TIME-ACTIVITY BUDGETS, BODY CONDITION, AND LIPID PREDICTION MODELS OF WINTERING DIVING DUCKS ON EAST TEXAS RESERVOIRS

By

SHAUN L. CROOK, B.S.F.

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ABSTRACT

To date, no work has focused specifically upon behavior and body condition of diving ducks wintering on east Texas reservoirs. During November – March, 2003 - 2004 and 2004 - 2005 seasons, I (1) developed time-activity budgets, (2) estimated body condition, and (3) developed lipid prediction models for canvasback (*Aythya valisineria*), lesser scaup (*Aythya affinis*), and ring-necked duck (*Aythya collaris*) during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs.

Behaviors were measured for each species using focal individual sampling during both study years. More than 1220 focal samples were collected for canvasback (n = 640), lesser scaup (n = 313), and ring-necked duck (n = 271) during approximately 50 hours of observation during this study. Behaviors varied among species ($P < 0.001$) in the proportion of time spent feeding and locomoting. Ring necked duck spent almost 30% of the time feeding, whereas canvasback spent only 19% of the time feeding, and nearly 40% of the time in locomotion activities. Lesser scaup tended to spend intermediate amounts of time in both behaviors. Time spent in loafing, comfort, and sleeping behaviors were similar among species ($P > 0.140$); combined these behaviors accounted for 31-34% of time activity budgets for all species combined. Few courtship or agonistic behaviors were observed for any species in either year.

A total of 248 ducks were collected between 8 November 2003 – 23 January 2004 and 3 November 2004 – 2 March 2005 to estimate body condition and develop lipid prediction models from morphological and internal tissue measures obtained from the birds. In general, average lipid content of diving ducks during this study ranged between 19-35%, depending on species and age and sex within species. Several significant models ($P < 0.05$) were successfully developed using a combination of morphological and internal fat and tissue measures. Model variables differed depending on species and age and sex within species, although skin mass was an important variable in most models, and alone accounted for 69-86% of the variation in percent lipid content.

This study generated important information of how diving ducks utilize reservoirs in east Texas. Diving ducks in this study had time-activity budgets similar to other studies, and also maintained relatively high lipid levels. This information may suggest that these reservoirs are providing sufficient habitat for wintering diving ducks. However, little is known of the quality/quantity habitat these reservoirs are providing for wintering diving ducks. Therefore, future research is needed to better understand the type of habitat these reservoirs are providing.

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CHAPTER I

TIME-ACTIVITY BUDGETS OF WINTERING DIVING DUCKS ON EAST TEXAS RESERVOIRS

INTRODUCTION

Several diving duck species have experienced long-term population declines throughout North America, resulting in reduced bag limits, shortened seasons, and outright season closures (Austin et al. 2000, Afton and Anderson 2001). Loss, degradation, and alteration of breeding, migrating, and wintering habitats are thought to have contributed to these long-term declines (Day et al. 1993, Baldassarre and Bolen 1994). Consequently, much research has been performed on diving ducks during summer (Doty et al. 1984, Noyes and Jarvis 1985, Barzen and Serie 1990), migration (Serie and Sharp 1989, Lovvorn 1990, Hine et al. 1996, Knapton et al. 2000), and winter (Hohman 1984, Bergan et al. 1989, Hohman and Rave 1990, Day et al. 1993) to examine what regulates waterfowl populations. Although reproductive success is generally perceived as the primary limiting factor for waterfowl (Anderson and Batt 1983, Krapu et al. 2000, Afton and Anderson 2001), and many studies have focused upon breeding season habitat use and behaviors (Dwyer 1975), waterfowl are also impacted by habitat, environmental changes (Quinlan and Baldassarre 1984, Miller 1985, Hohman and Rave 1990), and human disturbances during other seasons (Havera et al. 1992, Knapton et al. 2000). As such, events during winter may impact immediate survival, mate attraction, and subsequent migration and reproductive success (Frederickson and Heitmeyer 1981, Haramis et al. 1986, Kaminski and Gluesing 1987).

Time-activity budget studies of wintering waterfowl provide insight into seasonal habitat use (Rave and Baldassarre 1989, Baldassarre and Bolen 1994, Poulton et al. 2002, Michot et al. 2006), and the influence of hunting pressure, habitat changes, environmental variability, and other disturbances on behavior (Quinlan and Baldassarre 1984, Hohman and Rave 1990, Michot et al. 1994, Knapton et al. 2000, Woodin and Michot 2006). Wintering waterfowl generally spend most of their time feeding and loafing (Paulus 1988, Bergan et al. 1989, Michot et al. 1994, Woodin and Michot 2006), where deviations from normal activity budgets may severely affect energy budgets, reduce survival, and impair reproductive productivity and success (Burton and Hudson 1978, Haramis et al. 1986, Hepp et al. 1986, Paulus 1988). For example, during winter, waterfowl are often exposed to adverse or deteriorating environmental and habitat conditions (Nilsson 1970, Quinlan and Baldassarre 1984, Hohman and Rave 1990), changes in food quality and quantity (Thompson et al. 1988, Hohman and Rave 1990, Michot et al. 2006), hunting, and other disturbances, (Korschgen et al. 1985, Havera et al. 1992, Knapton et al. 2000) all of which may alter normal activity and energy budgets. Therefore, wintering waterfowl time-activity budgets can be used to evaluate relative habitat/food quality and quantity, hypothesize about energy demands and/or ability to meet those demands, compare activity patterns within and among species using similar habitats in different geographic regions, and project perceived responses to proposed management or conservation activities (Hohman 1984, Paulus 1988, Woodin and Michot 2006).

While many studies have focused on diving duck behavior (Hohman 1984, Bergan et al. 1989, Hohman and Rave 1990, and others), nutritional ecology (Hoppe et al. 1986, Hohman et al. 1990, Hohman 1993), and population biology during winter (Hohman et al. 1993, Herring and Collazo 2004), no studies have specifically developed time-activity budgets for diving ducks wintering in inland reservoir habitats in Texas. An estimated 97%, 99%, and 98% of the Central Flyway populations of canvasback (*Aythya valisineria*), lesser scaup (*A. affinis*), and ring-necked duck (*A. collaris*) respectively, winter in Texas (U.S. Fish and Wildlife Service 2003). Within the Pineywoods Ecoregion of east Texas, 3 manmade reservoirs (i.e., Toledo Bend, Sam Rayburn, and B. A. Steinhagen) provide potentially important wintering diving duck habitat. Prior to impoundment, these were primarily bottomland hardwood ecosystems, and provided habitat for dabbling ducks during winter and wood ducks (*Aix sponsa*) year round. However, after impoundment and with subsequent development of deep-water habitats and extensive submerged aquatic vegetation, these reservoirs provide suitable habitat for wintering diving ducks. As such, developing diving duck time-activity budgets on these reservoirs will (1) provide critical insight into how diving ducks partition time into different behaviors among species and among reservoirs, (2) allow for speculation about how these birds meet dietary/energy demands during winter, and (3) improve conservation and management strategies of these habitats for wintering diving ducks. Therefore, the objective of this study was to develop diurnal time-activity budgets of canvasback, lesser scaup, and ring-necked duck wintering on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas.

STUDY AREA

The Pineywoods Ecoregion of Texas is 1 of 6 major waterfowl habitat regions within the state (Moulton et al. 1988); encompassing 38 counties, it is comprised primarily of pine (*Pinus* spp.), hardwood, and mixed pine-hardwood forests (Figure 1.1). Bottomland hardwood forests, sloughs, freshwater marshes, and ponds are scattered throughout the region. There are > 30 major reservoirs on portions of the Angelina, Cypress, Neches, Red, Sabine, and Sulphur Rivers (Figure 1.1) (Moulton et al. 1988).

This research was conducted on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas (Figure 1.1). Toledo Bend Reservoir encompasses almost 75,000 ha extending into portions of Newton, Panola, Sabine, and Shelby counties, Texas, and De Soto and Sabine parishes, Louisiana (Wood 1972). Impounded in 1966, the reservoir is managed for water, hydroelectric generation, and recreation. Sam Rayburn Reservoir encompasses > 46,000 ha, extending into portions of Angelina, Jasper, Nacogdoches, Sabine, and San Augustine counties, Texas. Impounded in 1965, the reservoir is managed for flood control, hydroelectric power, and water for municipal, industrial, agricultural, and recreational uses (Rockwood and Whiting 1992). B. A. Steinhagen Reservoir encompasses > 6,800 ha; it extends into portions of Jasper and Tyler counties (Scaief 1985). Filled in 1951, with a maximum depth of 10.7 m, the reservoir is managed for flood control, water, and recreation.

METHODS

Time-activity Budgets

Time-activity budgets (*sensu* Bergan et al. 1989, Poulton et al. 2002) were developed for canvasback, lesser scaup and ring-necked duck wintering on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs from 19 November 2003 -13 March 2004 (study year 1) and 8 November 2004 - 18 February 2005 (study year 2). Behavior data were collected on each reservoir ≥ 1 day/week during each study year, depending upon weather and environmental conditions. Focal species (i.e., canvasback, lesser scaup, and ring-necked duck) were located (1) the evening prior to behavioral sampling, or (2) on the sampling day, where birds were found using binoculars and spotting scopes from a boat. Once located, behavioral data were collected while in the boat or from temporary blinds established on a nearby shoreline. Attempts were made to prevent disturbing the birds by maintaining a minimum observer-to-bird distance of 200 m.

When focal species were located, flock (i.e., raft) size and species composition was recorded. The focal-individual sampling technique was used to collect behavior data (Altmann 1974, Bergan et al. 1989, Poulton et al. 2002). Behavior data were collected from randomly selected individuals within rafts by selecting the bird closest to the center of the field of view (Bergan et al. 1989, Poulton et al. 2002). Each individual was observed for a maximum of 5 min.

(DeLeon and Smith 1999, Poulton et al. 2002), where the following behaviors were continuously recorded into a tape recorder: (1) feeding/food acquisition (i.e., surface or subsurface feeding), (2) inter-dive loaf (i.e., loafing between dives), (3) locomotion (i.e., swimming or flying), (4) agonistic (i.e., bill threats, chasing, and other aggressive behaviors), (5) loafing (i.e., stationary position with partially or fully retracted neck), (6) comfort movements (i.e., preening, stretching, bathing, etc.), (7) sleeping (i.e., bill tucked under wing), (8) courtship (i.e., pair bond displays, copulation, and head-pumping), and (9) out-of-sight (i.e., bird lost from view while on water surface) (Hohman 1984, Bergan et al. 1989, Hohman and Rave 1990, Byrkjedal 1997). If an individual was lost from view for > 10 s, that sample was terminated, a new individual was randomly selected, and a new focal sample was initiated. After 5 min of collecting data, the observer rested for 5 min. before initiating a new focal sample on a different individual of the same species but opposite sex. Attempts were made to sample equal numbers of males and females. If mixed-species rafts were encountered, data were collected on a different species each hour (Bergan et al. 1989). Sampling was terminated when (1) activities of each bird within small flocks (< 20 birds) had been sampled, (2) birds flushed or moved too far to be observed, or (3) birds could no longer be observed due to darkness. At the initiation of the study, a single observer was used to collect data. As new observers (n = 6) were added, they were trained to identify each behavior by the experienced observer.

Data Analysis

Time-activity budgets were developed by calculating the proportion (%) of time spent in each behavior for each focal sample. Each individual bird for which a focal sample was collected was the experimental unit. A factorial multivariate analysis of variance (MANOVA) was used to examine differences in proportion of time spent in specific behaviors (i.e., feeding/food acquisition, inter-dive loaf, locomotion, agonistic, loafing, comfort, sleeping, and courtship) among species (i.e., canvasback, lesser scaup, and ring-necked duck), between sexes, among reservoirs (i.e., B. A. Steinhagen, Sam Rayburn, and Toledo Bend), between seasons (i.e., season 1, 1 November–10 January; season 2, 11 January–13 March), and between study years. MANOVA was used because individual behaviors are not independent (Davis and Smith 1998). If differences occurred ($P < 0.05$) in MANOVA, univariate analysis of variance (ANOVA) was used to examine where differences ($P < 0.05$) occurred in MANOVA. Least squares mean separation was used to examine differences ($P < 0.05$) occurring during ANOVAs (DeLeon and Smith 1999).

RESULTS

Time-activity Budgets

A total of 1,275 focal samples were collected for canvasbacks (*n* = 663), lesser scaup (*n* = 332), and ring-necked ducks (*n* = 280), from 106 hours of observations. Only 19 lesser scaup and 9 ring-necked duck focal samples were collected on B.A. Steinhagen and Sam Rayburn Reservoirs, respectively, therefore these observations were removed from subsequent analyses.

Behaviors varied among species (Wilks' $\lambda = 0.95$; 18, 2462 df; $P < 0.001$) (Table 1.1), between study years (Wilks' $\lambda = 0.97$; 9, 1231 df; $P < 0.001$) (Table 1.2), between seasons (Wilks' $\lambda = 0.96$; 9, 1231 df; $P < 0.001$) (Table 1.3), between sexes (Wilks' $\lambda = 0.99$; 9, 1231 df; $P = 0.047$) (Table 1.4), and among reservoirs (Wilks' $\lambda = 0.96$; 18, 2462 df; $P < 0.001$) (Table 1.5). Species x season (Wilks' $\lambda = 0.88$; 27, 3581 df; $P < 0.001$) (Tables 1.6, 1.7), species x lake (Wilks' $\lambda = 0.93$; 36, 4596 df; $P <0.001$) (Tables 1.8, 1.9), and species x study year (Wilks' $\lambda = 0.94$; 27, 3581 df; $P <0.001$) (Tables 1.10, 1.11) interactions also occurred.

Regardless of species, food acquisition, locomotion, and resting-related behaviors dominated time-activity budgets (Table 1.1). Very little time (generally < 2%) was spent in alert, agonistic, or courtship behaviors (Table 1.1).

Canvasbacks spent the most time locomoting and the least time in food acquisition behaviors, while lesser scaup and ring-necked ducks spent similar time in food acquisition behaviors (Table 1.1). Although ring-necked ducks spent more time loafing than canvasbacks or lesser scaup, all 3 species spent similar amounts of time in resting-related behaviors (Table 1.1).

Irrespective of species, behaviors were generally similar ($P > 0.05$) between study years. However, during study year 1 ducks spent more time feeding than in study year 2; in the second year, they spent more time loafing (Table 1.2). Behaviors were generally similar ($P < 0.05$) between seasons, although more time was spent loafing and sleeping in season 1, and more time was spent feeding in season 2 (Table 1.3). Although time-activity budgets were similar between males and females, males tended to spend more time loafing than females (Table 1.4). More time was spent feeding on Toledo Bend and Sam Rayburn than B.A. Steinhagen, where focal species spent the most time loafing and sleeping (Table 1.5). Focal species spent more time locomoting on Sam Rayburn than either Toledo Bend or B. A. Steinhagen (Table 1.5).

Canvasback and ring-necked duck increased time spent feeding between seasons, whereas time spent in feeding behaviors was consistent between seasons for lesser scaup (Tables 1.6, 1.7). Canvasbacks reduced loafing time from season 1 to season 2, while loafing behaviors were similar between seasons for lesser scaup and ring-necked duck (Tables 1.6, 1.7). All 3 species spent more time feeding on Toledo Bend than the other reservoirs, while canvasbacks spent more time (> 50 %) locomoting on Sam Rayburn than Toledo Bend or B. A. Steinhagen (Tables 1.8, 1.9). Lesser scaup spent more time locomoting on Sam Rayburn than Toledo Bend, while ring-necked duck locomoting time was similar between Toledo Bend and B. A. Steinhagen (Tables 1.8, 1.9). Although loafing behaviors varied ($P < 0.05$) among species and lakes, time spent loafing was consistent among reservoirs within each species (Tables 1.8, 1.9).

Ring-necked duck and lesser scaup tended to feed more during study year 1 than study year 2, whereas time spent feeding was similar between study years for canvasbacks; both canvasbacks and lesser scaup spent more time loafing during study year 2 (Tables 1.10, 1.11). Canvasbacks spent more time in comfort behaviors in study year 1, whereas comfort behaviors were similar between years for lesser scaup and ring-necked duck, although both spent more time sleeping during study year 2. Sleeping behaviors were similar between years for canvasbacks (Tables 1.10, 1.11).

Study Year 1

Because of a species x study year interaction, further analyses were performed within each year. Within study year 1, behaviors varied among species (Wilks' $\lambda = 0.92$; 18, 1270 df; $P < 0.001$) (Table 1.12), between seasons (Wilks' $\lambda = 0.92$; 9, 635 df; $P < 0.001$) (Table 1.13), between sexes (Wilks' $\lambda = 0.97$; 9, 635 df; $P = 0.027$) (Table 1.14), and among reservoirs (Wilks' $\lambda = 0.92$;

18, 1270 df; $P < 0.001$) (Table 1.15).

