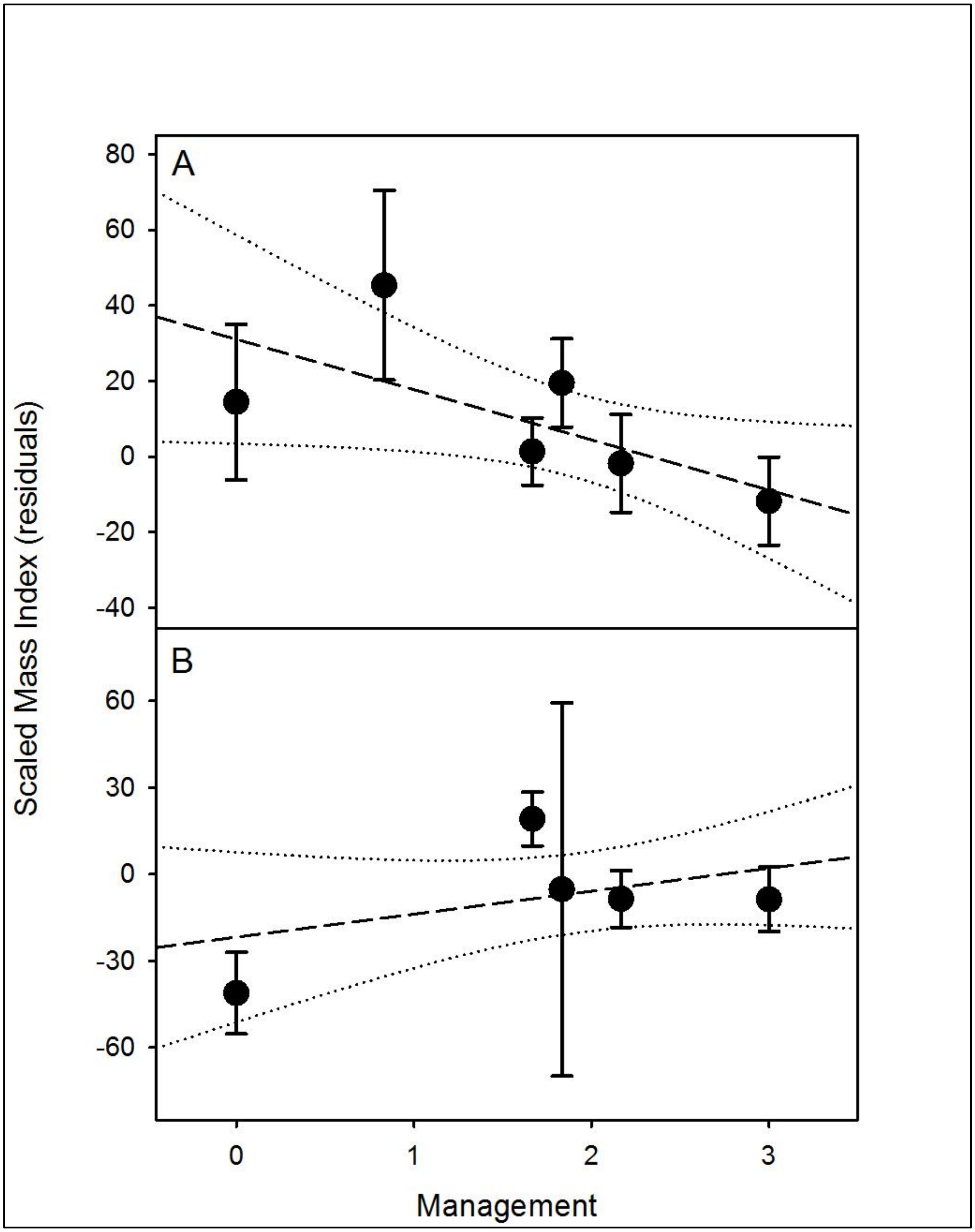

Figure 8: Effect of management intensity score (0-3) on immature (A) and adult (B) SMI for northern shovelers. Dots represent means, bars represent standard error, dashed lines are regression lines, and dotted lines are confidence intervals of the regression. The y-axis represents the residuals of a regression of day and sex on SMI for northern shovelers, which were the variables in the top model other than management and age.

4. DISCUSSION AND CONCLUSIONS

4.1 Sex Differences in Body Condition

We predicted that female ducks would be in lower body condition than male ducks, especially early in winter, because of the increased energetic demands of incubation and brood rearing for females (Baldassarre 2015). We did not find support for this hypothesis. Instead, female blue-winged teal, green-winged teal, northern shoveler, and gadwall were in higher body condition than male conspecifics. These results suggest that females may regain body condition very quickly following brood rearing, either early in the migratory route or at the breeding grounds. For green-winged teal, the effect of sex on SMI was moderated by year such that there was little difference in SMI by sex in year two (2018-19) of our study. This suggests yearly fluctuation in the relationship between sex and SMI for this population of green-winged teal. Few other studies have evaluated sex effects on winter body condition in ducks, however, our findings contrast with those of the Eurasian teal, for which body condition is higher in males than females over winter (Fox et al. 1992) and ring-necked ducks for which there was no difference (McCraken et al. 2000). This discrepancy in sex-specific body condition may be due to life history factors including timing of migration, mating systems, or mass gain and loss patterns over fall/winter. Additionally, our condition index calculation is slightly different than that used by Fox et al. (1992), who used a scaling component based on the wing/weight relationship, and McCracken et al. (2000), who used PCA scores of body size measures as a covariate in analyses. All species studied exhibit sexual size dimorphism with males being larger than females in size and mass. Thus, differences in body condition index calculations that scale size to mass could produce differences in sex-specific results. Indeed, our results using OLS regression (Appendix D) do suggest that sex-specific body condition results change with body condition calculation. However, OLS methods have important short-comings, including the assumption that structural size is measured without error (Arnold and Green 2007, Peig and Green 2009). In practice, measurement error for structural size is typically not negligible, and often higher than for mass (Krebs and Singleton 1993). The scaled mass index is an improvement over OLS regression techniques for body condition because it uses a multiplicative error function instead of an additive one (as in OLS), which better accounts for the scaling between mass and length (Peig and Green 2009). Furthermore, OLS regression techniques assume that mass increases linearly with structural size, an assumption that is often not met (as summarized in Clancey and Byers 2014), and are consistently biased towards larger individuals by underestimating the slope between mass and length (Arnold and Green 2007, Peig and Green 2009). This bias may explain the higher body condition of males obtained using OLS techniques compared to SMI.

4.2 Collection Day and Body Condition

We found support for our prediction that body condition would decline from November through January. As predicted, nearly all ducks (i.e., blue-winged teal, green-winged teal, northern shoveler, and northern pintail) declined in body condition across the winter hunting season, consistent with previous studies of dabbling ducks (Miller 1986, Fox et al. 1992, Haukos et al. 2001), but contrary to findings for diving ducks (Hohman and Weller 1994). There was no change in body condition across the winter season for gadwall, probably due to low sample sizes for this species at the beginning of the season. For no species was the effect of day sex-specific or age-specific. Thus, neither immatures nor females appear to be at significant risk compared to adult males regarding this decline in condition.

This observed winter body condition decline could be due to the energetic demands of mate pairing activities in late winter, a release from nutritional stress because of constantly available resources on the wintering grounds (Haukos et al. 2001), and/or differential migratory patterns for birds in high or low body condition. Additionally, our study relied on hunter collection, which imposed potential restraints on our sampling. Previous work has suggested that hunter-shot mallards and ring-necked ducks, especially those hunted near decoys, weigh less than the general population (Greenwood et al. 1986, Heitmeyer et al. 1993, McCraken et al. 2000), although no body condition hunter bias was found for northern pintails in Texas (Sheeley and Smith 1989). Because hunter-bias may be species-specific and dependent on region, hunting method, and body condition analysis (Sheeley and Smith 1989, Heitmeyer et al. 1993), future studies are needed to evaluate if hunter bias affects the species in this study, while wintering on the Texas coast.