Irrespective of season, lake, or sex, behaviors varied ($P < 0.05$) among species; except for agonistic, sleeping, courtship, and alert behaviors during study year 1 (Table 1.12). Canvasbacks spent more time locomoting and less time in food acquisition behaviors than lesser scaup or ring-necked duck, which spent similar time in both food acquisition and locomoting behaviors (Table 1.12). With data from all 3 species pooled, behaviors were generally similar ($P > 0.05$) between seasons, although food acquisition and alert behaviors increased and loafing and sleeping behaviors decreased from season 1 to season 2 (Table 1.13). Time-activity budgets were generally similar ($P > 0.05$) between sexes, with females spending slightly more time in agonistic behaviors than males (Table 1.14). Diving ducks spent more time in food acquisition behaviors on Toledo Bend than B. A. Steinhagen, but were similar between Sam Rayburn and the other 2 reservoirs. All 3 species spent more time sleeping on B. A. Steinhagen than either Toledo Bend or Sam Rayburn (Table 1.15).

Study Year 2

Within study year 2, behaviors varied among species (Wilks' $\lambda = 0.94$; 18, 1164 df; $P = 0.004$) (Table 1.16), between seasons (Wilks' $\lambda = 0.95$; 9, 582 df; $P < 0.001$) (Table 1.17), and among reservoirs (Wilks' $\lambda = 0.93$; 18, 1164 df; $P < 0.001$) (Table 1.18), but were similar between sexes (Wilks' $\lambda = 0.99$; 9, 582 df; $P = 0.576$) (Table 1.19).

Locomotion and sleeping behaviors varied ($P < 0.05$) among species during study year 2 (Table 1.16). Canvasbacks tended to spend more time locomoting, while ring-necked duck and lesser scaup spent more time sleeping than canvasbacks (Table 1.16). Feeding, loafing, inter-dive loaf, and alert behaviors varied ($P < 0.05$) between seasons; all 3 species increased time spent in food acquisition and decreased time spent loafing from season 1 to 2 (Table 1.17). Time-activity budgets were generally similar among reservoirs in study year 2, although diving ducks spent the more time in locomotion behaviors on Sam Rayburn and more time loafing on B. A. Steinhagen than on the other reservoirs (Table 1.18). Time-activity budgets were generally similar ($P > 0.05$) between sexes in study year 2 (Table 1.19).

DISCUSSION

Variability Among Studies

There is a tremendous body of wintering waterfowl behavior literature, where most studies attempt to link behavioral, environmental, and other factors with (1) observed time partitioning into different activities and (2) the potential fitness, condition, and/or survival consequences of deviations from "normal" winter activity budgets (see Paulus 1988 for a review of early literature). Variation in time activity budgets for focal species in this study as compared to other studies, may be attributed to a complex, interrelated suite of factors. For example, variation in behavioral sampling techniques (Green et al. 1999, Hepworth and Hamilton 2001, Poulton et al. 2002), waterfowl food acquisition technique(s) (see Tome and Wrubleski 1988), diet (Hoppe et al. 1986, Thompson et al. 1988, Gammonley and Heitmeyer 1990, Hohman and Rave 1990, Custer and Custer 1996), habitat, food availability and/or patchiness, and food quality or nutritional value (Hohman 1984, Alexander 1987, Paulus 1988, Hohman and Rave 1990), weather (see Nilsson 1970), season, geographic location, year, inter- or intraspecific competition (Alexander 1987) may all partially explain differences in time activity budgets within and among studies. Consequently, I developed a summary table of time-activity budgets of wintering canvasback, lesser scaup, and ring-necked duck in order to draw relative conclusions about fitness, condition, and/or survival of focal species in this study as compared to other studies (Table 1.20).

In general, time-activity budgets developed during this study were similar to those of other studies, where activity budgets were dominated by food acquisition, locomotion, and resting related behaviors although how species partitioned time varied among studies (Table 1.20). In this study, canvasback spent approximately 25% (range: 16 – 32%) of their time in food acquisition behaviors (i.e., feeding and inter-dive loaf), within the 13-33 % estimates from other winter studies (Table 1.20). Conversely, canvasback generally spent less time resting (20-26%) and more time locomoting (37-53%) than other studies (30-42% resting and 19-29% locomoting) (Table 1.20). Similarly, lesser scaup spent approximately 36% of their time feeding, similar to lesser scaup in Mississippi (35%) (Christopher and Hill 1988) and South Carolina (31%) (Bergan et al. 1989), but higher than in California (24%) (Poulton et al. 2002) (Table 1.20). Time spent in resting behaviors (19-27%) was also within the range of estimates from other studies (10-28%), but like canvasback, lesser scaup tended to locomote more in this study (Table 1.20). Ring-necked ducks spent approximately 42% of their time feeding, similar to ring-necked ducks in South Carolina (44%) (Bergan et al. 1989), Mississippi (36%) (Christopher and Hill 1988), and central Florida (35%) (Hohman 1984) (Table 1.20). Similar patterns of resting and locomoting were also observed for ring-necked ducks, where time spent resting were within ranges of other studies, but locomoting activities were higher in this study than (Table 1.20).

Although time spent in feeding activities for diving ducks can be misrepresented, depending upon sampling technique used (i.e., instantaneous, scan, or focal individual sampling), my data are within ranges reported in other studies (Table 1.20). Beyond specific data sampling techniques, many studies used fixed blinds from which to collect data (Alexander 1980, Hohman 1984, Hohman and Rave 1990), as opposed to use of boats or portable blinds established opportunistically at random shoreline locations (this study). However, collecting data from a fixed versus random location is a rarely considered sampling issue, where use of 1 or more fixed locations may bias time activity budgets to a few obvious or site specific behaviors (Green et al. 1999). During this study, birds did not occur at predictable locations within study site reservoirs, thus if birds were not located the prior evening, I had to search the designated reservoir each sampling day. Therefore, I assume there were no specific behavioral biases associated with sampling location, and my data truly represent the diurnal activity budgets of focal species. Although these sampling (i.e., technique and location) issues could be sources of variability among studies, my data are generally within the ranges reported in other studies (Table 1.20) and it appears that these diving ducks behave quite similarly among geographic regions.

Weather and seasonal variability

Wintering waterfowl time-activity budgets are directly influenced by weather conditions, where waterfowl will adjust time spent feeding, resting, and loafing in response to changes in temperature and other environmental factors (i.e., winds, waves, tides, etc.) (Goudie and Ankney 1986, Paulus 1988, Hohman and Rave 1990, Michot et al. 1994, Green et al. 1999, Lewis et al. 2005, Michot et al. 2006, Woodin and Michot 2006). Generally, ducks wintering in northerly regions tend to feed more than those in southerly regions, as costs and energy demands of thermoregulation in colder climates are higher than in warmer climates (Ryan 1972, Perry et al. 1986, Hohman and Weller 1994, Lovvorn 1994). However, thermoregulatory and metabolic costs are inversely related to body size, where smaller species incur higher costs under normal weather conditions (i.e., feed more frequently), and costs are intensified in colder weather (Goudie and Ankney 1986). Deviations from these generalized patterns frequently occur; diving ducks and sea ducks will frequently stop feeding and loaf/rest in extreme cold weather < 0°C (Paulus 1988, Baldassarre and Bolen 1994), as the thermoregulatory costs of continued feeding in such conditions exceed benefits gained by food consumption (Goudie and Ankney 1986, Paulus 1988). Even in generally warmer regions, diving ducks will feed more in colder weather up to an unknown thermoregulatory threshold, beyond which they cease feeding and loaf or rest more (*sensu* Hohman and Rave 1990, Michot et al. 1994).

Although weather variables were not specifically examined in this study, the observed similarities in time spent foraging as compared to studies performed in southerly portions of each species' winter range are not unexpected (Table 1.20). As such, it would appear that although weather will influence feeding activity of diving ducks in southerly wintering grounds (Hohman and Rave 1990, Michot et al. 1994), extended periods of extreme cold rarely occur, and weather influences upon these species' time-activity budgets are generally similar throughout the southeastern U.S.

Although specific weather events will influence activity budgets, non-breeding waterfowl exhibit fairly fixed feeding patterns as related to month or season (Paulus 1988). Non-breeding waterfowl typically spend significant time feeding in fall (August-November) to recover from breeding and migration, decrease feeding in mid-winter (December-January) to conserve energy, particularly in colder climates, and increase time feeding in late-winter/early spring (February-April), due to premigratory hyperphagia and subsequent breeding activities (Tamisier 1974, Miller 1985, Paulus 1988). Although my data do not specifically fit these seasonal windows (Table 1.3), canvasback and ring-necked duck exhibited the aforementioned generalized behavioral adjustments between seasons, whereas lesser scaup fed at consistent rates throughout the study period, and slept more later in winter than earlier (Tables 1.6 and 1.7).

External to weather influences, changes in feeding patterns are often explained in terms of food resources, where it has been hypothesized that seasonal activity budget alterations are related to food availability (i.e., patchiness or size), dietary switches, energetic quality (Paulus 1988, Michot and

Chadwick 1994), and timing of hunting season (Evans and Day 2001). Food patchiness may influence time spent feeding in several ways. Patchiness may increase search time, where non-uniform food distribution in late winter may force birds to search longer during dives and utilize foods outside of the optimal size category (Hoppe et al. 1986, Woodin and Michot 2006). Combined, these may all increase feeding costs, due to lower energy/nutrient acquisition, and decrease energetic benefits.

During late winter, ducks may switch food types altogether (i.e., plants to invertebrates, or vice versa), and/or switch to lower quality, but more abundant foods (*sensu*, Paulus 1982). For example, redheads increase time spent diving in late winter in tidal habitats, as opposed to shallow water foraging earlier in winter, perhaps due to depleted food (Woodin and Michot 2006). Finally, divers have been shown to feed more and rest less diurnally after hunting season in Europe. This pattern was likely intertwined with predictable seasonal behavioral shifts and/or abandonment of nocturnal foraging after hunting season (*sensu* Evans and Day 2001).

Diet and Food Availability

Food preferences, availability, and energy content are important elements influencing waterfowl behavior, where birds consuming foods with low water/high energy content spend less time feeding than birds consuming lower quality foods (Paulus 1988). It has been well established that lesser scaup predominantly feed upon animal matter during winter (Harmon 1962, Hoppe et al. 1986, Tome and

Wrubleski 1988, Gammonley and Heitmeyer 1990, Custer and Custer 1996, Poulton et al. 2002, Fox et al. 2005), while canvasback and ring-necked duck feed primarily on plant matter during winter (Hohman and Weller 1994, Hoppe et al. 1986, Hohman and Rave 1990). However, diets are directly influenced by geography and food availability at a given locale (Jones and Drobney 1986, Paulus 1988, Haramis et al. 2001).

Esophagus and gizzard contents examined during this study (see Chapter II) showed that canvasback and ring-necked duck primarily fed on vegetation (i.e., *Hydrilla* spp. seeds, tubers, leaves, and stems, etc.) while lesser scaup generally fed on invertebrates (i.e., insects, clams, mussels), similar to other studies (Harmon 1962, Hoppe et al. 1986, Jones and Drobney 1986, Gammonley and Heitmeyer 1990, Hohman and Rave 1990, Hohman and Weller 1994, Custer and Custer 1996, Haramis et al. 2001). Animal matter typically contains higher levels of gross caloric energy and water than plant matter, although energy/water content is dependent upon portion of plants examined (i.e., tubers, stems, leaves, or seeds) (Driver 1981, Paulus 1988, Michot and Chadwick 1994). If activity budgets are driven solely by energetic content of food, lesser scaup would theoretically spend less time feeding than the herbivorous canvasback and ring-necked duck. Generally this pattern was not observed in my study (Table 1.1). Overall, canvasback spent less time in food acquisition behaviors than lesser scaup or ring-necked duck, which spent more time in food acquisition behaviors than lesser scaup (Tables 1.1, 1.6, 1.7). Although wintering waterfowl often exhibit mid-winter declines in overall body mass, resulting in increased feeding during late winter (Hohman and Weller 1994), birds collected during this study tended to be in comparatively good condition and increased body mass over time (see Chapter II), making the discrepancies in time spent feeding among species difficult to explain based solely upon dietary preferences or energetic content of foods. It is more likely that differences in time spent feeding among species in this study were a function of a complex combination of dietary requirements, food availability, body size, and morphology.

Beyond simple predictions of behavior patterns based upon known energy content of food items, food availability will also play an important role in activity budgets of wintering waterfowl. If foods are patchy, non-uniformly distributed, discontinuous, or clumped, time spent feeding, or searching for food, would increase (*sensu* Bergan et al. 1989) as birds experiencing such conditions would require more overall matter to meet (or offset) energetic demands needed to find food resources in the first place (Paulus 1988). Based upon activity budgets in this study, food distribution and/or patchiness may not be an important factor influencing feeding behavior of focal species. Although increases in time spent feeding during late winter were observed for canvasback and ring-necked duck, feeding times were either below or well within the ranges of other studies (Table 1.20). Consequently, canvasback and ring-necked duck may have been successful in finding adequate food throughout winter, such that feeding activities never dominated activity budgets for either species throughout this study (Tables

1.1, 1.20).

Some studies have also demonstrated, particularly for scaup, that food size increases during winter because smaller, more manageable food items are selected earlier in winter (Hoppe et al. 1986, Custer and Custer 1996). As larger foods require increased handling time, scaup would be expected to increase feeding activities later in winter (Hoppe et al. 1986). As this pattern was not observed, nor was food size measured, (1) foraging by scaup early in winter may not have altered size structure of preferred food items, or (2) scaup food resources were abundant enough on study reservoirs, such that scaup foraging remained consistent throughout the study period (Paulus 1988).

Habitat and Morphological Variability

If food was not a limiting factor for these focal species, then differences in feeding activities among species may ultimately be related to water depth and species morphology (Lovvorn and Gillingham 1996). Diving ducks should spend more time feeding and have longer inter-dive loaf (i.e., dive recovery) intervals between feeding bouts in deep water habitats. My data generally support this hypothesis. Birds observed at Toledo Bend, the deepest of the 3 study site reservoirs, tended to feed more and spend more time in inter-dive loaf than birds on the shallower Sam Rayburn and B.A. Steinhagen Reservoirs (Table 1.5).

Although water depth might explain general differences in activity budgets among reservoirs, morphological variability among the 3 species may also be an explanation for the observed differences in feeding activities during this study. In theory, smaller birds should feed more than larger birds to (1) compensate for higher metabolic costs per unit body mass and (2) acquire enough foods to compensate for energetic demands not met by foraging upon more energetically valuable foods (Goudie and Ankney 1986). Although the metabolic costs of diving and resting converge at higher body mass and diving is less expensive for larger animals (de Leeuw 1996), smaller birds are more buoyant than larger birds, where the initial costs of overcoming buoyancy upon diving are higher in smaller birds (Lovvorn and Jones 1991). Moreover, underwater swimming is nearly energetically equal to flight, both of which are nearly 10 times as energetically expensive as surface swimming (Goldstein 1988). Similarly, recovery time (inter-dive loaf) should increase in deeper water, as more oxygen is consumed during deeper, longer dives (Lovvorn and Jones 1991). Combined, these hypotheses tend to explain interspecific and reservoir-related variability in time spent feeding and in inter-dive loaf behaviors, where (1) canvasback spent less time in both behaviors than the smaller scaup and ring-necked duck irrespective of reservoir and (2) inter-dive loaf intervals were longer on deeper water reservoirs for all 3 species.

Canvasback may have spent less time feeding because they may be physiologically more efficient at (1) maximizing time spent foraging during a given dive, (2) overcoming buoyancy costs, and (3) thermoregulating during dives (Lovvorn and Jones 1991). As both lesser scaup and ring-necked duck are smaller than canvasback, theory would predict, as observed, that they generally spent more time feeding than canvasback, irrespective of diet. Other studies also support this theory where relatively small buffleheads (*Bucephela albeola*) spent more diurnal time foraging than comparatively larger lesser scaup, ring-necked ducks, or ruddy ducks (*Oxyura dominicus*) (Bergan et al. 1989). Likewise, long-tailed ducks (*Clangula hyemalis*) and harlequins (*Histrionicus histrionicus*) spent between 65-85% of their time feeding, much higher than the larger common eider (*Somateria mollissima*) or black scoter (*Melanitta nigra*) (Goudie and Ankney 1986). Although water depth might not be the only factor causing lesser scaup to spend more time feeding than canvasback; scaup are more visual feeders, whereas canvasback tend to be more tactile feeders (Tome and Wrubleski 1988). If so, then scaup may feed longer, particularly in deeper water, to find food during a dive.

Impacts of Disturbance

Although not specifically quantified in this study, disturbance may be an important element influencing behavior of these species on east Texas reservoirs during winter. All 3 species spent more time locomoting in this study than in other studies (Table 1.20), most notably in canvasback, where locomoting behaviors were 3-4 times higher than in other studies; lesser scaup and ring-necked ducks spent 3-17 % more time locomoting than previously reported (Table 1.20). Canvasbacks were often observed in large rafts on points or bay mouths whereas small flocks of lesser scaup and ring-necked ducks were usually observed in the back of coves. All 3 species were susceptible to recreational boat traffic. Generally, boats traveling at high speeds forced birds on points or bay mouths to swim and/or fly out of the way. Conversely, birds located within a cove were often disturbed by more slowly moving (i.e., fishing) boats, and were usually forced to swim away.