4.3 Age and Year Differences in Body Condition

We found limited support for our hypothesis that immature ducks would be in lower body condition than adults. Immatures were in lower body condition than adults only for gadwall in 2017-18 and northern pintail in 2018-19, the latter of which was a relatively weak effect. These results provide some support for our hypothesis, and are consistent with findings for other duck species (Fox et al. 1992, Hohman and Weller 1994). However, on closer examination these age effects appear to be driven by the very high body condition of immature northern pintails and adult gadwall in 2017-18, a trend that was also detected for female green-winged teal of both age classes.

Carry-over effects of factors such as food and habitat quality on the breeding and migratory grounds could have produced our observed sex- and age-specific effects of year on body condition. Additionally, conditions on the wintering grounds, alone, or in conjunction with breeding/migratory conditions could have produced these results. Climatic changes, including recent catastrophic weather events are known to impact waterfowl body condition (Miller 1986, Nichols et al. 1995). Total precipitation in Matagorda County over the time period of this study was over twice as high in 2017-18 than 2018-19 (2017-18 mean of weather stations = 13.05 mm, 2018-19 = 6.29 mm), thus our results are consistent with previous studies which found higher duck body condition in wet winters than dry winters (Delnicki and Reinecke 1986, Miller 1986). Additionally, Hurricane Harvey occurred in August 2017, when land managers begin to dam off water and flood fields. Thus, to the influx of water from this hurricane may have positively affected body condition for some sex/age classes by facilitating more temporary wintering habitat. Interestingly, the positive effect of 2017-18 was sex-specific for green-winged teal, and age-specific for northern pintail and gadwall, with gadwall adults and northern pintail immatures benefiting. If increased winter body condition was associated with water availability, this would suggest differential foraging patterns based on sex and age. This is an important avenue of future research for northern pintail, especially, which remain 42% below the long-term average, and for which Texas hosts 78% of the wintering Central Flyway population (Pintail Action Group 2015). Age-specific impacts of winter water availability or climatic conditions on body condition could affect recruitment of immature pintail back to the breeding ground, which is critical for population increase.

Precipitation is predicted to increase in volume and regularity in the future (Fowler and Hennessy 1995) for the Gulf Coast, in the form of more frequent powerful clustered storms (Mulholland et al. 2002) such as hurricanes. Thus, understanding the response of vulnerable duck populations, such as females and immatures, to hurricanes and precipitation is of importance for predictive population modeling and management. Although our attribution of yearly body condition changes to winter rainfall patterns and/or late summer storms is speculative, our results do suggest that females and immatures are not in consistently poor body condition while wintering on the Texas coast, although northern pintail immatures may be particularly vulnerable to changes in resource availability. Longer-term research on the Gulf coast is needed to determine if these observed yearly fluctuations are due to precipitation patterns, or other factors.

4.4 Habitat and Land Management Differences in Body Condition

We found species-specific support for our prediction that habitat type and management strategies would affect body condition. Habitat type was in the top model for two of the five species studied, and management intensity was in the top model for four of the five species. Blue-winged teal had the highest SMI in marshes and lowest in moist soil, and body condition increased with management intensity, a trend also observed in northern pintails (although this latter effect was not significant, $p=0.06$). In contrast, gadwall SMI was highest in ponds and lowest in marsh habitat, and SMI decreased with management intensity. These findings are consistent with known winter foraging habits for these species, and typical accompanying management strategies. Previous research on the Texas coast has found that wintering blue-winged teal and pintail show a preference for mid-water depths (White and James 1978), such as those in marshes, while gadwall prefer deeper water with submerged vegetation (White and James 1978). Marshes in our study tended to have low management intensity (mean = 0.088), while ponds have high management intensity (mean = 1.83). Thus, the strong association between habitat type and management intensity makes it difficult to detect individual effects of either variable in these cases. These results do suggest that species-specific habitat preferences attract and perhaps yield ducks of high body condition. We did not find sex- or age-specific differences, suggesting that winter habitat does not differentially affect females or immatures.

For northern shovelers, the effect of management was age-specific. Consistent with our results for gadwall, body condition decreased with management intensity for immature northern shovelers, with no significant effect on adults. Similar to our findings for the effects of year on body condition, these results also suggest age-specific foraging patterns or habit selection that may be differently affected by management intensity. Overall, our management results indicate that increased management effort, which is time and labor-intensive, is associated with species-specific differences in body condition and should not be viewed as a tool for increasing body condition in immature northern shovelers, or gadwall of any age class.

Our study is constrained by potential movement of these species within the wintering grounds. Thus, we cannot directly attribute the habitat a duck was collected in to body condition. Instead, our observed associations between habitat, management intensity, and body condition could be due to a direct effect on body condition, or differential habitat use based on body condition in ducks. Both of these effects have been shown in other avian species. Summer tanagers (*Piranga rubra*) use and move between habitats differently depending on body condition determined by fat (Moore and Aborn 2000). In other song birds, the rate at which mass is gained or lost is dependent on habitat type (Ktitorov et al. 2008). Birds have high visual acuity compared to vertebrates with comparable eye sizes (Martin 2011), and dabbling ducks such as the mallard are able to survey the entire horizon with 360° horizontal vision (Martin 1986). This strong visual sensory ability suggests that ducks may be able to detect habitat quality while in flight, and preferentially land in habitats of high quality. Winter site fidelity in dabbling ducks varies greatly with species and study area size (Robertson and Cooke 1999), though wintering waterfowl typically have high winter site fidelity (Hestbeck 1993). It is difficult to establish causal relationships between winter habitat and fitness-related metrics due to variation in winter movements both between and among species, sexes, and age classes. However, regardless of cause and effect, our results suggest that associations between habitat, management strategies, and body condition are species and age-specific in dabbling ducks.

4.5 Conclusions

This study has contributed to the body of knowledge on wintering migratory duck species by using a modern body condition index calculation and detailed demographic comparisons. Our results suggest that sub-populations that are important for recruitment of breeding populations (i.e. females and immatures) are doing well in comparison to their counterparts (i.e. males and adults). We found that most females were in higher body condition than males. In terms of age we found no overall trends in body condition differences between age classes. We did confirm that over the wintering period studied (November –January) ducks body condition decreased overall as expected. Yearly differences in body condition were associated with major differences in precipitation and differed by sex, age class, and species suggesting differential responses to increased temporary habitats. We did not find evidence for sex or age differential body condition depending on habitat type, but management intensity was associated with different body condition depending on sex and age class.

Future work should investigate sex- and age-specificity of migratory patterns and wintering activity, and longer-term research should investigate fluctuations in body condition for these vulnerable populations in relation to weather and precipitation. Additionally, future research is needed to identify specific aspects of habitat and management techniques that contribute to our observed associations with body condition of wintering populations.

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APPENDIX A

WILDLIFE RESOURCE DOCUMENT

TEXAS PARKS & WILDLIFE

Wildlife Resource Document

Refer to ***Outdoor Annual*** sections on *Transfer of Wildlife Resources*, *Cold Storage/Processing Facility*, and *Taxidermist* for an explanation of requirements to complete and possess this document.

I, ______________________________, ______________________
(1) Name (2) Phone

______________________________, ________________, ____, ______
(3) Address City State Zip

give, donate, leave the wildlife resource(s) or parts thereof, listed below to: (complete Sections 4 thru 12), **OR** possess the wildlife resource(s) or parts thereof, listed below, without other applicable licenses, stamps, tags, or permits (complete Sections 6 thru 12):

Texas A&M University Department of Wildlife and Fisheries Sciences
(4) Receiver's Name

578 John Kimbrough Blvd, College Station, TX, 77840
(5) Address City State Zip

____
(6) Number and Type of Species or Parts

which was killed or caught on ______________________ at the following location:
(7) Date

____
(8) Name of Ranch, Area, Lake, Bay, or Stream and County, State, or Country

____, ________
(9) Hunt and/or Fish License of person who killed or caught the wildlife resource described in Section 8 (10) State

______________________________ ______________
(11) Signature (12) Date

Note: Reproduction of this information is allowed, in any form, including a legible hand written version.

PWD 980 – L2000 (10/04)

APPENDIX B

FAT BODY CONDITION INDEX

I. Fat Scoring Methods

To quantify body fat, each bird's gizzard was scored for presence or absence of a visceral fat deposit on the gizzard. Presence was defined as fat covering 11% or more, and absence was defined as fat covering 10% or less of the ventral side of the gizzard. Birds deposit adipose tissue first under the skin along feather tracts and last throughout the abdominal cavity (Blem 1976). This fat layer in the viscera is the first to be metabolized should energy stores need to be used. Thus, birds with gizzard fat present are 'excessively/very fat' while birds with gizzard fat absent are 'fat', 'moderately fat', or 'not fat' as established by Blanchard in 1941 (McCabe 1943). The gizzard was used as an indicator of visceral fat as it was the most intact, highly accessible organ in the abdominal cavity, and it is one of the larger fat pads in birds (Scanes 2015). This method was chosen over other types of fat measurements for several reasons. First, hunter salvaged specimens are often damaged in unpredictable ways making other more precise and continuous techniques difficult for these specimens. Second, our large sample size made other more time-intensive methods (e.g., collecting and weighing total fat for each bird) not feasible.

II. Relationship of Fat and SMI Methods

To evaluate whether both body condition variables (i.e., SMI and gizzard fat score) were significantly related I used a two-sided student's t-test at 95% confidence with Welch's correction for uneven sample sizes for each species (i.e. green-winged teal, blue-winged teal, gadwall, northern shoveler, and northern pintail) to see if there was a significant difference in SMI for gizzard fat presence or absence.

III. Fat Score General Linear Model (GLM) Methods

For each species the effect of day collected, year collected, sex, age class, and two-way interactions on fat score (1 = present, 0 = absent) were evaluated using a general linear model (GLM) analysis with logit link function, because fat score is a binomial response variable. This GLM was also run twice, once with all data ("entire dataset") and once excluding data that was not represented evenly in both years ("subset dataset").

IV. Relationship of Fat and SMI Results

The scaled mass index for ducks with gizzard fat was significantly higher than that for ducks without gizzard fat for all species (Table B1). This suggests that there is a strong relationship between gizzard fat score and SMI (Figure B1).

Table B1: Results of two-sided Welch's t-tests for SMI between ducks with gizzard fat present and absent.

Species	**t**	**df**	**p-value**
Blue-winged teal	4.595	158.93	<0.001
Green-winged teal	7.783	220.21	<0.001
Northern pintail	3.884	27.229	0.002
Gadwall	4.373	48.198	<0.001
Northern shoveler	2.148	43.823	<0.001

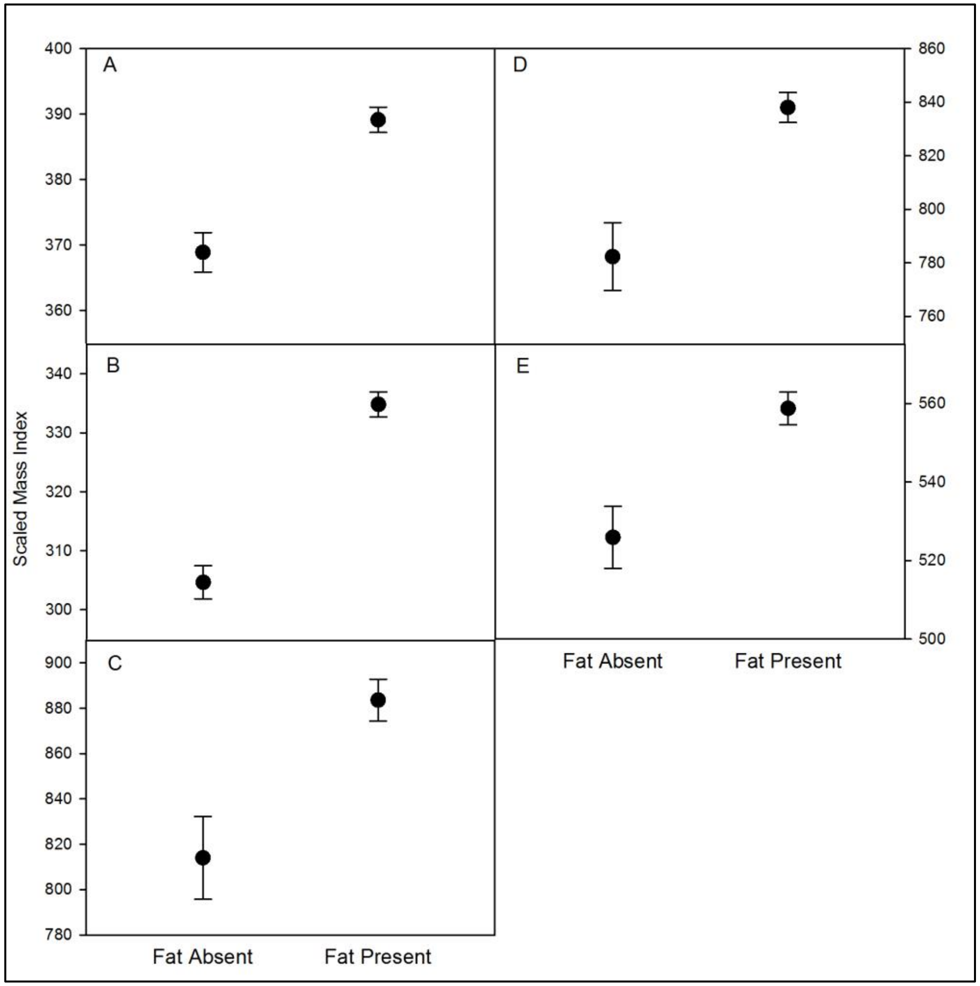

Figure B1: Scaled mass index was greater when gizzard fat was absent (A on the x-axis) vs. present (P on the x-axis) for all species: blue-winged teal (A), green-winged teal (B), northern pintail (C), gadwall (D), northern shoveler (E). Note different y-axis scales. Dots represent means and bars represent standard error.

V. Effect of Sex, Age, Date, and Year on Fat Score

There were no significant effects of sex, age, date of collection, year, or any interactions on duck gizzard fat presence or absence for any species when the entire dataset was analyzed (Table B2). When the subset dataset was analyzed, there was only one significant effect. Northern shoveler males had significantly more fat than females in 2018-19, with no difference in 2017-18 (sex by year interaction, p = 0.039, Table B2).

Table B2: Results of all general linear models evaluating the effects of “Sex” (male, female), “Age” (immature, adult), “Day” (1=November 1 to 92=January 31), “Year” (winter 2017/18 and winter 2018/19), and two-way interactions of each on gizzard fat score (present or absent). “All Data” includes all collection dates. “Subset Data” only considers dates collected in both years. Non-reference category can be found in parenthesis (i.e. Age (immature)). (* = significant).

All Data

Blue-winged teal

	Estimate	Std. Error	z value	p value
Sex (male)	1.327	0.945	1.404	0.160
Age (immature)	-1.143	0.896	-1.276	0.202
Day	0.000	0.015	-0.021	0.983
Year (2018-19)	-0.934	1.087	-0.859	0.390
Sex (male):Age (immature)	-0.355	0.533	-0.666	0.505
Sex (male):Day	-0.013	0.010	-1.302	0.193
Sex (male): Year (2018-19)	-0.525	0.599	-0.876	0.381
Age (immature):Day	0.006	0.010	0.611	0.541
Age (immature): Year (2018-19)	0.983	0.657	1.496	0.135
Day: Year (2018-19)	0.011	0.014	0.770	0.441