Time spent locomoting varied among reservoirs, where diving ducks spent less time locomoting on Toledo Bend than on the other 2 reservoirs; these differences may also be caused by disturbance. There was more open water on Sam Rayburn where boaters could travel at high speed than on Toledo Bend where high speed boat traffic was restricted to boat lanes. Although B. A. Steinhagen had submerged vegetation and was difficult to navigate, it was relatively small, thus hunting and fishing activities were concentrated which may have increased locomotion as compared to Toledo Bend. On B. A. Steinhagen birds were subjected to varying levels of hunting and boat traffic, the 2 most intense types of disturbance (Korschgen and Dahlgren 1992).

A disproportionate amount of time locomoting would generally indicate that birds would have an unbalanced energy budget. For example, high energetic costs associated with locomotion, especially flight, could offset energetic benefits obtained from feeding, which may compromise the ability of these birds to increase, maintain, or even acquire adequate body fat for overwinter survival (Haramis et al. 1986, Serie and Sharp 1989, Barzen and Serie 1990, Kahl 1991). For example, flight is 12-15 x basal metabolic rate (Frederickson and Reid 1988), whereby canvasback spending an additional 1 hour/day flying due to human disturbance would require a food intake increase of approximately 75 kcal/day above the estimated 400 kcal for maintenance (Korschgen et al. 1985).

Increased time spent locomoting may impact activity budgets in that birds may increase time spent feeding to offset the energetic costs of locomoting. However, neither obvious increases (or decreases) in time spent feeding nor poor body condition estimates were observed during this study. In general, time spent feeding, depending upon species and study site reservoir, was similar to other studies (Table 1.20). Also, the ducks appear to have acquired enough food resources to reach suitable and adequate total body fat levels (see Chapter 2). Taken together, these patterns suggest that the birds may have fed nocturnally, as other studies have shown that increased diurnal disturbance of waterfowl will cause them to increase nocturnal feeding (Pedroli 1982, Hohman 1984, Evans and Day 2001). Consequently, the high proportion of time spent locomoting, particularly for canvasback, may not have necessarily been detrimental to overall body condition levels.

Management and Research Recommendations

Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs are wintering areas to a substantial number of diving ducks and appear to provide suitable winter habitat. However, a potential problem noted in this study was the relatively high rates of locomoting, possibly due to disturbance. Currently, on these reservoirs there are few restrictions on hunting or water-based recreation.

During this study, I regularly observed disturbances from boaters, mainly fishermen and hunters. Therefore, because of the adverse effects of disturbance and the possible increase in water-based recreational activities on these reservoirs, future restrictions on human activities may need to be imposed. This is probably most critical in late winter and early spring when birds are trying to acquire reserves for migration and reproduction.

Further research is needed to (1) examine nocturnal foraging activities, (2) quantify and map the habitats in which birds are actually foraging, (3) perform nutritional analyses of food items likely encountered/used by these species, and (4) quantify disturbance. Such information, along with behavior and body condition data will give managers a clearer understanding of the quantity of habitat these man-made reservoirs are providing for wintering diving ducks.

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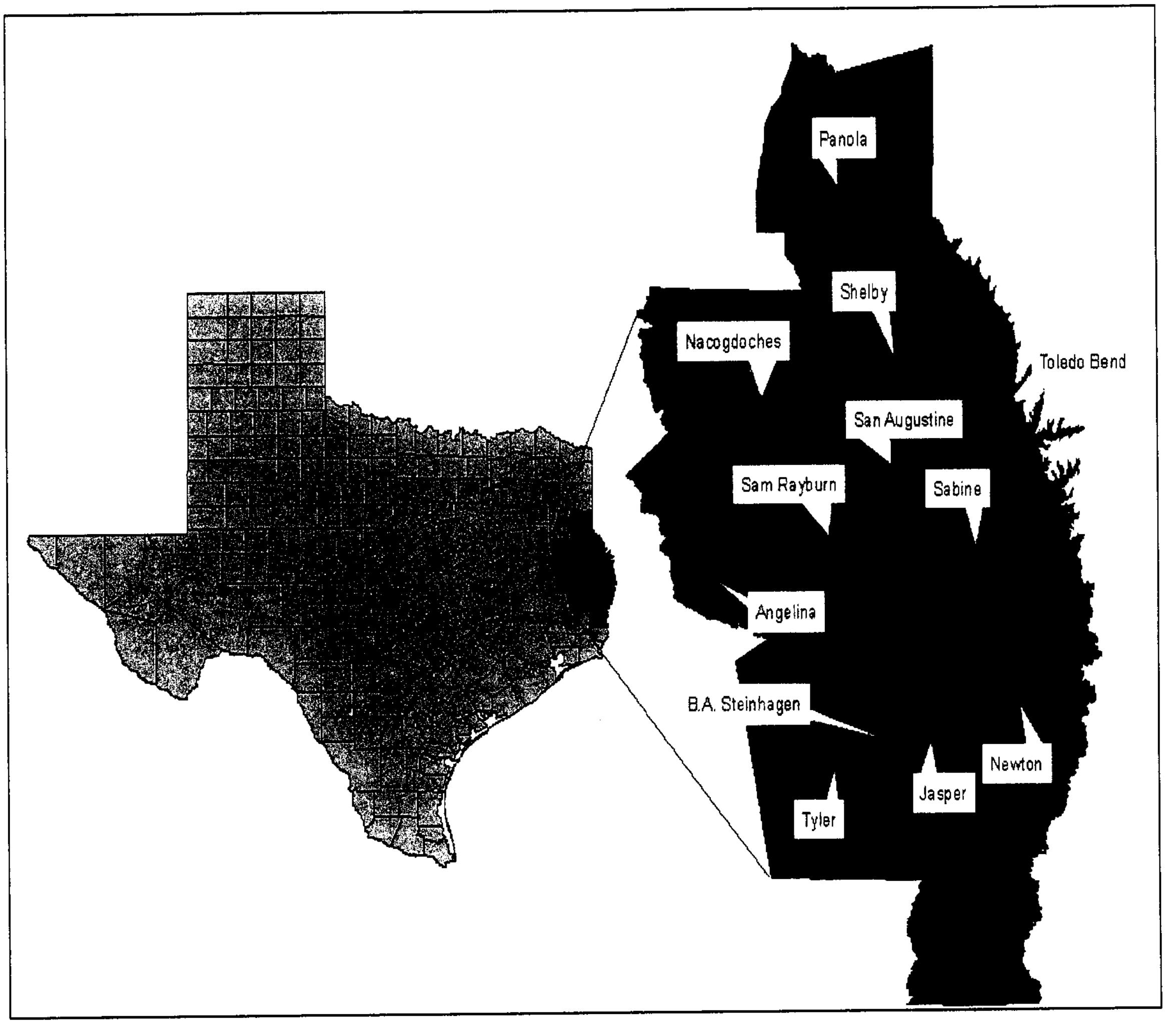

Figure 1.1. Location of Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs within the Pineywoods Ecoregion of east Texas.

Table 1.1. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 and 8 November 2004 - 18 February 2005.

	Canvasback		Lesser scaup		Ring-necked duck			
	(*n* = 663)		(*n* = 313)		(*n* = 271)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	18.24B[1]	0.99	26.82A	1.63	29.88A	1.59	7.06	< 0.001
Locomotion (%)	40.22A	1.34	31.56B	1.79	24.30B	1.52	20.63	< 0.001
Agonistic (%)	< 1.00A	0.01	< 1.00A	0.02	< 1.00A	0.03	2.09	0.124
Loafing (%)	13.59B	0.82	12.62B	1.08	16.18A	1.16	4.43	0.012
Comfort (%)	9.96A	0.81	9.21A	1.06	7.04A	0.94	1.57	0.209
Sleeping (%)	9.80A	1.05	9.24A	1.43	8.62A	1.43	0.77	0.464
Courtship (%)	< 1.00A	0.14	0.00A	0.00	< 1.00A	0.01	0.14	0.872
Inter-dive Loaf (%)	6.70B	0.46	9.45A	0.73	11.84A	0.84	7.33	< 0.001
Alert (%)	< 1.00A	0.29	< 1.00A	0.22	< 1.00A	0.35	1.14	0.320

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.2. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors between study years, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 and 8 November 2004 – 18 February 2005.

	Study year 1 (2003-2004) (*n* = 650)		Study year 2 (2004-2005) (*n* = 597)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	25.37A[1]	1.09	20.27B	1.05	5.69	0.017
Locomotion (%)	33.81A	1.25	35.44A	1.36	0.03	0.865
Agonistic (%)	< 1.00A	0.02	< 1.00A	0.01	1.06	0.304
Loafing (%)	11.58B	0.67	16.45A	0.93	17.08	< 0.001
Comfort (%)	9.90B	0.77	8.31B	0.77	2.93	0.087
Sleeping (%)	8.16A	0.96	10.76A	1.12	2.61	0.106
Courtship (%)	< 1.00A	0.14	< 1.00A	0.01	1.11	0.291
Inter-dive Loaf (%)	9.23A	0.51	7.73A	0.51	2.01	0.156
Alert (%)	< 1.00A	0.21	< 1.00A	0.25	0.90	0.344

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.3. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors between seasons, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 and 8 November 2004 - 18 February 2005.

	Season 1 (1 Nov. – 10 Jan.) (*n* = 546)		Season 2 (11 Jan. – 13 March) (*n* = 701)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	19.13B[1]	1.10	25.88A	1.04	18.55	< 0.001
Locomotion (%)	34.87A	1.38	34.38A	1.24	0.76	0.382
Agonistic (%)	< 1.00A	0.01	< 1.00A	0.02	1.51	0.219
Loafing (%)	16.55A	0.99	11.85B	0.65	21.49	< 0.001
Comfort (%)	9.52A	0.85	8.84A	0.72	0.44	0.506
Sleeping (%)	10.93A	1.21	8.22B	0.90	4.27	0.039
Courtship (%)	0.00A	0.00	< 1.00A	0.13	0.88	0.349
Inter-dive Loaf (%)	7.53A	0.55	9.27A	0.48	2.65	0.104
Alert (%)	< 1.00A	0.28	<1.00A	0.19	0.02	0.894

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.4. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors between sexes, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 - 13 March 2004 and 8 November 2004 - 18 February 2005.

	Male (n = 716)		Female (n = 531)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	23.13A[1]	1.03	22.65A	1.12	0.06	0.814
Locomotion (%)	33.32A	1.22	36.30A	1.41	1.52	0.217
Agonistic (%)	<1.00B	0.01	<1.00A	0.02	4.98	0.026
Loafing (%)	15.15A	0.80	12.24B	0.79	5.05	0.025
Comfort (%)	9.38A	0.74	8.81A	0.82	0.32	0.569
Sleeping (%)	9.35A	0.97	9.48A	1.12	0.03	0.854
Courtship (%)	<1.00A	0.13	<1.00A	0.03	0.74	0.389
Inter-dive Loaf (%)	8.15A	0.47	9.00A	0.57	1.92	0.166
Alert (%)	<1.00A	0.21	<1.00A	0.25	0.31	0.579

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.5. Means (%), Standard Errors (SE), and F and P values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors among reservoirs, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 and 8 November 2004 - 18 February 2005.

	Toledo Bend (n = 562)		Sam Rayburn (n = 286)		B. A. Steinhagen (n = 399)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	F	P
Feeding (%)	27.35A[1]	1.13	23.30AB	1.68	16.42B	1.23	7.84	< 0.001
Locomotion (%)	29.49B	1.26	39.33A	2.04	38.37B	1.69	8.71	< 0.001
Agonistic (%)	0.03B	0.01	0.09A	0.03	0.02AB	0.02	3.14	0.044
Loafing (%)	14.20AB	0.81	11.73B	1.07	15.06A	1.15	3.99	0.019
Comfort (%)	8.25A	0.77	8.93A	1.13	10.54A	1.04	0.85	0.428
Sleeping (%)	8.46B	1.01	8.01B	1.41	11.74A	1.49	3.67	0.026
Courtship (%)	< 1.00A	0.01	0.00A	0.00	< 1.00A	0.23	0.73	0.482
Inter-dive Loaf (%)	10.60A	0.58	7.45B	0.72	6.32B	0.58	6.20	0.002
Alert (%)	< 1.00A	0.23	< 1.00A	0.28	< 1.00A	0.33	0.74	0.477

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.6. Means (%) and Standard Errors (SE) resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors between seasons[1], quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 and 8 November 2004 - 18 February 2005.

	Canvasback				Lesser Scaup				Ring-necked duck			
	Season 1 (n = 286)		Season 2 (n = 377)		Season 1 (n = 183)		Season 2 (n = 130)		Season 1 (n = 77)		Season 2 (n = 194)	
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Feeding (%)	11.43C[2]	1.20	23.41B	1.42	29.45AB	2.23	23.12B	2.28	23.15B	2.59	32.55A	1.94
Locomotion (%)	38.60A	1.98	41.46A	1.81	32.70A	2.33	29.97A	2.79	26.16A	3.10	23.57A	1.73
Agonistic (%)	<1.00A	0.01	<1.00A	0.02	<1.00A	0.03	<1.00A	0.03	<1.00A	0.02	<1.00A	0.04
Loafing (%)	19.97A	1.52	8.75C	0.78	10.99BC	1.32	14.92AB	1.80	17.08A	2.58	15.82A	1.26
Comfort (%)	10.56A	1.28	9.50A	1.05	9.03A	1.36	9.48A	1.71	6.82A	1.77	7.12A	1.12
Sleeping (%)	13.58A	1.87	6.94C	1.16	6.94BC	1.66	12.49AB	2.51	10.57AB	3.06	7.84AB	1.58
Courtship (%)	0.00A	0.00	< 1.00A	0.25	0.00A	0.00	0.00A	0.00	0.00A	0.00	<1.00A	0.02
Inter-dive Loaf (%)	4.47D	0.64	8.40BC	0.65	10.08A	0.98	8.57BC	1.10	12.82AB	1.82	11.45AB	0.92
Alert (%)	1.02A	0.47	0.85A	0.26	0.07B	0.03	1.29A	0.53	1.80A	0.93	0.65B	0.32

[1] Season 1: 1 November – 10 January; Season 2: 11 January – 13 March.

[2] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.7. Type III *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors between seasons[1], quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 – 13 March 2004 and 8 November 2004 – 18 February 2005.

Behavior	*F*	*P*
Feeding (%)	21.15	<0.001
Locomotion (%)	0.40	0.753
Agonistic (%)	1.15	0.329
Loafing (%)	18.62	<0.001
Comfort (%)	0.48	0.696
Sleeping (%)	6.04	<0.001
Courtship (%)	0.41	0.748
Inter-dive Loaf (%)	10.86	<0.001
Alert (%)	3.63	0.013

[1] Season 1: 1 November – 10 January; Season 2: 11 January – 13 March.

Table 1.8. Means (%) and Standard Errors (SE) resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors among reservoirs, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 - 13 March 2004 and 8 November 2004 - 18 February 2005.

	Canvasback						Lesser Scaup				Ring-necked duck			
	Toledo Bend (n = 221)		Sam Rayburn (n = 81)		B.A. Steinhagen (n = 361)		Toledo Bend (n = 108)		Sam Rayburn (n = 205)		Toledo Bend (n = 233)		B.A. Steinhagen (n = 38)	
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Feeding (%)	22.95AB	1.81	13.28D	2.37	16.47CD	1.31	25.99A	2.54	27.26B	2.09	32.16A	1.71	15.88BC	3.56
Locomotion (%)	36.69B	2.23	52.64A	4.02	39.60B	1.80	26.81C	2.86	34.07B	2.26	23.91C	1.64	26.72BC	4.09
Agonistic (%)	<1.00A	0.01	<1.00A	0.03	<1.00A	0.02	0.00A	0.00	<1.00A	0.03	<1.00A	0.03	<1.00A	0.09
Loafing (%)	12.58BC	1.25	11.97BC	2.14	14.57AB	1.20	14.48B	2.07	11.64BC	1.23	15.61AB	1.21	19.71A	3.70
Comfort (%)	10.63A	1.49	7.47A	1.98	10.11A	1.09	8.66A	1.66	9.51A	1.37	5.80A	0.92	14.60A	3.46
Sleeping (%)	7.29A	1.51	9.37A	2.86	11.44A	1.57	12.61A	2.78	7.47A	1.61	7.63A	1.47	14.65A	4.70
Courtship (%)	<1.00A	0.01	0.00A	0.00	<1.00A	0.26	0.00A	0.00	0.00A	0.00	0.02A	0.01	<1.00A	0.03
Inter-dive Loaf (%)	8.63BC	0.88	3.34D	1.03	6.28C	0.61	10.19AB	1.29	9.07C	0.89	12.67A	0.92	6.72C	1.82
Alert (%)	<1.00A	0.39	1.40A	0.56	<1.00A	0.37	0.34A	0.23	<1.00A	0.31	1.12A	0.41	<1.00A	0.10

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.9. Type III *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors among reservoirs, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 – 13 March 2004 and 8 November and 8 November 2004 – 18 February 2005.