Table B2 Continued

All Data (continued)				
Green-winged teal				
	Estimate	Std. Error	z value	p value
Sex (male)	-0.209	0.806	-0.259	0.795
Age (immature)	-0.514	1.291	-0.398	0.691
Day	-0.001	0.011	-0.133	0.894
Year (2018-19)	-0.875	0.774	-1.130	0.258
Sex (male):Age (immature)	-0.319	0.756	-0.422	0.673
Sex (male):Day	0.000	0.010	0.037	0.971
Sex (male): Year (2018-19)	0.713	0.522	1.366	0.172
Age (immature):Day	-0.008	0.017	-0.480	0.631
Age (immature): Year (2018-19)	-0.099	0.891	-0.111	0.912
Day: Year (2018-19)	-0.003	0.011	-0.257	0.797
Gadwall				
	Estimate	Std. Error	z value	p value
Sex (male)	0.991	1.735	0.571	0.568
Age (immature)	-1.490	1.604	-0.929	0.353
Day	0.003	0.032	0.092	0.927
Year (2018-19)	-1.067	2.119	-0.503	0.615
Sex (male):Age (immature)	-1.071	0.820	-1.306	0.192
Sex (male):Day	-0.014	0.019	-0.722	0.470
Sex (male): Year (2018-19)	0.739	1.157	0.639	0.523
Age (immature):Day	0.022	0.019	1.126	0.260
Age (immature): Year (2018-19)	1.047	1.159	0.904	0.366
Day: Year (2018-19)	-0.002	0.029	-0.078	0.938
Northern shoveler				
	Estimate	Std. Error	z value	p value
Sex (male)	-2.102	1.773	-1.185	0.236
Age (immature)	-1.733	1.867	-0.928	0.353
Day	-0.011	0.026	-0.411	0.681
Year (2018-19)	-0.212	1.656	-0.128	0.898
Sex (male):Age (immature)	1.016	1.208	0.841	0.400
Sex (male):Day	0.011	0.020	0.559	0.577
Sex (male): Year (2018-19)	1.070	0.908	1.179	0.238
Age (immature):Day	0.000	0.022	-0.014	0.989
Age (immature): Year (2018-19)	-0.064	0.974	-0.066	0.947
Day: Year (2018-19)	-0.008	0.019	-0.444	0.657

Table B2 Continued

Subset Data

Blue-winged teal				
	Estimate	Std. Error	z value	p value
Sex (male)	0.703	1.415	0.497	0.619
Age (immature)	-1.595	1.392	-1.146	0.252
Day	0.006	0.021	0.292	0.770
Year (2018-19)	1.361	1.539	0.884	0.377
Sex (male):Age (immature)	-0.112	0.735	-0.152	0.879
Sex (male):Day	-0.002	0.020	-0.087	0.931
Sex (male): Year (2018-19)	-0.744	0.726	-1.026	0.305
Age (immature):Day	0.016	0.020	0.777	0.437
Age (immature): Year (2018-19)	0.594	0.758	0.784	0.433
Day: Year (2018-19)	-0.022	0.021	-1.051	0.293

Green-winged teal				
	Estimate	Std. Error	z value	p value
Sex (male)	-0.589	1.038	-0.568	0.570
Age (immature)	2.748	2.403	1.144	0.253
Day	0.000	0.015	-0.005	0.996
Year (2018-19)	0.596	1.040	0.573	0.566
Sex (male):Age (immature)	-1.488	1.320	-1.127	0.260
Sex (male):Day	0.008	0.016	0.506	0.613
Sex (male): Year (2018-19)	0.549	0.589	0.932	0.351
Age (immature):Day	-0.058	0.035	-1.636	0.102
Age (immature): Year (2018-19)	0.417	1.103	0.378	0.706
Day: Year (2018-19)	-0.024	0.016	-1.526	0.127

Gadwall				
	Estimate	Std. Error	z value	p value
Sex (male)	0.474	2.220	0.213	0.831
Age (immature)	0.439	2.000	0.220	0.826
Day	0.050	0.048	1.049	0.294
Year (2018-19)	-2.516	3.274	-0.769	0.442
Sex (male):Age (immature)	-0.274	1.026	-0.267	0.789
Sex (male):Day	-0.046	0.027	-1.656	0.0977 .
Sex (male): Year (2018-19)	2.798	1.627	1.720	0.0855 .
Age (immature):Day	-0.046	0.027	-1.659	0.0971 .
Age (immature): Year (2018-19)	2.686	1.533	1.752	0.0797 .
Day: Year (2018-19)	-0.013	0.042	-0.317	0.752

Table B2 Continued

Subset Data (continued)				
Northern shoveler				
	Estimate	Std. Error	z value	p value
Sex (male)	1.608	2.312	0.696	0.487
Age (immature)	-0.648	2.258	-0.287	0.774
Day	0.028	0.042	0.668	0.504
Year (2018-19)	0.779	2.241	0.347	0.728
Sex (male):Age (immature)	1.199	1.452	0.826	0.409
Sex (male):Day	-0.055	0.036	-1.503	0.133
Sex (male): Year (2018-19)	2.407	1.168	2.062	0.039*
Age (immature):Day	-0.026	0.037	-0.687	0.492
Age (immature): Year (2018-19)	0.652	1.179	0.553	0.580
Day: Year (2018-19)	-0.034	0.032	-1.082	0.280

VI. Fat Score Trends Discussion

We found only one significant effect of our explanatory variables on fat score, which contrasts with findings in this study for SMI. We suspect that this is because gizzard fat scoring is a very coarse measure of body condition. Gizzard fat is the last fat deposit to be gained and first to be lost, thus ducks with gizzard fat were “very fat” while ducks without gizzard fat ranged from “not fat” (i.e., very poor body condition), to “fat”. This range of possible conditions encompassed by a zero score appears to have made it difficult to draw conclusions. Entire body composition analysis of protein and fat, or digitizing the area of fat deposits via photographs would provide a higher resolution for fat and may be a better method than scoring. We did find that ducks with gizzard fat had a higher SMI than those without, suggesting consistency in these indicators of body condition. However, our results indicate that fat and SMI do not indicate body condition in the same way.

APPENDIX C

LAND MANAGER SURVEY

Subsite Name

Please mention if any of these sites are duplicates names and if so which is the duplicate.

1) If possible describe this site as one of the following categories, if not possible write NA:
   - Seasonal flooded cropland
   - Moist soil
   - Semi-permanent (marsh)
   - Permanent (pond)
   - Forested wetland (green-tree)
   - Other (please describe)
   - NA
2) If possible describe the area surrounding this site as one of the following categories, if not possible write NA:
   - Seasonal flooded cropland
   - Moist soil
   - Semi-permanent (marsh)
   - Permanent (pond)
   - Forested wetland (green-tree)
   - Other (please describe)
   - NA
3) Answer yes or no if each management tactic is used to manage this site during waterfowl season:
   - Water control
   - Controlled burn
   - Plowing/disking
   - Planting native plant species
   - Planting non-native attractants (i.e. fallow crops, corn, etc)
   - Removing invasive plant species
   - Removing invasive animal species
   - Other
   - Describe other
4) Answer yes or no if each management tactic is used to manage this site during off-waterfowl season:
   - Water control
   - Controlled burn
   - Plowing/disking
   - Planting native plant species
   - Planting non-native attractants (i.e. fallow crops, corn, etc)
   - Removing invasive plant species
   - Removing invasive animal species
   - Other
   - Describe other
5) Answer yes or no if this site is used for the following activities apart from waterfowl hunting:
   - Cattle grazing
   - Crop fields
   - Untouched
   - Other hunting activities
   - Recreation
   - Other

APPENDIX D

ORDINARY LEAST SQUARES REGRESSION BODY CONDITION INDEX

I. Methods of Body Condition Index via Ordinary Least Squares Regression

In addition to scaled mass index (SMI) calculation (Peig and Green 2009), another common body condition index was calculated using residuals of an ordinary least squares (OLS) regression (Deveries et al. 2008). First, for each species a correlative principal component analysis (PCA) was used to combine linear measures of tarsus, bill, and wing cord. A correlative approach was used to equally weight all linear measures because the range and variance of each measure differed. Mass was then regressed against PC1 (which explained the majority of variance for all species, Table D1) for each individual, and the residuals of that regression were used as indicators of body condition. We then ran the same models we used to predict our SMI body condition index values (main text Table 2), but predicted our OLS body condition index values, and compared the results.

II. Results of OLS Body Condition Index

When comparing the results of our linear models predicting the OLS body condition index to those predicting SMI, the directionality of most results are the same (with the notable exception of sex), although significance tends to be lower with the OLS body condition index. This loss of significance is not surprising considering we ran the top models for the SMI calculation not the OLS calculation, for comparison purposes. The direction and significance of our sex-specific results were especially different between SMI and OLS methods. All species in this study are all highly sexually dimorphic in size, therefore differences in the specific body condition index calculation (e.g., which linear measures are most heavily weighted) would lead to different results. Indeed, OLS techniques for estimating body condition are known to be consistently biased towards larger individuals by underestimating the slope between mass and length (Arnold and Green 2007, Peig and Green 2009). Additionally, OLS methods assume that structural size is measured without error (Arnold and Green 2007, Peig and Green 2009), a typically incorrect assumption (Krebs and Singleton 1993). In contrast, the scaled mass index uses a multiplicative error function instead of an additive one (as in OLS), which better accounts for the scaling between mass and length (Peig and Green 2009).

Table D1: Results of PCA combining linear measures of tarsus, bill, and wing cord for each species.

Blue-winged teal

Importance of Components			
	PC1	PC2	PC3
Eigenvalue	2.051	0.509	0.440
Proportion explained	0.684	0.170	0.147
Cumulative proportion	0.684	0.853	1.000
Species Scores			
Species	PC1	PC2	PC3
Tarsus	2.801	2.041	-0.043
Bill	2.900	-0.948	1.646
Wing	2.895	-1.026	-1.606

Green-winged teal

Importance of Components			
	PC1	PC2	PC3
Eigenvalue	1.911	0.639	0.450
Proportion explained	0.637	0.213	0.150
Cumulative proportion	0.637	0.850	1.000

Table D1 Continued

Green-winged teal (continued)			
Species Scores			
Species	PC1	PC2	PC3
Tarsus	-2.503	2.251	-0.312
Bill	-2.749	-1.310	-1.468
Wing	-2.832	-0.718	1.701

Northern pintail			
Importance of Components			
	PC1	PC2	PC3
Eigenvalue	2.386	0.348	0.267
Proportion explained	0.795	0.116	0.089
Cumulative proportion	0.795	0.911	1.000
Species Scores			
Species	PC1	PC2	PC3
Tarsus	-2.098	1.011	-0.483
Bill	-2.161	-0.036	0.993
Wing	-2.103	-0.972	-0.538

Gadwall			
Importance of Components			
	PC1	PC2	PC3
Eigenvalue	2.288	0.371	0.341
Proportion explained	0.763	0.124	0.114
Cumulative proportion	0.763	0.886	1.000
Species Scores			
Species	PC1	PC2	PC3
Tarsus	-2.390	0.832	-1.028
Bill	-2.367	-1.350	-0.184
Wing	-2.398	0.503	1.206

Northern shoveler			
Importance of Components			
	PC1	PC2	PC3
Eigenvalue	2.325	0.437	0.238
Proportion explained	0.775	0.146	0.079
Cumulative proportion	0.775	0.921	1.000
Species Scores			
Species	PC1	PC2	PC3
Tarsus	2.325	0.437	0.238
Bill	0.775	0.146	0.079
Wing	0.775	0.921	1.000

Table D2: Results of linear model top linear models testing including the effects of sex, age, day, year, and all two-way interactions on the residual score of OLS regression for each species. A * indicates a significant effect, and the non-reference factor is in parentheses for fixed factors.

Sex					
Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Sex (male)	5.729	2.991	1.915	0.056
Green-winged teal	Sex (male)	5.794	7.265	0.798	0.426
Green-winged teal	Sex (male):Year (2018-19)	0.303	8.067	0.038	0.970
Northern shoveler	Sex (male)	-11.948	19.944	-0.599	0.550
Northern shoveler	Sex (male):Day	0.256	0.319	0.803	0.423
Gadwall	Sex (male)	-3.098	9.408	-0.329	0.742

Age					
Species	Effect	Estimate	Std. Error	t value	p value
Northern pintail	Age (immature)	-5.806	26.294	-0.221	0.826
Northern pintail	Age (immature): Year (2018-19)	-106.828	36.105	-2.959	0.004*
Gadwall	Age (immature)	-65.967	21.317	-3.095	0.002*
Gadwall	Age (immature): Year (2018-19)	60.044	23.703	2.533	0.012*

Day					
Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Day	-0.185	0.057	-3.232	0.001*
Green-winged teal	Day	-0.136	0.066	-2.074	0.039*
Northern shoveler	Day	-0.407	0.235	-1.735	0.085
Northern pintail	Day	-1.207	0.384	-3.146	0.002*

Year					
Species	Effect	Estimate	Std. Error	t value	p value
Blue-winged teal	Year (2018-19)	9.937	3.541	2.806	0.005*
Green-winged teal	Year (2018-19)	-5.373	5.831	-0.922	0.357
Northern pintail	Year (2018-19)	-7.120	17.081	-0.417	0.678
Gadwall	Year (2018-19)	-53.904	16.220	-3.323	0.001*

APPENDIX E

COMPARISON OF UNEVEN SAMPLINING BETWEEN YEARS

Table E1: All results for linear models evaluating the effects of "Sex" (male, female), "Age" (immature, adult), "Day" (1=November 1, 92=January 31), "Year" (winter 2017/18 = year 1, and winter 2018/19 = year 2) and all two-way interactions on scaled mass index. "All Data" includes all collection dates. "Subset Data" only considers dates collected in both years. The non-reference category can be found in parenthesis (i.e. Age (immature)). (* = significant).

All Data

Blue-winged teal				
	Estimate	Std. Error	t value	p-value
Sex (male)	-36.427	12.296	-2.963	0.003 *
Age (immature	-12.606	12.430	-1.014	0.311
Day	-0.577	0.198	-2.918	0.004 *
Year (2018-19)	-12.845	14.170	-0.906	0.365
Sex (male):Age (immature)	11.365	7.396	1.537	0.125
Sex (male):Day	0.274	0.139	1.977	0.049 *
Sex (male): Year (2018-19)	-2.126	7.754	-0.274	0.784
Age (immature):Day	0.121	0.142	0.851	0.396
Age (immature): Year (2018-19)	10.551	8.776	1.202	0.230
Day:Year (2)	0.334	0.185	1.801	0.072

Green-winged teal				
	Estimate	Std. Error	t value	p-value
Sex (male)	-25.330	12.013	-2.108	0.036 *
Age (immature	-16.087	21.258	-0.757	0.450
Day	-0.396	0.157	-2.517	0.012*
Year (2018-19)	-31.621	11.111	-2.846	0.005*
Sex (male):Age (immature)	9.390	12.846	0.731	0.465
Sex (male):Day	0.012	0.160	0.073	0.942
Sex (male): Year (2018-19)	14.922	7.877	1.894	0.059
Age (immature):Day	0.107	0.284	0.377	0.707
Age (immature): Year (2018-19)	5.114	14.729	0.347	0.729
Day: Year (2018-19)	0.297	0.162	1.833	0.068

Table E1 Continued

All Data (continued)				
Northern pintail				
	Estimate	Std. Error	t value	p-value
Sex (male)	-15.450	76.209	-0.203	0.840
Age (immature	-44.900	81.277	-0.552	0.582
Day	-1.751	0.943	-1.857	0.067
Year (2018-19)	-22.396	67.041	-0.334	0.739
Sex (male):Age (immature)	50.486	50.651	0.997	0.322
Sex (male):Day	0.264	0.965	0.274	0.785
Sex (male): Year (2018-19)	29.496	37.802	0.780	0.438
Age (immature):Day	1.317	1.091	1.207	0.231
Age (immature): Year (2018-19)	-120.920	48.554	-2.490	0.015 *
Day: Year (2018-19)	-0.324	0.852	-0.380	0.705

Gadwall				
	Estimate	Std. Error	t value	p-value
Sex (male)	-20.024	41.521	-0.482	0.630
Age (immature	-85.984	40.315	-2.133	0.035 *
Day	-1.461	0.754	-1.938	0.054
Year (2018-19)	-136.892	49.896	-2.744	0.007 *
Sex (male):Age (immature)	-5.292	20.713	-0.255	0.799
Sex (male):Day	-0.074	0.496	-0.149	0.882
Sex (male): Year (2018-19)	-19.399	27.452	-0.707	0.481
Age (immature):Day	0.503	0.494	1.017	0.311
Age (immature): Year (2018-19)	70.066	27.473	2.550	0.012*
Day: Year (2018-19)	1.305	0.696	1.875	0.063