Behavior	*F*	*P*
Feeding (%)	8.84	<0.001
Locomotion (%)	4.67	0.001
Agonistic (%)	0.99	0.411
Loafing (%)	4.05	0.003
Comfort (%)	1.14	0.334
Sleeping (%)	1.62	0.167
Courtship (%)	0.25	0.909
Inter-dive Loaf (%)	7.63	<0.001
Alert (%)	1.43	0.220

Table 1.10. Means (%) and Standard Errors (SE) resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors according to study year, measured on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 and 8 November 2004 - 18 February 2005.

	Study Year 1 (2003-2004)						Study Year 2 (2004-2005)					
	Canvasback (*n* = 302)		Lesser Scaup (*n* = 184)		Ring-necked Duck (*n* = 164)		Canvasback (*n* = 361)		Lesser Scaup (*n* = 129)		Ring-necked Duck (*n* = 107)	
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Feeding (%)	17.48C	1.48	30.35AB	2.20	34.30A	1.95	18.89BC	1.32	21.80B	2.33	23.10B	2.57
Locomotion (%)	40.11A	1.99	31.50A	2.20	24.80A	2.00	40.32A	1.81	31.66A	3.01	23.55A	2.35
Agonistic (%)	<1.00A	0.02	<1.00A	0.04	<1.00A	0.04	<1.00A	0.02	<1.00A	0.01	<1.00A	0.04
Loafing (%)	9.86B	0.98	10.14B	1.11	16.37A	1.46	16.71A	1.24	16.16A	2.05	15.90A	1.93
Comfort (%)	12.48A	1.34	9.97AB	1.31	5.07AB	0.95	7.85B	0.97	8.13AB	1.78	10.05AB	1.86
Sleeping (%)	11.73AB	1.72	5.84CD	1.39	4.18D	1.31	8.19BC	1.28	14.09A	2.80	15.42A	2.89
Courtship (%)	<1.00A	0.31	0.00A	0.00	<1.00A	0.02	<1.00A	0.02	0.00A	0.00	<1.00A	0.01
Inter-dive Loaf (%)	6.47A	0.69	10.39A	1.01	13.01A	1.03	6.90A	0.63	8.12A	1.05	10.04A	1.40
Alert (%)	<1.00A	0.30	<1.00A	0.37	1.07A	0.48	<1.00A	0.38	0.00A	0.00	<1.00A	0.50

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.11. Type III *F* and *P* values resulting from univariate analysis of variance of wintering canvasbacks, lesser scaup, and ring-necked ducks according to study year, measured on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 – 13 March 2004 and 8 November 2004 – 18 February 2005.

Behavior	*F*	*P*
Feeding (%)	4.54	0.004
Locomotion (%)	0.33	0.806
Agonistic (%)	0.79	0.500
Loafing (%)	8.14	<0.001
Comfort (%)	3.76	0.010
Sleeping (%)	6.58	<0.001
Courtship (%)	0.47	0.702
Inter-dive Loaf (%)	1.87	0.133
Alert (%)	0.51	0.677

Table 1.12. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004.

	Canvasback (n = 302)		Lesser Scaup (n = 184)		Ring-necked Duck (n = 164)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	17.48B[1]	1.48	31.50A	2.20	34.30A	1.95	8.08	<0.001
Locomotion (%)	40.11A	1.99	31.50B	2.20	24.80B	2.00	5.12	0.006
Agonistic (%)	<1.00A	0.02	<1.00A	0.04	<1.00A	0.04	0.63	0.532
Loafing (%)	9.86B	0.98	10.14B	1.11	16.37A	1.46	7.41	<0.001
Comfort (%)	12.48A	1.34	9.97B	1.31	5.07B	0.95	7.77	<0.001
Sleeping (%)	11.73A	1.72	5.84A	1.39	4.18A	1.31	0.01	0.987
Courtship (%)	<1.00A	0.31	0.00A	0.00	<1.00A	0.02	0.00	0.998
Inter-dive Loaf (%)	6.47B	0.69	10.39A	1.01	13.01A	1.03	4.49	0.012
Alert (%)	<1.00A	0.30	<1.00A	0.37	1.07A	0.48	2.98	0.051

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.13. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors between seasons, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004.

	Season 1 (1 Nov.–10 Jan.) (*n* = 260)		Season 2 (11 Jan.–13 March) (*n* = 390)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	21.21B[1]	1.71	28.14A	1.40	13.83	<0.001
Locomotion (%)	33.45A	1.97	34.05A	1.61	0.33	0.563
Agonistic (%)	<1.00A	0.03	<1.00A	0.02	0.35	0.553
Loafing (%)	12.46A	1.26	10.99B	0.74	4.34	0.038
Comfort (%)	11.48A	1.29	8.85A	0.96	0.76	0.383
Sleeping (%)	11.19A	1.80	6.14B	1.04	11.82	<0.001
Courtship (%)	0.00A	0.00	<1.00A	0.24	0.59	0.442
Inter-dive Loaf (%)	8.86A	0.87	9.47A	0.63	0.10	0.757
Alert (%)	<1.00B	0.20	1.44A	0.33	11.70	<0.001

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.14. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering diving duck (i.e., canvasbacks, lesser scaup, and ring-necked ducks combined) behaviors between sexes measured on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March. 2004.

	Male (n = 375)		Female (n = 275)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	26.23A	1.50	24.20A	1.56	1.34	0.248
Locomotion (%)	32.98A	1.64	34.94A	1.92	0.53	0.467
Agonistic (%)	<1.00B	0.02	<1.00A	0.03	4.10	0.043
Loafing (%)	12.53A	0.94	10.29A	0.94	2.61	0.107
Comfort (%)	10.06A	1.04	9.69A	1.15	0.01	0.935
Sleeping (%)	7.68A	1.24	8.83A	1.50	0.56	0.456
Courtship (%)	<1.00A	0.24	<1.00A	0.05	0.60	0.437
Inter-dive Loaf (%)	8.53A	0.65	10.18A	0.83	2.73	0.099
Alert (%)	<1.00A	0.27	1.04A	0.34	0.00	0.948

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.15. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering diving duck (i.e., canvasbacks, lesser scaup, and ring-necked ducks combined) behaviors among reservoirs, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004.

	Toledo Bend (*n* = 287)		Sam Rayburn (*n* = 163)		B. A. Steinhagen (*n* = 200)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	21.20B	1.53	26.62A	2.36	15.98A	1.83	3.23	0.040
Locomotion (%)	27.70A	1.62	35.41A	2.49	41.27A	2.53	2.79	0.062
Agonistic (%)	<1.00A	0.03	<1.00A	0.05	<1.00A	0.02	2.69	0.068
Loafing (%)	13.40A	1.00	10.23A	1.22	10.07A	1.30	0.25	0.777
Comfort (%)	8.54A	1.07	11.12A	1.56	10.86A	1.52	1.75	0.175
Sleeping (%)	4.95B	1.04	5.89B	1.52	14.61A	2.37	5.96	0.003
Courtship (%)	<1.00A	0.01	0.00A	0.00	<1.00A	0.46	0.59	0.557
Inter-dive Loaf (%)	11.83A	0.80	8.85B	1.05	5.81AB	0.81	3.15	0.043
Alert (%)	1.13A	0.38	1.53A	0.48	<1.00B	0.18	7.26	<0.001

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.16. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering canvasback, lesser scaup, and ring-necked duck behaviors quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 8 November 2004 - 18 February 2005.

	Canvasback (*n* = 361)		Lesser Scaup (*n* = 129)		Ring-necked Duck (*n* = 107)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	18.88A[1]	1.32	21.80A	2.33	23.10A	2.57	0.57	0.565
Locomotion (%)	40.32A	1.81	31.66B	3.01	23.55B	2.35	11.51	<0.001
Agonistic (%)	<1.00A	0.02	<1.00A	0.01	<1.00A	0.04	1.10	0.335
Loafing (%)	16.71A	1.24	16.16A	2.05	15.90A	1.93	0.93	0.396
Comfort (%)	7.85A	0.97	8.13A	1.78	10.05A	1.86	0.81	0.447
Sleeping (%)	8.19B	1.28	14.09AB	2.80	15.42A	2.89	3.43	0.033
Courtship (%)	<1.00A	0.02	0.00A	0.00	<1.00A	0.01	0.16	0.856
Inter-dive Loaf (%)	6.90A	0.63	8.12A	1.05	10.04A	1.40	1.60	0.202
Alert (%)	<1.00A	0.38	0.00A	0.00	<1.00A	0.50	0.28	0.758

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.17. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering diving duck (i.e., canvasbacks, lesser scaup, and ring-necked ducks combined) behaviors between seasons, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 8 November 2004 - 18 February 2005.

	Season 1 (1 Nov. – 10 Jan.) (*n* = 286)		Season 2 (11 Jan. – 13 March) (*n* = 311)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	17.23B[1]	1.41	23.06A	1.53	6.79	0.009
Locomotion (%)	36.15A	1.94	34.80A	1.92	0.20	0.651
Agonistic (%)	<1.00A	0.01	<1.00A	0.03	2.26	0.133
Loafing (%)	20.27A	1.48	12.93B	1.14	19.08	<0.001
Comfort (%)	7.74A	1.11	8.83A	1.08	0.13	0.717
Sleeping (%)	10.69A	1.64	10.82A	1.53	0.01	0.927
Courtship (%)	0.00A	0.00	<1.00A	0.02	1.53	0.217
Inter-dive Loaf (%)	6.31B	0.69	9.02A	0.74	4.69	0.031
Alert (%)	1.27A	0.50	<1.00B	0.12	6.15	0.013

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.18. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering diving duck (i.e., canvasbacks, lesser scaup, and ring-necked ducks combined) behaviors among reservoirs, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 8 November 2004 - 18 February 2005.

	Toledo Bend (n = 275)		Sam Rayburn (n = 123)		B. A. Steinhagen (n = 199)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	23.34A[1]	1.64	18.92A	2.29	16.86A	1.65	2.87	0.057
Locomotion (%)	31.36B	1.94	44.53A	3.36	35.47B	2.22	6.93	0.001
Agonistic (%)	<1.00A	0.01	<1.00A	0.01	<1.00A	0.04	2.26	0.106
Loafing (%)	15.04B	1.28	13.72B	1.87	20.08A	1.82	6.40	0.002
Comfort (%)	7.95A	1.11	6.03A	1.60	10.21A	1.43	2.13	0.119
Sleeping (%)	12.11A	1.72	10.82A	2.56	8.86A	1.77	0.20	0.819
Courtship (%)	<1.00A	0.00	0.00A	0.00	<1.00A	0.03	0.66	0.517
Inter-dive Loaf (%)	9.33A	0.83	5.59A	0.91	6.83A	0.83	2.81	0.061
Alert (%)	<1.00A	0.27	<1.00A	0.06	1.14A	0.64	0.99	0.373

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.19. Means (%), Standard Errors (SE), and *F* and *P* values resulting from univariate analysis of variance of wintering diving duck (i.e., canvasbacks, lesser scaup, and ring necked ducks combined) behaviors between sexes, quantified on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas, 8 November 2004 - 18 February 2005.

	Male (*n* = 341)		Female (*n* = 256)			
Behavior	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Feeding (%)	19.73A[1]	1.39	20.99A	1.61	0.48	0.490
Locomotion (%)	33.70A	1.81	37.77A	2.07	0.96	0.328
Agonistic (%)	<1.00A	0.01	<1.00A	0.03	1.01	0.315
Loafing (%)	18.03A	1.32	14.34A	1.29	3.68	0.056
Comfort (%)	8.64A	1.04	7.86A	1.16	0.15	0.702
Sleeping (%)	11.19A	1.50	10.19A	1.67	0.03	0.872
Courtship (%)	<1.00A	0.02	0.00A	0.00	1.53	0.216
Inter-dive Loaf (%)	7.72A	0.69	7.73A	0.76	0.04	0.846
Alert (%)	<1.00A	0.32	<1.00A	0.38	0.40	0.528

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

Table 1.20. Diurnal behavior of wintering canvasbacks, lesser scaup, and ring-necked ducks in North America.

Location	Behavior[1]				Reference
	Feeding	Resting	Locomoting	Comfort	
Canvasback					
Mississippi	23[2]	30	24	20	Christopher and Hill (1988)
South Carolina	33[3]	34	20	11	Alexander (1980)
Louisiana					
Catahoula Lake	13[3]	42	29	13	Hohman and Rave (1990)
Mississippi Delta	23[3]	42	19	9	Hohman and Rave (1990)
Texas					
Toledo Bend	32[3]	20	37	11	This study
Sam Rayburn	16[3]	21	53	7	This study
B.A. Steinhagen	16[3]	26	40	10	This study
Lesser Scaup					
California[4]	24[3]	10	12	6	Poulton et al. (2002)
Mississippi	35[2]	28	17	18	Christopher and Hill (1988)
South Carolina[5]	31[3]	19	31	9	Bergan et al. (1989)
Texas					
Toledo Bend	36[3]	27	27	9	This study
Sam Rayburn	36[3]	19	34	9	This study
Ring-necked duck					
Florida[5]	35[2]	24	17	15	Hohman (1986)
Mississippi	36[2]	34	16	12	Christopher and Hill (1988)
South Carolina[5]	44[3]	20	18	7	Bergan et al. (1989)
Texas					
Toledo Bend	45[3]	24	24	6	This study
B.A. Steinhagen	23[3]	35	27	15	This study

[1] Percentage of time performing individual behavior.

[2] Feeding behaviors were a combination of diving and tipping without inter-dive loaf.

[3] Feeding behaviors were a combination of diving, tipping, and inter-dive loaf.

[4] Mean proportion of time spent in behaviors among five study areas.

[5] Behaviors approximated from figures.

CHAPTER II

BODY CONDITION AND LIPID PREDICTION MODELS OF WINTERING DIVING DUCKS ON EAST TEXAS RESERVOIRS

INTRODUCTION

During winter, waterfowl experience numerous stresses associated with food shortages, habitat quality and quantity, inclement weather, molt, courtship, pair formation, human disturbance, and recovering from and preparing for migration, all of which may influence waterfowl body condition (Hepp and Hair 1983, Quinlan and Baldassarre 1984, Baldassarre et al. 1986, Heitmeyer 1988, Knapton et al. 2000). Waterfowl accumulation of nutrient reserves, usually in the form of lipids, is an adaptation to survive during such stressful events (Bailey 1979). Many studies have examined waterfowl body condition during summer (Owen and Cook 1977, Hohman and Taylor 1986, Ankney and Afton 1988, Alisauskas et al. 1990, Afton and Ankney 1991), migration (Chappell and Titman 1983, Austin and Fredrickson 1987, Serie and Sharp 1989, Gammonley and Heitmeyer 1990), and winter (Baldassarre et al. 1986, Haramis et al. 1986, Hohman and Taylor 1986, Afton et al. 1989, Hohman 1993, Hohman and Weller 1994, Haukos et al. 2001, DeVault et al. 2003), where each season will impact immediate and future survival. Wintering waterfowl physiological condition is correlated with overwinter survival and subsequent breeding success (Heitmeyer and Fredrickson 1981, Haramis et al. 1986, Kaminski and Gluesing 1986, Heitmeyer 1988, Raveling and Heitmeyer 1989), whereby winter body condition could indicate an individual's survival probability and ability to meet current and future energy demands (Owen and Cook 1977). However, relationship(s) between body condition and winter survival may vary, as the impact of body condition on winter survival might not be detected if birds in poorer condition do not arrive or arrive later to wintering areas (Cox et al. 1998).

The probability of waterfowl meeting both immediate and future energy demands can be roughly predicted by estimating total lipid content and body condition of individual birds. The most accurate method to quantify body condition is through direct estimates of lipid content of sacrificed birds (Conway et al. 1994, Harder and Kirkpatrick 1996, Spengler et al. 1995). Such data are then used to develop lipid prediction models using combinations of external morphology, internal tissue, and internal fat store measures in a regression setting (Wishart 1979, Hohman and Taylor 1986, DeVault et al. 2003). Body condition indices (BCIs) can also be generated by using external morphological measures of living or recently harvested birds, providing a way to examine body condition in a non-destructive fashion (Hine et al. 1996, Haukos et al. 2001). However, the ability of such BCIs to reflect true lipid content may be highly variable (Bailey 1979, Wishart 1979, DeVault et al. 2003). Few studies (Wishart 1979, Ringelman and Szymczak 1985, DeVault et al. 2003) have (1) developed lipid prediction models and BCIs simultaneously, (2) evaluated the ability of BCI models to actually predict lipid content, or (3) combined model building and BCI verification for diving ducks.

An estimated 97%, 99%, and 98% of the Central Flyway populations of canvasback (*Aythya valisineria*), lesser scaup (*A. affinis*), and ring-necked duck (*A. collaris*), respectively winter in Texas (U.S. Fish and Wildlife Service 2003). Within the Pineywoods Ecoregion of east Texas, 3 manmade reservoirs (i.e., Toledo Bend, Sam Rayburn, and B. A. Steinhagen) provide important wintering diving duck habitat (Rockwood and Whiting 1992), where an estimated 17% and 3% of the Texas wintering population of canvasback and lesser scaup winter in the region (U.S. Fish and Wildlife Service 2003). Deep-water habitats and extensive submerged aquatic vegetation, associated with these reservoirs provide suitable habitat for wintering diving ducks (Rockwood and Whiting 1992).