Northern shoveler				
	Estimate	Std. Error	t value	p-value
Sex (male)	-46.569	25.030	-1.861	0.065
Age (immature	45.710	24.606	1.858	0.065
Day	-0.585	0.389	-1.505	0.134
Year (2018-19)	14.354	25.245	0.569	0.570
Sex (male):Age (immature)	20.231	15.605	1.296	0.197
Sex (male):Day	0.276	0.329	0.839	0.403
Sex (male): Year (2018-19)	-21.769	15.768	-1.381	0.169
Age (immature):Day	-0.482	0.327	-1.473	0.143
Age (immature): Year (2018-19)	-37.335	15.531	-2.404	0.017 *
Day: Year (2018-19)	0.478	0.323	1.481	0.140

Table E1 Continued

Subset Data

Blue-winged teal				
	Estimate	Std. Error	t value	p-value
Sex (male)	-29.017	17.472	-1.661	0.098
Age (immature	-22.415	18.415	-1.217	0.225
Day	-0.513	0.266	-1.929	0.055
Year (2018-19)	10.408	18.920	0.550	0.583
Sex (male):Age (immature)	12.945	9.430	1.373	0.171
Sex (male):Day	0.237	0.241	0.983	0.327
Sex (male): Year (2018-19)	-5.767	8.770	-0.658	0.511
Age (immature):Day	0.382	0.262	1.455	0.147
Age (immature): Year (2018-19)	0.914	9.710	0.094	0.925
Day: Year (2018-19)	0.031	0.261	0.120	0.905

Green-winged teal				
	Estimate	Std. Error	t value	p-value
Sex (male)	-32.914	15.269	-2.156	0.032 *
Age (immature	-10.461	29.950	-0.349	0.727
Day	-0.593	0.208	-2.848	0.005*
Year (2018-19)	-8.530	14.833	-0.575	0.566
Sex (male):Age (immature)	24.198	18.446	1.312	0.191
Sex (male):Day	0.163	0.240	0.681	0.496
Sex (male): Year (2018-19))	14.643	8.585	1.706	0.089
Age (immature):Day	0.060	0.488	0.122	0.903
Age (immature): Year (2018-19)	12.770	16.320	0.782	0.435
Day: Year (2018-19)	-0.011	0.232	-0.046	0.963

Northern pintail				
	Estimate	Std. Error	t value	p-value
Sex (male)	52.667	75.405	0.698	0.488
Age (immature	123.145	93.199	1.321	0.191
Day	-0.021	1.132	-0.019	0.985
Year (2018-19)	57.875	73.094	0.792	0.432
Sex (male):Age (immature)	44.420	50.566	0.878	0.383
Sex (male):Day	-0.898	1.048	-0.856	0.395
Sex (male): Year (2018-19)	33.560	37.435	0.896	0.374
Age (immature):Day	-1.625	1.394	-1.166	0.248
Age (immature): Year (2018-19)	-85.637	48.267	-1.774	0.081
Day: Year (2018-19)	-1.596	0.993	-1.608	0.113

Table E1 Continued

Subset Data (continued)				
	Gadwall			
	Estimate	Std. Error	t value	p-value
Sex (male)	-43.855	48.056	-0.913	0.363
Age (immature	-110.029	46.401	-2.371	0.019 *
Day	-1.881	0.881	-2.134	0.035 *
Year (2018-19)	-112.176	58.914	-1.904	0.059
Sex (male):Age (immature)	0.239	22.388	0.011	0.992
Sex (male):Day	0.038	0.644	0.060	0.953
Sex (male): Year (2018-19)	-2.766	29.360	-0.094	0.925
Age (immature):Day	0.796	0.628	1.267	0.207
Age (immature): Year (2018-19)	69.099	28.945	2.387	0.018 *
Day: Year (2018-19)	0.807	0.848	0.952	0.343

	Northern shoveler			
	Estimate	Std. Error	t value	p-value
Sex (male)	-62.481	29.068	-2.149	0.033 *
Age (immature	44.701	28.670	1.559	0.121
Day	-0.653	0.482	-1.355	0.178
Year (2018-19)	90.427	29.735	3.041	0.003*
Sex (male):Age (immature)	19.075	16.572	1.151	0.252
Sex (male):Day	0.548	0.443	1.238	0.218
Sex (male): Year (2018-19)	-22.243	15.956	-1.394	0.166
Age (immature):Day	-0.433	0.438	-0.988	0.325
Age (immature): Year (2018-19)	-35.147	15.715	-2.237	0.027 *
Day: Year (2018-19)	-0.676	0.409	-1.653	0.101

APPENDIX F

ALL DEMOGRAPHIC AKAIKE INFORMATION CRITERION (AIC) MODEL RESULTS

Table F1: Model evaluation parameters for models that are within Δ2 of the top model, for each species, predicting scaled mass index using demographic variables. Fixed model predictors are listed in the first row, followed by AIC model evaluation parameters. A "+" or numerical value in the column of a predictor indicates that predictor was included in the model. A : indicates an interaction, "df" is degrees of freedom, "logLik" is the log likelihood, and "delta" indicates the difference between the AICc values of the top model and the model in question. Bold models are those that were used in further analysis (i.e., determined to be the "top" model by our model selection criteria). All models are derived from the global model: *SMI~ Sex*Age + Sex*Day + Sex*Year + Age*Day + Age*Year + Day*Year*.

Blue-winged teal models													
Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
+	-0.484	+	+		+		+	+		9	-2112.009	4242.400	0.000
+	-0.439	+	+				+	+		8	-2113.125	4242.600	0.140
+	-0.218	+	+				+			7	-2114.200	4242.700	0.220
+	-0.245	+	+		+		+			8	-2113.242	4242.800	0.380
+	-0.113	+	+							6	-2115.448	4243.100	0.650
+	-0.322	+	+					+		7	-2114.467	4243.200	0.750
	-0.157	**+**	**+**							**5**	**-2116.588**	**4243.300**	**0.870**
	-0.255	+	+				+			6	-2115.589	4243.400	0.930
+	-0.523	+	+		+	+	+	+		10	-2111.495	4243.500	1.070
	-0.465	+	+				+	+		7	-2114.631	4243.500	1.080
+	-0.481	+	+			+	+	+		9	-2112.580	4243.600	1.140

Table F1 Continued

Blue-winged teal models (continued)

Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
	-0.357	+	+					+		6	-2115.701	4243.600	1.150
+		+	+							5	-2116.859	4243.900	1.410
+	-0.345	+	+					+	+	8	-2113.876	4244.100	1.650
+	-0.359	+	+			+		+		8	-2113.982	4244.300	1.860
+	-0.482	+	+		+		+	+	+	10	-2111.892	4244.300	1.860
+	-0.117	+	+						+	7	-2115.034	4244.300	1.890
+	-0.504	+	+	+	+		+	+		10	-2111.908	4244.300	1.890
+	-0.438	+	+				+	+	+	9	-2112.962	4244.400	1.900
+	-0.214	+	+			+	+			8	-2114.052	4244.400	2.000

Green-winged teal models

Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
	-0.378	+	+					+	+	7	-1938.535	3891.4	0
+	-0.382	+	+					+	+	8	-1938.193	3892.8	1.4
	-0.196	**+**	**+**						**+**	**6**	**-1940.281**	**3892.8**	**1.42**
	-0.396	+	+					+		6	-1940.468	3893.2	1.79

Northern shoveler models

Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
+	-0.433	+	+	+		+		+	+	10	-912.305	1846.000	0.000
+	-0.754	+	+			+	+			8	-914.711	1846.300	0.340
+	-0.442	+	+	+		+		+		9	-913.605	1846.300	0.350
+	-0.392	+	+	+	+	+		+	+	11	-911.385	1846.400	0.440
+	-1.033	+	+			+	+	+		9	-913.680	1846.500	0.500
+	-0.086	+	+	+		+			+	9	-913.749	1846.600	0.640
+	-0.785	+					+			6	-917.131	1846.800	0.810
+	-0.058	+	+	+	+	+			+	10	-912.725	1846.800	0.840
+	-0.098	+	+	+		+				8	-915.005	1846.900	0.930

Table F1 Continued

Northern shoveler models (continued)													
Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
+	-0.718	+	+	+		+	+	+		10	-912.776	1846.900	0.940
	-1.019	+	+				+	+		7	-916.112	1846.900	0.940
+	-0.446	+	+	+		+	+			9	-913.936	1847.000	1.010
+	-0.405	+	+	+	+	+		+		10	-912.846	1847.000	1.080
	-0.800	+	+					+		6	-917.274	1847.000	1.100
	-0.775	**+**					**+**			**5**	**-918.350**	**1847.100**	**1.100**
+	-0.748	+	+		+	+	+			9	-913.994	1847.100	1.130
+	-0.682	+	+			+	+		+	9	-914.012	1847.100	1.160
+	-0.744	+	+			+		+	+	9	-914.022	1847.100	1.180
+	-0.967	+	+			+	+	+	+	10	-912.907	1847.200	1.200
+	-1.015	+	+				+	+		8	-915.147	1847.200	1.210
+	-0.715	+	+				+			7	-916.302	1847.300	1.320
	-0.700	+	+				+			6	-917.399	1847.300	1.350
+	-0.072	+	+	+	+	+				9	-914.150	1847.400	1.440
+	-0.633	+	+	+		+	+	+	+	11	-911.902	1847.400	1.470
+	-1.016	+	+		+	+	+	+		10	-913.046	1847.400	1.480
+	-0.417	+	+	+	+	+	+			10	-913.095	1847.500	1.580
+	-0.399	+	+			+			+	8	-915.372	1847.600	1.660
+	-0.784	+	+					+		7	-916.473	1847.600	1.660
+	-0.356	+	+	+		+	+		+	10	-913.155	1847.700	1.700
+	-0.680	+	+	+	+	+	+	+		11	-912.021	1847.700	1.710
+	-0.671	+	+		+	+	+		+	10	-913.180	1847.700	1.750
+	-0.775	+			+		+			7	-916.517	1847.700	1.750
+	-0.551	+	+	+				+		8	-915.436	1847.700	1.790
+	-0.768	+	+			+		+		8	-915.446	1847.800	1.810
	-0.430	+	+							5	-918.777	1847.900	1.960
+	-0.721	+	+		+	+		+	+	10	-913.285	1847.900	1.960
+	-0.944	+	+		+	+	+	+	+	11	-912.161	1847.900	1.990

Table F1 Continued

Northern shoveler models (continued)

Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
+	-0.585	+	+	+	+	+	+	+	+	12	-911.010	1847.900	2.000

Northern pintail models

Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
+	**-1.538**		**+**			**+**				**6**	**-536.905**	**1086.800**	**0.000**
+	-1.529	+	+			+				7	-536.100	1087.500	0.730

Gadwall models

Age	Day	Sex	Year	Age:Day	Age:Sex	Age:Year	Day:Sex	Day:Year	Sex:Year	df	logLik	AICc	delta
+		**+**	**+**			**+**				**6**	**-920.273**	**1853.100**	**0.000**
+	-1.279	+	+			+		+		8	-918.203	1853.300	0.250
+	-1.515	+	+	+		+		+		9	-917.643	1854.400	1.370
+		+	+			+			+	7	-919.970	1854.700	1.570
+	-0.178	+	+			+				7	-919.997	1854.700	1.630
+	-1.266	+	+			+		+	+	9	-917.932	1855.000	1.950

APPENDIX G

LINEAR MODEL COMPARISON OF MAJOR HUNTING SITE

Table G1: Results of linear models predicting SMI by hunting site (anonymized) yielded few significant results. A * indicates significance ($p<0.05$). Sex, age and habitat type were also included as predictor variables to account for possible uneven sampling at each site.

Blue-winged teal				
	Estimate	Std. Error	t value	p value
Site 2	-2.882	6.413	-0.449	0.653
Site 3	-1.126	5.178	-0.218	0.828
Site 4	-10.837	6.297	-1.721	0.086
Sex (male)	-19.895	3.245	-6.131	<0.001*
Age (immature)	9.354	3.388	2.761	0.006*
Habitat (cropland)	-5.611	17.719	-0.317	0.752
Habitat (marsh)	2.788	6.753	0.413	0.680
Habitat (pond)	11.420	4.450	2.566	0.011*
Habitat (moist soil)	2.547	5.350	0.476	0.634

Green-winged teal				
	Estimate	Std. Error	t value	p value
Site 2	10.546	6.372	1.655	0.099
Site 3	10.748	6.501	1.653	0.099
Site 4	15.035	6.815	2.206	0.028*
Sex (male)	-17.093	3.684	-4.640	<0.001*
Age (immature)	-2.255	5.923	-0.381	0.704
Habitat (cropland)	-25.022	36.109	-0.693	0.489
Habitat (marsh)	7.310	6.894	1.060	0.290
Habitat (pond)	1.747	7.755	0.225	0.822
Habitat (moist soil)	-5.851	5.600	-1.045	0.297

Table G1 Continued

Northern pintail				
	Estimate	Std. Error	t value	p value
Site 2	-27.290	49.440	-0.552	0.582
Site 3	-11.620	42.860	-0.271	0.787
Site 4	15.700	35.720	0.440	0.661
Sex (male)	18.680	19.320	0.967	0.336
Age (immature)	15.200	22.510	0.675	0.501
Habitat (cropland)	-79.920	59.110	-1.352	0.180
Habitat (marsh)	-38.670	54.130	-0.714	0.477
Habitat (pond)	-23.200	44.550	-0.521	0.604
Habitat (moist soil)				

Gadwall				
	Estimate	Std. Error	t value	p value
Site 2	46.594	12.882	3.617	<0.001*
Site 3	46.042	34.130	1.349	0.179
Site 4	12.720	21.014	0.605	0.546
Sex (male)	-40.654	10.403	-3.908	<0.001*
Age (immature)	-6.854	10.245	-0.669	0.505
Habitat (cropland)	-104.485	65.731	-1.590	0.114
Habitat (marsh)	-7.475	19.066	-0.392	0.696
Habitat (pond)	23.404	18.539	1.262	0.209
Habitat (moist soil)	-9.925	11.815	-0.840	0.402

Northern shoveler				
	Estimate	Std. Error	t value	p value
Site 2	31.862	10.888	2.926	0.004*
Site 3	-7.932	14.381	-0.552	0.582
Site 4	-0.956	10.299	-0.093	0.926
Sex (male)	-30.261	7.882	-3.839	<0.001*
Age (immature)	11.217	7.702	1.456	0.147
Habitat (cropland)	-13.262	23.075	-0.575	0.566
Habitat (marsh)	3.421	14.291	0.239	0.811
Habitat (pond)	3.795	15.044	0.252	0.801
Habitat (moist soil)	-15.530	8.687	-1.788	0.076

APPENDIX H

ALL HABITAT AND MANAGEMENT AKAIKE INFORMATION CRITERION (AIC) MODEL RESULTS

Table H1: Model evaluation parameters for models that are within Δ2 of the top model, for each species, predicting scaled mass index (SMI) with habitat type and management intensity. For each species, the significant effects of previous models (i.e. collection day and year, sex, age class, and two-way interactions), habitat type, management score, and relevant two-way interactions on SMI were evaluated by comparing models derived from a global model. Fixed model predictors are listed in the first row, followed by AIC model evaluation parameters. A "+" or numerical value in the column of a predictor indicates that predictor was included in the model. A : indicates an interaction, "df" is degrees of freedom, "logLik" is the log likelihood, and "delta" indicates the difference between the AICc values of the top model and the model in question. Bold models are those that were used in further analysis (i.e., determined to be the "top" model by our model selection criteria).