Nutrient reserves vary both temporally and geographically, depending upon events occurring during the annual cycle. Understanding how and why nutrient reserves vary throughout winter in a given region should provide important information which can be (1) used to correlate body condition with current habitat quality/quantity and (2) translated into the probability of overwinter survival and subsequent breeding success. Such data are needed to examine the link(s) between habitat quality of these reservoirs and body condition of diving ducks which winter on them. Specifically, this study addresses an information gap that exists on body condition of wintering diving ducks within the east Texas region, while simultaneously attempting to determine the most useful condition models for predicting body condition of wintering diving ducks under field conditions (*sensu* Spengler et al. 1995). Therefore, the specific objectives of this study were to (1) develop species, sex, and age-specific morphological

BCIs, (2) estimate species, sex, and age-specific total body lipid content, (3) develop species, sex, and age-specific lipid prediction models using a combination of morphological BCIs, and fat, skin, and internal organ measures of canvasback, lesser scaup, and ring-necked duck wintering on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs in east Texas.

STUDY AREA

The Pineywoods Ecoregion of Texas is 1 of 6 major waterfowl habitat regions within the state (Moulton et al. 1988); encompassing 38 counties, it is comprised primarily of pine (*Pinus* spp.), hardwood, and mixed pine-hardwood forests (Figure 1.1). Bottomland hardwood forests, sloughs, freshwater marshes, and ponds are scattered throughout the region. There are > 30 major reservoirs on portions of the Angelina, Cypress, Neches, Red, Sabine, and Sulphur Rivers (Figure 1.1) (Moulton et al. 1988).

This research was conducted on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas (Figure 1.1). Toledo Bend Reservoir encompasses almost 75,000 ha extending into portions of Newton, Panola, Sabine, and Shelby counties, Texas, and De Soto and Sabine parishes, Louisiana (Wood 1972). Impounded in 1966, the reservoir is managed for water, hydroelectric generation, and recreation. Sam Rayburn Reservoir encompasses > 46,000 ha, extending into portions of Angelina, Jasper, Nacogdoches, Sabine, and San Augustine counties, Texas. Impounded in 1965, the reservoir is managed for flood control, hydroelectric power, and water for municipal, industrial, agricultural, and recreational uses (Rockwood and Whiting 1992). B. A. Steinhagen Reservoir encompasses > 6,800 ha; it extends into portions of Jasper and Tyler counties (Scaief 1985). Filled in 1951, with a maximum depth of 10.7 m, the reservoir is managed for flood control, water, and recreation.

METHODS

Collection

Canvasback, lesser scaup, and ring-necked duck were collected from 8 November 2003 - 23 January 2004 and from 3 November 2004 - 2 March 2005 on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs. Birds were collected with shotguns using steel shot, either with decoys (85.5 %) or without decoys (14.5 %) (U.S. Fish and Wildlife Service Scientific Collecting Permit MB093044-0, Texas Parks and Wildlife Department Scientific Collecting Permit Number SPR-0804-009). Decoys were used in this study because use of rifles or non-lethal capture techniques was not permitted on these public reservoirs.

After retrieval, each bird was aged and sexed, frozen (Haramis et al. 1982, Carney 1992), and stored at Stephen F. Austin State University. Each frozen duck was partially thawed and mass was measured using an electronic scale (College B154/Mettler Toledo) to obtain wet gross body mass (g). Left wing cord length (cm) was measured using a ruler, while left tarsus (mm), exposed culmen (mm), and total bill length (commissural point to tip of nail) (mm), and maximum bill width (mm) were measured using calipers (*sensu* Hohman 1993). Each carcass was then plucked except for the middle rectrix. Total body length (cm) was measured using a ruler from bill tip to middle rectrix tip, with each bird outstretched on its back. The middle rectrix was then removed, rachis length (cm) measured and subtracted from total body length to obtain net body length (cm). Each carcass was then remeasured to obtain feather-free body mass (g). All feathers were discarded.

Skin and Internal Morphological Measures

Skin and carcass surface fat (i.e., fat associated with skin) were removed from each carcass and measured to obtain mass (g). The pectoralis, supracoracoideus, and coracobrachialis (i.e., flight muscles) were removed from the left side of the sternum (Owen and Cook 1977, Morton et al. 1990). External fat on flight muscles was removed and set aside. The left leg was removed from the carcass and the tarsus removed and discarded. Then fat was removed from the leg muscles (i.e., muscles with origin or insertion on femur and tibiotarsus) and set aside. Skin, flight muscle, and leg muscle (including femur) mass were then measured to the nearest 0.01 g. After skin and muscles were removed, keel length (cm) was measured (Hohman and Taylor 1986, Morton et al. 1990).

Each carcass body cavity was exposed by splitting the left side of the keel, after which the heart, liver, kidneys, and the entire gastrointestinal tract were removed. The gizzard was removed from the gastrointestinal tract, measured to nearest 0.01 g, and then opened and its contents removed. The gizzard was remeasured to nearest 0.01g and its contents were saved for future analysis. Contents of the esophagus, proventriculus, and intestine were removed and measured to the nearest 0.01 g; contents of the esophagus and proventriculus were also saved. Upper gastrointestinal tract mass (g) and length (cm) were measured (Austin and Fredrickson 1987). Digestive content mass was subtracted from feather-free body mass to obtain ingesta-free carcass mass (DeVault et al. 2003). Visceral fat was removed from the heart, liver, and kidneys, omental fat was removed from the gizzard and abdominal wall (Woodall 1978), and mesentery fat was removed from the intestines. Each was measured to the nearest 0.01 g.

Lipid Extraction

Bill and tarsi were removed from the carcass and discarded. All remaining excised organs and tissues were returned to each carcass, which was homogenized in an electric meat grinder. Three 30-g subsamples from each whole carcass homogenate were oven dried at 65° C to constant mass (Kerr et al. 1982). This temperature was maintained to prevent volatilization of carcass lipids during homogenate drying (Kerr et al. 1982).

After drying, 5-g subsamples of each homogenized 30-g subsample were ground with a mortar and pestle and placed into a 22 ml extraction cell (Dionex 1999). Each 5-g subsample was then subjected to lipid extraction using petroleum ether in an Accelerated Solvent Extractor (ASE). Extractions were performed at 125° C, at 10.3 Mpa (1500 psi), for 6 min. equilibration, extracted for 2 min., flushed with 60% petroleum ether, and purged for 60 s with Nitrogen (Dionex 1999). This cycle was performed twice for each subsample. After extraction, each cell and its contents were removed and oven dried at 65° C to constant mass (i.e., 12-14 h). Once dry, each subsample mass was measured to the nearest 0.01 g to obtain subsample lean dry mass.

Morphological Body Condition Indices

Three morphological body condition indices were generated for each bird. First, following Hine et al. (1996) and Haukos et al. (2001), BCI1 was calculated for each bird by dividing total body mass (g) by wing cord length (mm). Second, following Rhodes and Smith (1993), BCI2 was calculated for each bird by dividing total body mass (g) by the sum of total body length (cm) and wing cord length (cm). Finally, following Bennett and Bolen (1978), BCI3 was calculated by dividing total body mass (g) by the product of bill length (cm) and keel length (cm).

Total Body Lipid Estimation

Lipid content (%) of each subsample (*n* = 3 for each bird) was calculated by dividing subsample dry mass after extraction by subsample dry mass before extraction and multiplying by 100. If 1 subsample deviated ≥ 10 % of the calculated lipid content for the other 2 subsamples, new subsamples from the carcass homogenate were exposed to ether extraction procedures until all lipid content (%) of all subsamples for an individual bird were < 10 % from one another. For data analysis (see below), lipid content (%) of each carcass was calculated by averaging 2 subsamples that were closest to one another.

Data Analyses

Univariate factorial analysis of variance (ANOVA) was used to examine differences in external and internal morphological features within each species, between sexes, between ages (adult and juvenile), and their interaction. Univariate ANOVA was also used to examine differences in BCI1, BCI2, BCI3, and lipid content (%) (1) among species and (2) within species, between age classes, between sex classes, and among age-sex classes. Subsequent ANOVAs were performed to examine differences in BCI1, BCI2, BCI3, and lipid content within each species between seasons (i.e., 3 November – 10 January, Season 1; 11 January - 2 March, Season 2). In all instances, Type III sums of squares F and P values were used to identify where differences occurred in the overall model. If differences ($P < 0.05$) occurred in Type III analyses, least squares mean separation was used to more closely examine those differences.

Three different lipid prediction models were built using stepwise linear regression (SLR) for each age and sex class within each species to determine the predictive power of the 3 morphological BCIs for estimating total lipid content (%). The first model examined the predictive power of the 3 morphological BCIs for estimating total lipid content (%). Stepwise linear regression was used to build age, sex, and age-sex class specific models within each species incorporating each BCI model. The second model was a field-oriented lipid prediction model, where only external morphological measurements (i.e., total body mass (g), log body mass (g), total body length (cm), wing cord (cm), culmen (cm), total bill length (cm), tarsus length (cm), and bill width (cm)) or morphological BCIs were used as independent variables. Stepwise linear regression was also used for each age, sex, and age-sex class within each species to evaluate the ability of these data to predict lipid content for future use on live and/or harvested birds. Finally, SLR was used to develop an exhaustive lipid prediction model for each age, sex, and age-sex class within a species using the full data set, which included BCIs, external morphology (i.e., total body mass, total body length, etc.), and internal morphology/fat measures (i.e., heart mass, gizzard mass, omental fat mass, etc.) to more thoroughly examine which features most accurately predict lipid content. For all regression models, variables were included only if they contributed ($P < 0.05$) to the regression model.

RESULTS

Morphology

Canvasbacks

As there are obvious morphological differences among species, no analyses were performed examining variability in external morphology, internal organ, or internal fat measures among species, but these data are summarized (Table 2.1). Within canvasback, most external morphological and internal organ measures varied ($P < 0.05$) between ages and sexes, with only 1 age x sex interaction (i.e., kidney mass) (Table 2.2). Although males and adults tended to be larger than females and juveniles, respectively, most fat measures were similar ($P > 0.05$) between sexes and ages (Tables 2.2, 2.3). When age-sex classes were combined, adult males tended to be larger morphologically than any other age-sex class, whereas adult females tended to possess more omental, mesentary, and visceral fat and more skin mass (Table 2.4).

Lesser Scaup

Within lesser scaup, few external morphological and internal organ measures varied ($P > 0.05$) between ages and sexes and no interactions ($P > 0.05$) occurred (Table 2.5). In the few instances where morphological features varied ($P < 0.05$), they generally occurred between sexes, where males tended to be larger than females (Table 2.6). Moreover, all internal fat measures were similar ($P > 0.05$) between sexes and ages (Tables 2.5, 2.6). Finally, when age-sex classes were combined, adult males tended to be larger morphologically than other age-sex class, whereas adult females tended to possess more omental, mesentery, and visceral fat mass and more skin mass ($P > 0.05$) (Table 2.7).

Ring-necked Ducks

For Ring-necked duck, several external morphological and internal organ measures varied ($P < 0.05$), and several age x sex interactions occurred (Table 2.8). In general, adults and males were larger and had higher fat content than juveniles and females (Tables 2.8, 2.9). Finally, when age-sex classes were combined, adult males tended to be larger morphologically, and possess more omental, mesentery, and visceral fat mass, and more skin mass than other age-sex classes ($P < 0.05$) (Table 2.10).

Morphological Condition Indices and Lipid Levels

Variation Among and Within Species

Morphological BCIs varied among species (BCI1; F= 384.05; 2, 243 df; $P < 0.001$), (BCI2; F= 277.86; 2, 240 df; $P < 0.001$), (BCI3; F= 15.85; 2, 236 df; $P < 0.001$) as did lipid content (F= 3.22; 2, 232 df; $P = 0.042$) (Table 2.11). Lesser scaup had the highest lipid content, while canvasback had greater BCIs (i.e., BCI1, BCI2, and BCI3) than either lesser scaup or ring-necked duck (Table 2.11).

Within canvasback, complete models varied for BCI1 ($F = 4.57$; 3, 69 df; $P = 0.006$), BCI2 ($F = 5.81$; 3, 69 df; $P = 0.001$), BCI3 ($F = 6.34$; 3, 68 df; $P < 0.001$), and lipid content ($F = 3.56$; 3, 66 df; $P = 0.019$). However, when complete models were partitioned, differences between age classes accounted for all of the variability within each model (Table 2.12); adults had higher lipid levels and higher BCIs than juveniles (Tables 2.13, 2.14). Lipid content and BCI values were similar ($P > 0.05$) between sexes and no age x sex interactions ($P > 0.05$) occurred (Tables 2.12, 2.13, 2.14).

For lesser scaup, complete models were similar for BCI1 ($F = 2.65$; 3, 84 df; $P = 0.054$), BCI2 ($F = 1.44$; 3, 82 df; $P = 0.238$), BCI3 ($F = 0.54$; 3, 81 df; $P = 0.654$), and lipid content ($F = 0.43$; 3, 81 df; $P = 0.731$) (Tables 2.12, 2.13, 2.14). The only consistent (nonsignificant) trend ($P > 0.05$) for lesser scaup was that adults tended to have slightly higher BCIs and lipid levels than juveniles (Tables 2.13, 2.14).

Within ring-necked duck, complete models varied for BCI1 ($F = 7.37$; 3, 81 df; $P < 0.001$), BCI2 ($F = 7.96$; 3, 80 df; $P < 0.001$), and BCI3 ($F = 2.85$; 3, 78 df; $P = 0.043$), but were similar for lipid content ($F = 2.58$; 3, 76 df; $P = 0.060$). However, when complete models were partitioned, few differences remained (Table 2.12). There were age x sex interactions ($P < 0.05$) for BCI2 and lipid content, and BCI1 varied ($P < 0.05$) between ages (Table 2.12). Again, adults and males tended to have higher BCIs and lipid levels than juveniles and females, respectively (Tables 2.13, 2.14).

Variation Among Age-sex Classes Within Species

Within canvasback, morphological BCIs varied among age-sex classes (BCI1; F= 4.57; 3, 69 df; P = 0.006), (BCI2; F= 581; 3, 69 df; P = 0.001), (BCI3; F= 6.34; 3, 68 df; P < 0.001) as did lipid content (F= 3.56; 3, 66 df; P = 0.019) (Tables 2.15, 2.16). Adult and juvenile female canvasback generally had the highest and lowest lipid content and BCI values, respectively (Tables 2.15, 2.16). Within lesser scaup, BCI1 (F = 2.65; 3, 84 df; P = 0.054), BCI2 (F = 1.44; 3, 82 df; P = 0.238), BCI3 (F = 0.54; 3, 81 df; P = 0.654), and lipid content (F = 0.43; 3, 81 df; P = 0.731) were similar among age-sex classes (Tables 2.17, 2.18), although adult females tended to have the highest lipid content. Within ring-necked duck, BCI1 (F = 7.37; 3, 81 df; P < 0.001), BCI2 (F = 7.96; 3, 80 df; P < 0.001), and BCI3 (F = 2.85; 3, 78 df; P = 0.043) varied among age-sex classes, but lipid content was similar (F = 2.58; 3, 76 df; P = 0.060) (Tables 2.19, 2.20). Adult male ring-necked ducks had higher BCI values than the other age-sex classes, and tended (P > 0.05) to have higher lipid content, although these analyses were constrained by unequal sample sizes among age-sex classes (Tables 2.19, 2.20).

Variation Between Seasons

Within canvasback, BCI1 (F = 0.02; 1, 71 df; P = 0.881), BCI2 (F = 0.03; 1, 71 df; P = 0.856), BCI3 (F = 0.64; 1, 70 df; P = 0.428), and lipid content (F = 0.01; 1, 68 df; P = 0.911) were consistent between seasons (Table 2.21). Within lesser scaup, BCI1 (F = 0.35; 1, 86 df; P = 0.553), BCI2 (F = 0.26; 1, 84 df; P =

0.612), BCI3 ($F = 2.09$; 1, 83 df; $P = 0.152$), and lipid content ($F = 0.42$; 1, 83 df; $P = 0.518$) were also consistent between seasons, although disproportionate sample sizes between seasons likely influenced these analyses (Table 2.22). Finally, the lack of seasonal variability in canvasbacks and lesser scaup was also observed within ring-necked ducks, where BCI1 ($F = 0.75$; 1, 83 df; $P = 0.360$), BCI3 ($F = 0.04$; 1, 80 df; $P = 0.849$), and lipid content ($F = 2.72$; 1, 78 df; $P = 0.103$) were similar between seasons. However, BCI2 was higher ($F = 5.35$; 1, 82 df; $P = 0.023$) in season 2 than season 1 for ring-necked ducks (Table 2.23).

Lipid Prediction Models

Canvasbacks

For adult male canvasback, BCI2 alone explained 63% of the variation in lipid content ($F = 45.30$; 1, 26 df; $P < 0.001$; $R^2 = 0.63$). Neither BCI1 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology , BCI2 still explained 63% of the variation in lipid content, but model strength increased ($P > 0.05$) when culmen length was added ($F = 31.61$; 2, 25 df; $P < 0.001$; $R^2 = 0.72$). No other BCI or external morphological feature added ($P > 0.05$) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 88% of the variation in lipid content ($F = 181.51$; 1, 24 df; $P < 0.001$; $R^2 = 0.88$). The final lipid prediction model combined skin mass, gizzard mass, and total body length ($F = 96.04$; 3, 22 df; $P < 0.001$; $R^2 = 0.93$) to explain 93% of the variation in lipid content in adult male canvasback (Table 2.24).

For juvenile male canvasback, BCI2 alone explained 74% of the variation in lipid content (*F* = 14; 1, 5 df; *P* = 0.013; $R^2 = 0.74$). Neither BCI1 nor BCI3 added (*P* > 0.05) to the model. When BCIs were combined with external morphology, BCI2 still explained 74% of the variation in lipid content, but model strength increased when body mass and tarsus length were added (*F* = 72.17; 3, 3 df; *P* = 0.003; $R^2 = 0.99$). No other BCI or external morphological feature added (*P* > 0.05) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 86% of the variation in lipid content (*F* = 31.77; 1, 5 df; *P* = 0.002; $R^2 = 0.86$). The final lipid prediction model combined skin mass and total body length (*F* = 48.75; 2, 4 df; *P* = 0.002; $R^2 = 0.96$) to explain 96% of the variation in lipid content in juvenile male canvasback (Table 2.24).

For adult female canvasback, BCI2 alone explained 68% of the variation in lipid content (*F* = 38.30; 1, 18 df; *P* < 0.001; $R^2 = 0.68$). Neither BCI1 nor BCI3 added (*P* > 0.05) to the model. When BCIs were combined with external morphology, BCI2 alone still explained 68% of the variation in lipid content. No other BCI or external morphological feature added (*P* > 0.05) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 81% of the variation in lipid content (*F* = 76.63; 1, 18 df; *P* < 0.001; $R^2 = 0.81$). The final lipid prediction model combined skin mass and bill length (*F* = 62.64; 2, 17 df; *P* < 0.001; $R^2 = 0.88$) to explain 88% of the variation in lipid content in adult female canvasback (Table 2.24).

For juvenile female canvasback, BCI1 alone explained 68% of the variation in lipid content ($F = 25.76$; 1, 12 df; $P < 0.001$; $R^2 = 0.68$). Neither BCI2 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphological features, BCI1 alone still explained 73% of the variation in lipid content. No other BCI or external morphological feature added ($P > 0.05$) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 83% of the variation in lipid content ($F = 57.81$; 1, 12 df; $P < 0.001$; $R^2 = 0.83$). The final lipid prediction model combined wing cord, heart mass, and skin mass ($F = 48.09$; 3, 10 df; $P < 0.001$; $R^2 = 0.93$) to explain 93% of the variation in lipid content in juvenile female canvasback (Table 2.24).

For male canvasback, BCI2 alone explained 59% of the variation in lipid content ($F = 48.50$; 1, 33 df; $P < 0.001$; $R^2 = 0.59$). Neither BCI1 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI1 still explained 59% of the variation in lipid content, but model strength increased when culmen length was added ($F = 30.61$; 2, 32 df; $P < 0.001$; $R^2 = 0.66$). No other BCI or external morphological feature added ($P > 0.05$) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 86% of the variation in lipid content ($F = 193.33$; 1, 31 df; $P < 0.001$; $R^2 = 0.86$). The final lipid prediction model combined skin mass, gizzard mass, and total body length ($F = 106.89$; 3, 29 df; $P < 0.001$;

$R^2 = 0.92$) to explain 92% of the variation in lipid content in male canvasback (Table 2.25).

For female canvasback, BCI1 alone explained 73% of the variation in lipid content ($F = 84.82$; 1, 32 df; $P < 0.001$; $R^2 = 0.73$). Neither BCI2 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI1 alone still explained 73% of the variation in lipid content. Model strength increased when bill length was added ($F = 59.85$; 2, 31 df; $P < 0.001$; $R^2 = 0.79$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 84% of the variation in lipid content ($F = 165.50$; 1, 32 df; $P < 0.001$; $R^2 = 0.84$). The final lipid prediction model combined bill length, gizzard mass, and skin mass ($F = 76.81$; 3, 30 df; $P < 0.001$; $R^2 = 0.88$) to explain 88% of the variation in lipid content in female canvasback (Table 2.25).

For adult canvasback, BCI2 alone explained 56% of the variation in lipid content, but model strength increased by adding BCI3 ($F = 38.99$; 2, 45 df; $P < 0.001$; $R^2 = 0.63$). When BCIs were combined with external morphological features, BCI2 alone still explained 56% of the variation in lipid content. Model strength increased when wing cord length and culmen length were added ($F = 40.30$; 3, 44 df; $P < 0.001$; $R^2 = 0.73$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 83% of the variation in lipid content ($F = 213.05$; 1, 44 df; $P < 0.001$; $R^2 = 0.83$). The final lipid prediction model combined skin mass, total body length, and gizzard mass ($F = 136.18$; 3, 42; $P < 0.001$; $R^2 = 0.91$) to explain 91% of the variation in lipid content in adult canvasback (Table 2.25).

For juvenile canvasback, BCI3 alone explained 64% of the variation in lipid content (*F* = 33.61; 1, 19 df; $P < 0.001$; $R^2 = 0.64$). Neither BCI1 nor BCI2 added ($P > 0.05$) to the model. When BCIs were combined with external morphological features, BCI2 alone still explained 64% of the variation in lipid content and no other BCI or external morphological feature added ($P > 0.05$) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 83% of the variation in lipid content (*F* = 90.62; 1, 19 df; $P < 0.001$; $R^2 = 0.83$). The final lipid prediction model combined skin mass, tarsus length, and omental fat mass (*F* = 49.83; 3, 17 df; $P < 0.001$; $R^2 = 0.90$) to explain 90% of the variation in lipid content in juvenile canvasback (Table 2.25).

<u>Lesser scaup</u>

For adult male lesser scaup, BCI3 alone explained 72% of the variation in lipid content (*F* = 48.21; 1, 19 df; $P < 0.001$; $R^2 = 0.72$). Neither BCI1 nor BC2 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI3 still explained 72% of the variation in lipid content. No other BCI or external morphological feature added ($P > 0.05$) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 85% of the variation in lipid content (*F* = 105.62; 1, 19 df; $P < 0.001$; $R^2 = 0.85$). The final lipid prediction model combined BCI3 and skin mass (*F* = 67.24; 2, 18 df; $P < 0.001$; $R^2 = 0.88$) to explain 88% of the variation in lipid content in adult male lesser scaup (Table 2.26).

For juvenile male lesser scaup, BCI3 alone explained 43% of the variation in lipid content (*F* = 14.41; 1, 19 df; *P* = 0.001; R^2 = 0.43). Neither BCI1 nor BC2 added (*P* > 0.05) to the model. When BCIs were combined with external morphology, BCI3 still explained 43% of the variation in lipid content. No other BCI or external morphological feature added (*P* > 0.05) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 70% of the variation in lipid content (*F* = 36.58; 1, 16 df; *P* < 0.001; R^2 = 0.70). The final lipid prediction model combined BCI2 and skin mass (*F* = 36.05; 2, 15 df; *P* < 0.001; R^2 = 0.83) to explain 83% of the variation in lipid content in juvenile male lesser scaup (Table 2.26).

For adult female lesser scaup, BCI1 alone explained 46% of the variation in lipid content (*F* = 6.08; 1, 7 df; *P* = 0.040; R^2 = 0.46). Neither BCI2 nor BCI3 added (*P* > 0.05) to the model. When BCIs were combined with external morphology, BCI1 still explained 46% of the variation in lipid content. No other BCI or external morphological feature added (*P* > 0.05) to the model. Finally, when all data were entered into the stepwise regression procedure, omental fat mass alone explained 71% of the variation in lipid content (*F* = 17.18; 1, 7 df; *P* = 0.004; R^2 = 0.71). The final lipid prediction model combined bill length, gizzard mass, and omental fat mass (*F* = 47.70; 3, 5 df; *P* < 0.001; R^2 = 0.97) to explain 97% of the variation in lipid content in adult female lesser scaup (Table 2.26).

For juvenile female lesser scaup, BCI1 alone explained 25% of the variation in lipid content ($F = 8.31$; 1, 25 df; $P = 0.008$; $R^2 = 0.25$). Neither BCI2 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI1 still explained 25% of the variation in lipid content. Model strength increased when bill width was added ($F = 10.40$; 2, 24 df; $P < 0.001$; $R^2 = 0.46$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 71% of the variation in lipid content ($F = 59.80$; 1, 24 df; $P < 0.001$; $R^2 = 0.71$). The final lipid prediction model combined leg muscle mass and skin mass ($F = 51.30$; 2, 23 df; $P < 0.001$; $R^2 = 0.82$) to explain 82% of the variation in lipid content in juvenile female lesser scaup (Table 2.26).

For male lesser scaup, BCI3 alone explained 57% of the variation in lipid content ($F = 55.13$; 1, 41 df; $P < 0.001$; $R^2 = 0.57$). Neither BCI1 nor BC2 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI3 still explained 57% of the variation in lipid content. No other BCI or external morphological feature added ($P > 0.05$) to the model. Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 75% of the variation in lipid content ($F = 111.96$; 1, 37 df; $P < 0.001$; $R^2 = 0.75$). The final lipid prediction model combined skin mass, intestine mass and bill length ($F = 67.74$; 2, 36 df; $P < 0.001$; $R^2 = 0.79$) to explain 79% of the variation in lipid content in male lesser scaup (Table 2.27).

For female lesser scaup, BCI1 alone explained 30% of the variation in lipid content ($F = 14.65$; 1, 34 df; $P < 0.001$; $R^2 = 0.30$). Neither BCI2 nor BCI3 added

($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI1 still explained 30% of the variation in lipid content. Model strength increased when bill width was added ($F = 14.21$; 2, 33 df; $P < 0.001$; $R^2 = 0.46$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 70% of the variation in lipid content ($F = 77.92$; 1, 33 df; $P < 0.001$; $R^2 = 0.70$). The final lipid prediction model combined bill length, omental fat mass, and skin mass ($F = 53.10$; 3, 31 df; $P < 0.001$; $R^2 = 0.84$) to explain 84% of the variation in lipid content in female lesser scaup (Table 2.27).

For adult lesser scaup, BCI3 alone explained 63% of the variation in lipid content ($F = 49.41$; 1, 29 df; $P < 0.001$; $R^2 = 0.63$). Neither BCI1 nor BC2 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI3 alone explained 62% of the variation in lipid content ($F = 45.06$; 1, 28 df; $P < 0.001$; $R^2 = 0.62$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 81% of the variation in lipid content ($F = 115.74$; 1, 28 df; $P < 0.001$; $R^2 = 0.81$). The final lipid prediction model combined skin mass, bill length, kidney mass, and leg muscle mass ($F = 56.26$; 4, 25 df; $P < 0.001$; $R^2 = 0.90$) to explain 90% of the variation in lipid content in adult lesser scaup (Table 2.27).

For juvenile lesser scaup, BCI1 alone explained 30% of the variation in lipid content ($F = 19.53$; 1, 46 df; $P < 0.001$; $R^2 = 0.30$). Neither BCI2 nor BC3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, BCI1 alone explained 29% of the variation in lipid content. Model strength increased when bill length was added (*F* = 18.08; 2, 44 df; $P < 0.001$; $R^2 = 0.45$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 67% of the variation in lipid content (*F* = 84.01; 1, 42 df; $P < 0.001$; $R^2 = 0.67$). The final lipid prediction model combined skin mass, log body mass, and body mass (*F* = 69.38; 3, 40 df; $P < 0.001$; $R^2 = 0.84$) to explain 84% of the variation in lipid content in juvenile lesser scaup (Table 2.27).

Ring-necked ducks

For adult male ring-necked duck, BCI1 alone explained 30% of the variation in lipid content (*F* = 21.73; 1, 51 df; $P < 0.001$; $R^2 = 0.30$). Neither BCI2 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, the log of body mass explained 36% of the variation in lipid content (*F* = 28.47; 1, 50 df; $P < 0.001$; $R^2 = 0.36$). Model strength increased when tarsus length was added (*F* = 17.88; 2, 49 df; $P < 0.001$; $R^2 = 0.42$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 76% of the variation in lipid content (*F* = 149.38; 1, 48 df; $P < 0.001$; $R^2 = 0.76$). The final lipid prediction model combined esophagus-proventriculus mass and skin mass (*F* = 86.14; 2, 47 df; $P < 0.001$; $R^2 = 0.79$) to explain 79% of the variation in lipid content in adult male ring-necked duck (Table 2.28).

For juvenile male ring-necked duck, neither BCIs nor morphological features explained any variation in lipid content ($P > 0.05$). When all data were entered into the stepwise regression procedure, kidney mass alone explained 59% of the variation in lipid content (*F* = 8.64; 1, 6 df; *P* = 0.030; $R^2 = 0.59$) (Table 2.28).

For adult female ring-necked duck, neither BCIs nor morphological features explained any variation in lipid content (*P* > 0.05). When all data were entered into the stepwise regression procedure, skin mass alone explained 89% of the variation in lipid content (*F* = 50.79; 1, 6 df; *P* < 0.001; $R^2 = 0.89$) (Table 2.28).

For juvenile female ring-necked duck, neither BCIs nor morphological features explained any variation in lipid content (*P* > 0.05). When all data were entered into the stepwise regression procedure, heart mass alone explained 80% of the variation in lipid content (*F* = 19.70; 1, 5 df; *P* = 0.007; $R^2 = 0.80$) (Table 2.28).

For male ring-necked duck, BCI1 alone explained 34% of the variation in lipid content (*F* = 31.13; 1, 59 df; *P* < 0.001; $R^2 = 0.34$). Neither BCI2 nor BCI3 added (*P* > 0.05) to the model. When BCIs were combined with external morphology, the log of body mass explained 40% of the variation in lipid content (*F* = 38.46; 1, 58 df; *P* < 0.001; $R^2 = 0.40$). Model strength increased when tarsus length was added (*F* = 23.20; 2, 57 df; *P* < 0.001; $R^2 = 0.45$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 69% of the variation in lipid content (*F* = 124.73; 1, 56 df; *P* < 0.001; $R^2 = 0.69$). The final lipid prediction model combined esophagus-proventriculus mass, omental fat mass, and skin mass (*F* = 56.27; 3, 54 df; $P <$ 0.001; $R^2 = 0.76$) to explain 76% of the variation in lipid content in male ring-necked duck (Table 2.28).

For female ring-necked duck, neither BCIs nor morphological features explained any variation ($P > 0.05$) in lipid content. Finally, when all data were entered into the stepwise regression procedure, esophagus-proventriculus mass alone explained 51% of the variation in lipid content (*F* = 13.50; 1, 13 df; *P* = 0.003; $R^2 = 0.51$). The final lipid prediction model combined esophagus-proventriculus mass and intestine mass (*F* = 11.07; 2, 12 df; *P* = 0.002; $R^2 =$ 0.65) to explain 65% of the variation in lipid content in female ring-necked duck (Table 2.29).

For adult ring-necked duck, BCI1 alone explained 32% of the variation in lipid content (*F* = 27.36; 1, 59 df; $P < 0.001$; $R^2 = 0.32$). Neither BCI2 nor BCI3 added ($P > 0.05$) to the model. When BCIs were combined with external morphology, the log of body mass alone explained 37 % of the variation in lipid content (*F* = 33.77; 1, 58 df; $P < 0.001$; $R^2 = 0.37$). Model strength increased when tarsus length was added (*F* = 20.49; 2, 57 df; $P < 0.001$; $R^2 = 0.42$). Finally, when all data were entered into the stepwise regression procedure, skin mass alone explained 77% of the variation in lipid content (*F* = 189.41; 1, 56 df; P < 0.001; $R^2 = 0.77$). The final lipid prediction model combined skin mass and esophagus-proventriculus mass (*F* = 112.98; 2, 55 df; $P < 0.001$; $R^2 = 0.80$) to explain 80% of the variation in lipid content in adult ring-necked duck (Table

2.29).

For juvenile ring-necked ducks, neither BCIs nor morphological features explained any variation (*P* > 0.05) in lipid content. Finally, when all data were entered into the stepwise regression procedure, mesentery fat mass alone explained 45% of the variation in lipid content ($F = 10.50$; 1, 13 df; $P = 0.006$; $R^2 = 0.45$) (Table 2.29).