Blue-winged teal

Age	Day	Habitat	Management	Sex	Year	Age:Habitat	Age:Management	Habitat:Sex	Management:Sex	df	logLik	AICc	delta
		+	22.000	+	20.550				+	8	-1150.100	2316.800	0.000
		+	**26.380**	**+**	**20.470**					**7**	**-1151.465**	**2317.400**	**0.590**
+		+	20.850	+	20.130				+	9	-1149.316	2317.400	0.590
+		+	25.420	+	20.070					8	-1150.774	2318.200	1.350

Green-winged teal

Age	Day	Habitat	Management	Sex	Year	Age:Habitat	Age:Management	Habitat:Sex	Management:Sex	Sex:Year	df	logLik	AICc	delta
	-0.179			+	-18.430					+	6	-1153.137	2318.600	0.000
				+	**-15.210**					**+**	**5**	**-1154.857**	**2320.000**	**1.330**

Table H1 Continued

Green-winged teal

Age	Day	Habitat	Management	Sex	Year	Age:Habitat	Age:Management	Habitat:Sex	Management:Sex	Sex:Year	df	logLik	AICc	delta
	-0.172			+	-9.517						5	-1154.874	2320.000	1.370
+	-0.184			+	-18.920					+	7	-1153.039	2320.600	1.930

Northern shoveler

Age	Day	Habitat	Management	Sex	Age:Habitat	Age:Management	Day:Sex	Habitat:Sex	Management:Sex	df	logLik	AICc	delta
+	-1.183	+		+	+		+			10	-530.926	1084.200	0.000
+	-1.199	+	-13.340	+	+		+			11	-529.685	1084.300	0.030
+	-1.446	+	-14.330	+	+		+	+		13	-527.868	1085.800	1.580
+	**-1.086**		**7.918**	**+**		**+**	**+**			**8**	**-534.195**	**1085.900**	**1.680**
+	-1.279	+	-6.554	+	+		+		+	12	-529.245	1086.000	1.710
+	-1.206	+	-19.830	+	+	+	+			12	-529.322	1086.100	1.870
+	-1.409	+		+	+		+	+		12	-529.334	1086.100	1.890
+	-0.639	+	-14.440	+	+					10	-531.915	1086.200	1.980

Northern pintail

Age	Day	Habitat	Management	Sex	Year	Age:Habitat	Age:Management	Age:Year	Habitat:Sex	Management:Sex	df	logLik	AICc	delta
	-1.832				-106.700						4	-201.920	413.100	0.000
	-1.794		18.800		-91.430						5	-200.798	413.600	0.470
	-2.624		59.520	+	-104.900					+	7	-197.991	414.000	0.850
	-2.265		23.970	+	-106.800						6	-199.760	414.400	1.290
			25.430								**3**	**-204.120**	**415.000**	**1.860**
	-2.136			+	-119.000						5	-201.507	415.000	1.880

Gadwall

Age	Habitat	Management	Sex	Year	Age:Habitat	Age:Management	Age:Year	Habitat:Sex	Management:Sex	df	logLik	AICc	delta
	+	-67.580	+	-63.850					+	8	-574.430	1166.400	0.000
	+	**-76.710**	**+**	**-63.410**						**7**	**-575.709**	**1166.600**	**0.210**
+	+	-69.320	+	-87.910			+			9	-573.819	1167.500	1.170
+	+	-62.600	+	-85.570			+		+	10	-572.945	1168.200	1.870

APPENDIX I

DESCRIPTIVE STATISTICS FOR DUCK SPECIES

Table I1: Whole mass, tarsus, flattened wing cord, and bill (nostril to tip) measurement means, medians, standard deviations, minimums, and maximums for blue-winged teal, green-winged teal, northern pintail, northern shoveler, and gadwall collected in winter (November to January 2017-18 and 2018-19) along the Texas Gulf coast.

Blue-winged teal																					
		Mass (g)					**Tarsus (mm)**					**Wing (mm)**					**Bill (mm)**				
Age	**Sex**	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max
Immature	Female	363.270	362.000	37.980	233.000	480.000	31.590	31.500	1.090	28.800	34.300	187.850	188.000	4.050	179.000	198.000	30.160	30.000	1.280	27.400	33.100
Immature	Male	402.230	402.500	34.580	312.000	495.000	32.610	32.600	1.030	30.000	35.200	196.760	196.000	4.380	187.000	208.000	31.660	31.600	1.130	29.300	34.400
Adult	Female	368.990	366.000	41.770	285.000	573.000	31.800	31.700	1.160	28.400	35.600	188.970	189.000	4.330	177.000	199.000	30.220	30.100	1.420	26.200	34.600
Adult	Male	401.550	400.500	38.450	309.000	566.000	32.620	32.700	1.080	29.700	34.900	197.790	198.000	4.530	186.000	209.000	31.880	32.000	1.200	28.900	34.600

Green-winged teal																					
		Mass (g)					**Tarsus (mm)**					**Wing (mm)**					**Bill (mm)**				
Age	**Sex**	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max
Immature	Female	302.270	291.000	39.360	250.000	451.000	30.290	30.250	0.850	29.000	32.700	183.630	184.000	3.960	176.000	190.000	27.940	27.900	1.030	25.500	30.500
Immature	Male	332.910	334.000	42.170	247.000	438.000	31.420	31.600	1.260	29.600	33.900	190.420	191.000	4.440	180.000	198.000	29.450	29.550	1.390	26.500	32.200
Adult	Female	313.890	310.000	35.920	234.000	483.000	30.550	30.500	1.120	27.100	34.000	185.470	185.500	4.680	171.000	195.000	27.890	27.800	0.930	25.700	31.100
Adult	Male	348.930	343.000	43.740	266.000	557.000	31.310	31.300	1.040	28.400	34.300	193.570	194.000	4.580	179.000	207.000	29.400	29.300	1.100	26.700	33.500

Table I1 Continued

Northern pintail

		Mass (g)					Tarsus (mm)					Wing (mm)					Bill (mm)				
Age	**Sex**	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max
Immature	Female	755.070	773.000	75.020	618.000	860.000	41.790	42.100	1.370	39.700	44.400	259.540	260.000	9.920	231.000	272.000	37.020	36.900	1.270	35.500	39.400
Immature	Male	871.730	888.000	109.440	686.000	1020.000	44.710	45.300	1.480	42.100	46.500	274.300	274.500	6.240	261.000	286.000	39.570	39.350	1.420	37.500	41.600
Adult	Female	794.900	806.000	82.040	628.000	978.000	42.080	42.250	1.450	39.900	44.200	264.370	264.000	9.870	242.000	288.000	36.310	36.200	1.190	33.800	39.100
Adult	Male	951.900	944.500	106.430	754.000	1259.000	44.520	44.550	1.360	41.100	47.100	282.880	283.000	8.290	261.000	302.000	40.200	40.000	1.950	35.600	44.500

Northern shoveler

		Mass (g)					Tarsus (mm)					Wing (mm)					Bill (mm)				
Age	**Sex**	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max
Immature	Female	520.460	509.500	50.410	431.000	711.000	37.150	37.000	1.620	33.200	41.500	236.850	238.000	6.380	220.000	254.000	45.800	45.700	1.600	41.700	51.500
Immature	Male	580.500	572.500	74.910	428.000	849.000	38.710	39.000	1.430	34.600	41.500	249.820	249.500	6.450	236.000	266.000	49.570	49.850	2.020	44.400	55.400
Adult	Female	533.580	521.000	62.630	457.000	689.000	37.130	36.950	1.290	34.900	39.100	240.790	240.000	5.930	230.000	257.000	45.780	46.100	2.270	42.000	50.500
Adult	Male	600.600	589.000	61.090	480.000	832.000	39.050	39.000	1.560	36.300	48.700	256.130	257.000	5.250	244.000	267.000	49.940	49.800	1.810	44.900	53.200

Gadwall

		Mass (g)					Tarsus (mm)					Wing (mm)					Bill (mm)				
Age	**Sex**	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max	Mean	Median	Std dev	Min	Max
Immature	Female	767.240	761.000	75.270	637.000	967.000	41.110	41.200	1.400	37.600	43.900	263.380	264.000	8.050	249.000	278.000	33.210	33.300	1.360	29.900	35.800
Immature	Male	843.700	859.000	66.940	690.000	1010.000	42.440	42.300	1.220	39.500	46.500	279.750	279.000	6.310	268.000	296.000	35.740	35.900	1.260	32.700	38.600
Adult	Female	777.930	776.000	69.350	614.000	1040.000	41.140	41.100	1.670	36.600	43.800	265.160	266.000	6.260	249.000	278.000	33.420	33.500	1.450	30.100	37.400
Adult	Male	889.610	892.000	91.510	685.000	1053.000	43.010	43.100	1.350	40.400	47.600	285.280	285.000	5.890	274.000	295.000	36.000	36.000	1.410	33.200	39.900