DISCUSSION

Lipid Prediction Models

Although various BCIs have been successful at predicting lipid content for diving and dabbling ducks (Bailey 1979, Chappell and Titman 1983, Ringelman and Szymczak 1985, Hohman and Taylor 1986, DeVault et al. 2003), the variation among and within species from different geographical locations during different portions of the annual cycle decreases the universality of these indices. Although most studies have no lipid content data in which to validate BCI predictive power, this study directly assessed their utility. In this study, most lipid prediction models incorporating BCIs successfully predicted lipid content (R^2 = 0.25 – 0.73), but BCI explanatory power was (1) highly variable among species and sex/age classes and (2) inconsistent among BCIs (i.e., BCI1, BCI2, or BCI3). For example, BCI1 predicted lipid content in female canvasbacks, BCI2 predicted lipid content in male and adult canvasbacks, and BCI3 predicted lipid content in juvenile canvasbacks and male and adult lesser scaup. These results are in general concordance with other studies, which (1) question the universality and utility of BCI models in general and (2) demand species, sex, age, and geographically specific BCI model development (Chappell and Titman 1983, Ringelman 1988, Morton et al. 1990, DeVault et al. 2003). Such variability in BCI prediction success is disconcerting, particularly in terms of applying management decisions based on inconsistent indices. Ideally, the best body condition index is one developed to obtain a rapid body condition assessment on live birds. However, if such indices do not reliably predict lipid content, especially within species, then other means should be developed to examine body condition in wintering diving ducks.

In this study, lipid content was reliably estimated using various combinations of morphological and internal organ and fat mass measurements. Predictive power of lipid content for models developed for canvasback (R^2 = 0.66 - 0.99), lesser scaup (R^2 = 0.45 - 0.97), and ring-necked duck (R^2 = 0.42 - 0.89) were comparable to other studies. For example, the explanatory power of models developed for ring-necked duck (i.e., R^2 = 0.42 - 0.96, Hohman and Taylor 1986), lesser scaup (i.e., R^2 = 0.81 - 0.96, Chappell and Titman 1983), greater scaup (*A. marila*) (i.e., R^2 = 0.77 - 0.95, Chappell and Titman 1983), redhead (*A. americana*) (i.e., R^2 = 0.65 - 0.93, Bailey 1979), and American wigeon (*Anas americana*) (i.e., R^2 = 0.46 - 0.93, DeVault et al. 2003) were similar to my models. However variable inclusion within models varied among studies, and within this study variable inclusion varied depending upon species, and sex and age within species. Irrespective of species, age, or sex, skin mass consistently contributed to successful models, accounting for 69-86% of lipid content variation. These estimates are similar to the predictive power of skin mass in ring-necked duck, redheads American wigeon, greater scaup, and lesser scaup where skin mass accounted for 72%, 90%, 81%, 94%, and 95% of lipid content variation, respectively (Bailey 1979, Wishart 1979, Chappell and Titman 1983, Hohman and Taylor 1986). Although there were some similarities between my models and models from other studies, variable inclusion varied widely between this study and others. This supports the hypothesis that species, seasonal, and regional specific models should be developed for waterfowl to obtain the most accurate estimate of body condition.

Body Condition

Sources of Variation

In this study, mean total body lipid content ranged from 19-35%, depending upon species. In order to compare lipid content values to other studies, I calculated total body lipid content (%) of ducks in other studies using values of body mass (g) and total fat (g) as reported within each paper. Lipid content values from this study were within ranges of wintering canvasback (i.e., 14-20%, Hohman 1993), migrant canvasback (i.e., 10-30%, Serie and Sharp 1989), wintering lesser scaup (i.e., 11-14%, Afton et al. 1989), and migrant lesser scaup (i.e., 6-34%, Austin and Frederickson 1987). Some dabbling ducks, such as spring migrating Northern pintail (*A. acuta*) (i.e., 15-19%, Dombrowski et al. 2003), wintering female mallards (*A. platyrynchos*) (i.e., 6-17%, Heitmeyer 1988), and wintering (i.e., January) green-winged teal (*A. crecca*) (i.e., 21-23%, Baldassarre et al. 1986) had lipid levels within or below those of diving ducks in this study. In general, diving ducks in this study were in comparatively good condition, as indicated by total lipid content. However, birds in this study tended to have lower body masses and structural BCIs than those from other studies (Ryan 1972, Hohman 1993, Lovvorn 1994, Haukos et al. 2001). The few studies that have directly estimated lipid and protein content have presented their data based on mass and not as a proportion (%) of body composition. In this study, I calculated total body lipid content as a proportion of body composition in an attempt to generate useful, easily understood, field-based lipid prediction/estimation models. I also ground the whole bird excluding plumage, bill, and feet, whereas other studies excluded omental fat from the homogenate and then added that (wet) mass to the extracted lipid content of the bird to obtain individual lipid mass (Hohman 1993, Anteau and Afton 2004). These analytical differences may account for some of the variability in lipid content values presented in this and other studies.

Geographical variation in body condition is well documented for both diving and dabbling ducks, and such variation exemplifies (1) the complex relationships between environment and duck condition in a given region (Hohman 1993, Hohman and Weller 1994, Haukos et al. 2001) and (2) the difficulty in making broad generalizations about body condition to guide future management decisions within or among geographic regions. For example, food abundance, availability, and type, disturbance, weather, molt, courtship, and changing population densities may all individually or synergistically influence waterfowl body condition within a given region (e.g., Weller 1965, Hepp and Hair

1983, Korschgen et al. 1985, Gammonley and Heitmeyer 1990, Hohman 1990, Hohman et al. 1990, Knapton et al. 2000). As such, it is complicated and difficult to identify a specific factor, or specific combinations thereof, that influence waterfowl condition during winter.

Although several studies have examined body condition of wintering diving ducks on their southerly range, most have compared wet body/carcass mass to make inferences on condition among studies (Kaminski and Ryan 1981, Lovvorn 1987, Serie and Sharp 1989, Hohman 1993, Haukos et al. 2001). Although not always a good predictor of body lipid content, body mass is (1) generally correlated with overall condition (Owen and Cook 1977, Bailey 1979), (2) easily measured, and (3) relatively comparable within a species among regions, and therefore often used as a surrogate condition measure (Lovvorn 1994). However, body mass, uncorrected for structural size, never substantially accounted for any variability in lipid content in this study.

Although total body lipid content values were relatively high in this study, body masses tended to be lower than reported in other studies. For example, wintering canvasback were approximately 130 g lighter than those from Louisiana (Hohman 1993) and generally lighter, depending upon age/sex classes, than canvasback in North Carolina (Lovvorn 1994). Similarly, wintering lesser scaup were 50-70 g lighter from those in Louisiana (Afton et al. 1989) and 100-150 g lighter than lesser scaup during migration in Illinois (Hine et al. 1996). In this study, male canvasback and both sexes of ring-necked duck had lower body masses than canvasback and ring-necked duck wintering on the Texas coast, whereas lesser scaup had similar body masses among regions (Haukos et al. 2001). However, there may be some flaws in making these comparisons. First, average body mass values from other studies may mask age/sex class variability, particularly for birds in regions where body mass varies widely during winter (Lovvorn 1987, Hohman and Weller 1994). Second, birds in this study may be successfully attaining higher rates of lipid reserves, as proximate conditions (i.e., food, weather, etc.) are not as severe in east Texas as in more northerly regions (Lovvorn 1994).

In general, diving ducks wintering in more northerly areas usually experience mid-winter body mass and lipid content declines, whereas birds wintering in southerly areas do not (Ryan 1972, Perry et al. 1986, Lovvorn 1987, Hohman 1993, Hohman and Weller 1994, Lovvorn 1994). For example, canvasback wintering in North Carolina and the Chesapeake Bay exhibited mid-winter declines in body mass and fat content, attributed to dietary shifts during late winter from American wildcelery (*Vallisineria americana*) tubers to clams (*Macoma* spp.) (Nichols and Haramis 1980, Lovvorn 1987), whereas canvasback wintering in Louisiana maintained a higher, more constant body mass (Hohman 1993). Similarly, ring-necked duck wintering in Florida increased body mass throughout winter (Hohman and Weller 1994), as did ring-necked ducks on the Texas coast (Haukos et al. 2001). In this study, canvasback and ring-necked duck had similar increases in lipid content throughout the winter. Lesser scaup wintering on the Texas coast also showed condition increases from fall to mid-winter with a slight decrease in January (Haukos et al. 2001). In general, diving ducks in this study appear to exhibited body mass and lipid content patterns typical of southerly wintering birds.

There are several hypotheses concerning mid-winter decline in body condition, but in general, birds wintering in extreme northerly areas are subjected to harsh environmental conditions, placing considerable energetic demands on thermoregulation (Ryan 1972). Waterfowl increase foraging activity as temperatures decrease to 0°C, but reduce feeding activities when temperatures are < 0° C, where energy costs of foraging at temperatures < 0° C exceed energy gains (Paulus 1988). For example, captive canvasback, redhead, and lesser scaup stop eating when mean air temperatures drop from 5° C to –5° C over 6 days, and resume normal feeding when mean air temperatures exceeded 0° C (Lovvorn 1994). Moreover, foraging may become unprofitable when low mean air temperatures prevents efficient rewarming of body temperature after diving in cold water (Bevan and Butler 1992, Lovvorn 1994)

Diving ducks wintering in southerly areas rarely experience harsh weather conditions, especially in east Texas, where severe freezes are rare. This may partially explain the relatively high lipid levels maintained throughout winter, but generally lower condition indices and body mass as compared to ducks from other migrating and wintering areas (Lovvorn 1994, Haukos et al. 2001). Moreover, in warmer climates, food resources may not be limiting, which would decrease need to store reserves to prepare for stressful events (Lovvorn 1994, Haukos et al. 2001). Moreover, diving ducks in this study spent approximately the same amount of time in food acquisition behaviors as diving ducks in other studies (see Table 1.20). If food quality or quantity were limiting in this study, then diving ducks would have (1) attempted more dives or (2) spent more time in below water food acquisition behaviors to meet daily energy requirements. If foods were patchy or unevenly distributed, or were otherwise difficult to access, dive duration or time spent searching for food would correspondingly increase. However, these patterns were generally not observed in this study (see Chapter 1), which suggests that diving ducks wintering on these reservoirs are below carrying capacity and do not experience increasingly severe proximate factors (i.e., food shortages, inclement weather, etc.) during winter, and therefore are able to maintain relatively high lipid content, despite having generally lower body masses.

Diving ducks in this study spent a higher percentage of time in locomotion behaviors than other studies, perhaps from disturbance (i.e., hunting, boating, etc.). Increased locomotion may influence nutrient reserve acquisition due to the energetic costs of locomotion, primarily flight, but also swimming. Several studies have suggested that abnormal amounts of locomotion will hinder the ability of birds to increase, maintain, or even acquire adequate body fat for overwinter survival, (Haramis et al. 1986, Serie and Sharp 1989, Barzen and Serie 1990, Kahl 1991), as flight is 12-15 X basal metabolic rate (BMR), and swimming is 3.2 X BMR (Fredrickson and Reid 1988). However, diving ducks in this study did not spend a disproportionate amount of time feeding as compared to other studies; therefore disturbance on these reservoirs may not have affected body fat acquisition of these birds (see Chapter I).

Other Sources of Variation

There are conflicting views of using hunter-killed birds to estimate waterfowl condition. During this study it was neither feasible nor permissible to scientifically collect diving ducks on these reservoirs, as they are open to the public and are utilized by both recreational fisherman and waterfowl hunters. Also, because these birds were mainly found in open water areas, it was difficult to approach and collect them by jump shooting. Therefore, the only means to collect these birds was by using decoys. This "hunter killed bias" (Greenwood et al. 1986) could be a reason why birds in this study had lower condition indices and body mass than birds in other studies. For example, hunter-shot mallards had lower condition indices than rocket-netted birds (Reinecke and Shaiffer 1988) and hunter-shot ring-necked ducks were in poorer condition than randomly collected birds (McCracken et al. 2000). However, this bias is inconsistent among species and studies. For example, Sheeley and Smith (1989) found no condition bias in Northern pintails collected over decoys and birds collected from flushing or shot in travel corridors, and Bergan and Smith (1993) found female mallard body masses were similar among those bait-trapped and randomly collected.

Management and Research Recommendations

Although plucked skin and omental fat mass are important variables in predicting lipid content, they are time consuming and require sacrificing the bird. However, few studies have developed reliable models using easily obtainable morphological measurements. Likewise, I developed few reliable models that incorporated easily obtainable morphological measurements, where models were inconsistent within and among species in this study. Therefore, models incorporating a combination of morphological, internal fat, and tissue mass measurements should be used to predict lipid content in diving ducks wintering on east Texas reservoirs.

As sample sizes of some age and sex classes used in this study were small, future research which includes more birds from each age/sex class is needed to develop efficient and reliable models. Quantity and quality of habitat these reservoirs are providing for wintering diving ducks should be examined. Such data would provide information to develop management decisions to enhance habitat on these reservoirs. Research should concentrate on food abundance, availability, and utilization of submergent and emergent vegetation on these reservoirs.

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Table 2.1. Means and Standard Errors (SE) of morphological features of wintering canvasbacks, lesser scaup, and ring-necked ducks on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Canvasback (*n* = 73)		Lesser scaup (*n* = 89)		Ring-necked duck (*n* = 86)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Total body mass (g)	1169.4	12.9	690.8	8.4	725.4	6.9
Plucked body mass (g)	1064.9	12.4	638.4	8.3	658.1	7.1
Ingesta mass (g)	22.1	1.3	23.1	1.3	15.9	0.9
Corrected body mass (g)	1042.8	12.6	615.3	8.1	642.5	6.9
Total body length (cm)	47.3	0.3	36.9	0.3	37.6	0.3
Wing cord (cm)	23.7	0.1	20.3	0.1	20.2	0.1
Culmen (cm)	6.0	<0.1	4.1	<0.1	4.6	<0.1
Total bill length (cm)	6.3	<0.1	4.7	<0.1	4.7	<0.1
Tarsus (cm)	4.3	<0.1	3.5	<0.1	3.5	<0.1
Bill width (cm)	2.1	<0.1	2.3	<0.1	2.2	<0.1
Keel length (cm)	10.1	<0.1	8.5	<0.1	8.9	<0.1
Esophagus-proventriculus length (cm)	29.9	0.3	21.0	0.3	22.5	0.3
Intestine length (cm)	147.0	1.4	171.0	1.7	121.2	2.2
Gizzard mass (g)	44.6	0.9	34.9	0.9	44.2	1.2
Heart mass (g)	11.5	0.2	6.6	0.1	7.5	0.1

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Table 2.1. Continued.

	Canvasback (n = 73)		Lesser scaup (n = 89)		Ring-necked duck (n = 86)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Liver mass (g)	28.0	0.8	19.7	0.4	18.7	0.4
Esophagus-proventriculus mass (g)	12.5	0.3	7.7	0.2	8.4	0.2
Flight muscle mass (g)	98.8	1.1	56.3	0.8	66.2	0.7
Leg muscle mass (g)	49.4	0.6	24.5	0.4	26.1	0.5
Kidney mass (g)	7.6	0.2	6.7	0.2	4.5	0.1
Intestine mass (g)	24.5	0.6	28.9	0.7	17.7	0.5
Omental fat mass (g)	10.0	0.7	7.2	0.6	4.7	0.3
Mesentary fat mass (g)	6.6	0.5	4.9	0.4	2.7	0.2
Visceral fat mass (g)	0.9	0.1	0.7	0.1	0.6	<0.1
Skin mass (g)	167.4	5.9	105.9	4.3	93.9	2.9

Table 2.2. Type III *F* and *P* values from analysis of variance of morphological features for canvasbacks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

			Source of variability					
	Overall model[1]		Age[2]		Sex[2]		Age*Sex[2]	
Morphological feature	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Total body mass (g)	9.71	<0.001	14.12	<0.001	7.74	0.007	1.24	0.270
Plucked body mass (g)	8.75	<0.001	14.20	<0.001	5.45	0.023	2.07	0.155
Ingesta mass (g)	3.52	0.027	3.80	0.056	4.54	0.037	0.49	0.485
Corrected body mass (g)	8.67	<0.001	15.34	<0.001	4.20	0.044	2.22	0.141
Total body length (cm)	6.22	<0.001	0.79	0.376	15.28	<0.001	0.01	0.942
Wing chord (cm)	31.65	<0.001	12.81	<0.001	55.47	<0.001	0.20	0.653
Culmen (cm)	11.88	<0.001	0.31	0.578	26.66	<0.001	0.29	0.589
Total bill length (cm)	9.99	<0.001	0.27	0.605	20.67	<0.001	0.02	0.884
Tarsus (cm)	6.10	0.001	0.10	0.749	12.13	<0.001	0.31	0.578
Bill width (cm)	5.56	0.002	3.74	0.057	8.24	0.005	0.08	0.783
Keel length (cm)	9.02	<0.001	0.69	0.409	22.42	<0.001	0.00	0.999
Esophagus-proventriculus length (cm)	4.21	0.009	0.40	0.529	8.64	0.005	0.01	0.919
Intestine length (cm)	1.72	0.172	0.05	0.823	3.92	0.052	2.35	0.129
Gizzard mass (g)	7.71	<0.001	12.30	<0.001	5.22	0.026	0.65	0.425
Heart mass (g)	4.40	0.007	1.98	0.164	7.09	0.009	0.00	0.958
Liver mass (g)	0.75	0.526	0.21	0.645	0.44	0.510	1.77	0.188
Esophagus-proventriculus mass (g)	5.95	0.001	5.25	0.025	7.31	0.009	0.01	0.911
Flight muscle mass (g)	7.89	<0.001	10.95	0.002	6.03	0.017	0.00	0.982

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Table 2.2. Continued.

	Source of variability							
	Overall model[1]		Age[2]		Sex[2]		Age*Sex[2]	
Morphological feature	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Leg muscle mass (g)	8.46	<0.001	5.47	0.022	13.11	0.001	0.31	0.582
Kidney mass (g)	6.10	0.001	4.40	0.039	3.21	0.078	4.08	0.047
Intestine mass (g)	3.07	0.033	2.87	0.095	7.71	0.007	0.29	0.592
Omental fat mass (g)	3.31	0.025	2.46	0.121	2.64	0.109	2.29	0.135
Mesentary fat mass (g)	4.04	0.011	5.80	0.019	2.04	0.158	2.32	0.133
Visceral fat mass (g)	1.79	0.157	2.74	0.103	0.40	0.530	1.37	0.245
Skin mass (g)	2.61	0.059	3.32	0.073	0.11	0.739	3.06	0.085

[1] Initial model, where sex, age, and their interaction are pooled.

[2] Type III sums of squares *F* and *P* values.

Table 2.3. Means and Standard Errors (SE) of morphological features for wintering canvasbacks collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Canvasbacks							
	Male (*n* = 39)		Female (*n* = 34)		Adult (*n* = 51)		Juvenile (*n* = 22)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Total body mass (g)	1205.7	15.6	1127.7	18.9	1202.9	12.3	1091.7	25.5
Plucked body mass (g)	1093.9	15.5	1031.6	18.5	1096.9	11.6	990.6	25.4
Ingesta mass (g)	24.7	1.8	19.1	1.8	20.8	1.5	47.3	0.6
Corrected body mass (g)	1069.2	15.9	1012.5	18.9	1076.1	11.8	23.3	0.1
Total body length (cm)	48.3	0.2	46.2	0.4	7.3	0.3	5.9	0.1
Wing chord (cm)	24.2	0.1	23.2	0.1	23.9	0.1	6.2	0.1
Culmen (cm)	6.2	0.1	5.8	<0.1	6.0	0.1	4.3	<0.1
Total bill length (cm)	6.4	<0.1	6.1	<0.1	6.3	<0.1	2.1	<0.1
Tarsus (cm)	4.4	<0.1	4.2	<0.1	4.3	<0.1	10.1	0.1
Bill width (cm)	2.2	<0.1	2.1	<0.1	2.2	<0.1	29.3	0.4
Keel length (cm)	10.2	<0.1	9.9	<0.1	10.1	0.1	145.4	1.9
Esophagus-proventriculus length (cm)	30.9	0.4	28.9	0.4	30.2	0.4	39.1	1.3
Intestine length (cm)	149.1	1.7	144.7	2.2	147.7	1.8	10.8	0.4
Gizzard mass (g)	47.0	1.3	41.8	1.3	46.9	1.1	27.1	1.4
Heart mass (g)	12.1	0.3	10.7	0.2	11.8	0.3	11.4	0.5
Liver mass (g)	28.2	0.9	27.8	1.4	28.4	1.0	92.6	2.1
Esophagus-proventriculus mass (g)	13.4	0.4	11.6	0.4	13.1	0.3	46.5	1.1
Flight muscle mass (g)	102.1	1.6	94.9	1.3	101.5	1.2	6.9	0.4
Leg muscle mass (g)	51.7	0.9	46.8	0.8	50.7	0.7	25.5	1.1

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Table 2.3. Continued.

	Canvasback							
	Male (n = 39)		Female (n = 34)		Adult (n = 51)		Juvenile (n = 22)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Kidney mass (g)	8.2	0.3	6.9	0.2	7.9	0.2	6.9	0.4
Intestine mass (g)	25.9	0.9	22.9	0.6	24.1	0.7	25.5	1.2
Omental fat mass (g)	8.6	0.9	11.7	1.1	10.7	0.9	8.7	1.5
Mesentary fat mass (g)	5.8	0.6	7.5	0.9	7.3	0.6	4.9	0.9
Visceral fat mass (g)	0.9	0.1	1.0	0.2	1.0	0.1	0.7	0.1
Skin mass (g)	163.6	7.9	171.7	8.9	174.3	6.5	151.4	11.9

Table 2.4. Means, Standard Errors (SE), and *F* and *P* values resulting from analysis of variance of morphological features for age-sex classes of wintering canvasbacks collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Male				Female					
	Adult (*n* = 31)		Juvenile (*n* = 8)		Adult (*n* = 20)		Juvenile (*n* =14)			
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Total body mass (g)	1219.3A	16.0	1153.4A	41.4	1177.6A	18.5	1056.4B	28.8	9.71	<0.001
Plucked body mass (g)	1105.5A	15.8	1048.9A	42.4	1083.7A	16.7	957.1B	28.3	8.75	<0.001
Ingesta mass (g)	23.9A	2.1	27.4A	3.3	16.0A	1.3	23.4A	3.7	3.25	0.027
Corrected body mass (g)	1081.6A	16.3	1021.4A	43.9	1067.7A	16.4	933.7B	28.7	8.67	<0.001
Total body length (cm)	48.2A	0.3	48.6A	0.4	46.0B	0.5	46.5B	0.8	6.22	<0.001
Wing chord (cm)	24.2A	0.1	23.9B	0.2	23.4C	0.1	22.9D	0.1	31.65	<0.001
Culmen (cm)	6.2A	0.1	6.2A	0.1	5.7B	0.1	5.8B	<0.1	11.88	<0.001
Total bill length (cm)	6.4A	<0.1	6.4A	0.1	6.1B	<0.1	6.1B	0.1	9.99	<0.001
Tarsus (cm)	4.4A	<0.1	4.3A	<0.1	4.2B	<0.1	4.2B	<0.1	6.10	0.001
Bill width (cm)	2.2A	<0.1	2.1AB	<0.1	2.1B	<0.1	2.1B	<0.1	5.56	0.002
Keel length (cm)	10.2A	0.1	10.3A	0.1	9.9B	0.1	9.9B	0.1	9.02	<0.001
Esophagus-proventriculus length (cm)	31.0A	0.5	30.5AB	0.8	29.0B	0.6	28.6B	0.4	4.21	0.009
Intestine length (cm)	148.2A	2.1	152.2A	2.3	146.9A	3.3	141.5A	2.3	1.72	0.172
Gizzard mass (g)	48.1A	1.5	42.9AB	1.9	45.2A	1.5	36.9B	1.4	7.71	<0.001
Heart mass (g)	12.3A	0.4	11.6AB	0.7	11.0B	0.2	10.4B	0.4	4.40	0.007
Liver mass (g)	27.9A	1.1	29.5A	2.1	29.1A	1.9	25.8A	1.9	0.75	0.525
Esophagus-proventriculus mass (g)	13.6A	0.3	12.4AB	1.2	12.1B	0.5	10.8B	0.4	5.95	0.001
Flight muscle mass (g)	103.7A	1.7	96.1BC	4.1	98.0B	1.2	90.6C	2.3	7.89	<0.001
Leg muscle mass (g)	52.2A	1.0	49.3AB	1.5	48.3B	0.9	44.6C	1.1	8.46	<0.001
Kidney mass (g)	8.5A	0.3	6.8B	0.8	7.0B	0.3	6.9B	0.4	6.10	0.001

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Table 2.4. Continued.

	Male				Female					
	Adult (n = 31)		Juvenile (n = 8)		Adult (n = 20)		Juvenile (n =14)			
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	F	P
Intestine mass (g)	25.3A	1.0	28.3A	2.5	22.3B	0.7	23.9A	1.2	3.25	0.027
Omental fat mass (g)	8.6B	1.0	8.6B	2.5	13.7A	1.2	8.7B	1.9	3.31	0.025
Mesentary fat mass (g)	6.0B	0.7	5.0B	1.4	9.4A	1.1	4.9B	1.2	4.04	0.010
Visceral fat mass (g)	0.9A	0.1	0.8A	0.1	1.3A	0.3	0.6A	0.1	1.79	0.157
Skin mass (g)	163.8A	8.1	162.9A	23.4	190.5A	9.9	144.7A	13.5	2.61	0.059

Table 2.5. Type III *F* and *P* values from analysis of variance of morphological features for lesser scaup collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Source of variability							
	Overall model^1		Age^2		Sex^2		Age*Sex^2	
Morphological feature	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Total body mass (g)	4.32	0.007	2.52	0.116	5.71	0.019	0.00	0.999
Plucked body mass (g)	3.55	0.018	1.91	0.170	4.87	0.030	0.01	0.934
Ingesta mass (g)	0.33	0.802	0.08	0.773	0.45	0.504	0.26	0.608
Corrected body mass (g)	3.40	0.021	1.86	0.176	4.58	0.035	0.03	0.866
Total body length (cm)	2.02	0.117	1.60	0.209	1.86	0.176	0.75	0.389
Wing chord (cm)	1.44	0.236	0.01	0.914	2.15	0.146	0.79	0.376
Culmen (cm)	3.79	0.013	1.24	0.269	9.53	0.003	0.10	0.756
Total bill length (cm)	2.89	0.040	0.04	0.844	6.49	0.013	0.05	0.817
Tarsus (cm)	1.75	0.163	2.03	0.158	1.26	0.266	0.03	0.865
Bill width (cm)	3.52	0.018	3.55	0.063	2.58	0.112	0.80	0.373
Keel length (cm)	5.79	0.001	0.11	0.740	13.57	<0.001	0.03	0.866
Esophagus-proventriculus length (cm)	4.84	0.004	0.03	0.875	9.84	0.002	5.02	0.028
Intestine length (cm)	2.22	0.092	0.75	0.388	2.77	0.100	1.60	0.201
Gizzard mass (g)	1.87	0.141	0.23	0.636	3.73	0.057	0.57	0.452
Heart mass (g)	1.76	0.162	0.76	0.385	4.42	0.038	2.29	0.134
Liver mass (g)	1.33	0.269	1.90	0.172	3.04	0.085	1.52	0.221

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Table 2.5. Continued.

			Source of variability					
	Overall model[1]		Age[2]		Sex[2]		Age*Sex[2]	
Morphological feature	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Esophagus-proventriculus mass (g)	1.59	0.198	1.58	0.212	1.12	0.292	0.44	0.509
Flight muscle mass (g)	2.70	0.051	1.61	0.207	3.17	0.079	0.69	0.409
Leg muscle mass (g)	3.75	0.014	0.73	0.396	6.36	0.014	1.92	0.169
Kidney mass (g)	0.92	0.436	0.14	0.709	2.66	0.709	0.29	0.593
Intestine mass (g)	0.28	0.841	0.65	0.421	0.11	0.743	0.02	0.878
Omental fat mass (g)	0.90	0.445	0.00	0.989	0.67	0.415	2.15	0.147
Mesentary fat mass (g)	0.94	0.426	0.28	0.597	0.00	0.996	2.50	0.118
Visceral fat mass (g)	0.58	0.628	0.99	0.323	1.08	0.302	0.00	0.999
Skin mass (g)	0.39	0.761	0.80	0.373	0.02	0.896	0.22	0.641

[1] Initial model, where sex, age, and their interaction are pooled.

[2] Type III sums of squares *F* and *P* values.

Table 2.6. Means and Standard Errors (SE) of morphological features of lesser scaup collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Lesser Scaup							
	Male (n = 51)		Female (n = 38)		Adult (n = 37)		Juvenile (n = 52)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Total body mass (g)	712.9	11.1	661.2	11.6	715.3	12.7	673.4	10.8
Plucked body mass (g)	658.5	10.8	611.4	11.6	659.7	12.4	623.2	10.7
Ingesta mass (g)	23.9	1.8	21.9	1.7	37.8	0.5	22.3	1.6
Corrected body mass (g)	634.6	10.7	589.4	11.2	20.4	0.3	600.8	10.5
Total body length (cm)	37.5	0.5	36.3	0.4	4.1	0.3	36.4	0.5
Wing chord (cm)	20.5	0.2	20.1	0.1	4.8	0.3	20.3	0.1
Culmen (cm)	4.2	<0.1	4.0	<0.1	3.6	<0.1	4.1	<0.1
Total bill length (cm)	4.8	<0.1	4.7	<0.1	4.8	<0.1	4.7	<0.1
Tarsus (cm)	3.6	<0.1	3.5	<0.1	3.6	0.1	3.5	<0.1
Bill width (cm)	2.4	<0.1	2.3	<0.1	2.4	<0.1	2.3	<0.1
Keel length (cm)	8.7	<0.1	8.4	<0.1	8.6	0.1	8.5	0.1
Esophagus-proventriculus length (cm)	21.8	0.3	19.9	0.7	21.7	0.6	20.6	0.4
Intestine length (cm)	173.6	2.3	167.6	2.2	169.8	2.5	171.9	2.2
Gizzard mass (g)	36.4	1.2	32.8	1.2	36.2	1.5	33.9	0.9
Heart mass (g)	6.8	0.2	6.4	0.2	6.6	0.2	6.6	0.2
Liver mass (g)	20.2	0.5	19.2	0.7	19.4	0.5	19.9	0.6
Esophagus-proventriculus mass (g)	7.9	0.3	7.4	0.2	8.1	0.3	7.5	0.3

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Table 2.6. Continued.

	Lesser Scaup							
	Male (n = 51)		Female (n = 38)		Adult (n = 37)		Juvenile (n = 52)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Flight muscle mass (g)	57.8	0.9	54.4	1.2	58.3	1.1	54.9	1.0
Leg muscle mass (g)	25.4	0.5	23.3	0.6	25.4	0.5	23.8	0.5
Kidney mass (g)	6.9	0.3	6.3	0.3	6.7	0.3	6.6	0.3
Intestine mass (g)	28.9	0.9	28.8	1.1	28.2	1.2	29.4	0.9
Omental fat mass (g)	6.9	0.8	7.6	0.9	6.7	0.9	7.5	0.9
Mesentary fat mass (g)	5.1	0.5	4.7	0.5	5.0	0.6	4.8	0.5
Visceral fat mass (g)	0.8	0.2	0.6	0.1	0.6	0.1	0.8	0.2
Skin mass (g)	108.1	6.2	103.1	5.7	110.7	6.9	102.6	5.4

Table 2.7. Means, Standard Errors (SE), and *F* and *P* values resulting from analysis of variance of morphological features for age-sex classes of wintering lesser scaup collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Male				Female					
	Adult (*n* = 28)		Juvenile (*n* = 23)		Adult (*n* = 9)		Juvenile (*n* =29)			
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Total body mass (g)	725.7A	14.3	697.3A	17.1	682.9AB	25.6	654.5B	12.9	4.32	0.007
Plucked body mass (g)	668.9A	14.3	645.8A	16.5	631.2A	23.8	605.2A	13.3	3.55	0.180
Ingesta mass (g)	24.9A	2.4	22.6A	2.9	21.5A	3.6	22.1A	1.9	0.33	0.802
Corrected body mass (g)	644.0A	14.1	623.2AB	16.3	609.7AB	22.2	583.1B	12.9	3.40	0.021
Total body length (cm)	28.2A	0.6	36.6A	0.9	36.5A	0.7	36.2A	0.5	2.02	0.117
Wing chord (cm)	20.4A	0.3	20.6A	0.1	20.3A	0.1	20.0A	0.1	1.44	0.236
Culmen (cm)	4.1AB	<0.1	4.2A	<0.1	4.0B	0.1	4.0B	<0.1	3.79	0.013
Total bill length (cm)	4.8A	<0.1	4.8A	<0.1	4.7AB	0.1	4.6B	0.1	2.89	0.040
Tarsus (cm)	3.6A	0.1	3.5A	0.1	3.5A	0.1	3.5A	0.1	1.75	0.163
Bill width (cm)	2.4A	0.1	2.3B	<0.1	2.3AB	<0.1	2.3B	<0.1	3.52	0.018
Keel length (cm)	8.7A	0.1	8.7A	0.1	8.4B	0.1	8.3B	0.1	5.79	0.001
Esophagus-proventriculus length (cm)	22.6A	0.3	20.9B	0.4	18.8B	2.2	20.3B	0.5	4.84	0.004
Intestine length (cm)	170.1A	3.0	177.8A	3.5	168.7A	4.8	167.2A	2.6	2.22	0.091
Gizzard mass (g)	37.5A	1.9	35.1A	1.2	32.4A	1.4	32.9A	1.5	1.87	0.141
Heart mass (g)	6.9A	0.2	6.7A	0.3	5.8A	0.3	6.5A	0.2	1.76	0.162
Liver mass (g)	20.1A	0.5	20.2A	0.9	17.4A	0.7	19.8A	0.8	1.33	0.270
Esophagus-proventriculus mass (g)	8.3A	0.3	7.5A	0.4	7.6A	0.5	7.4A	0.2	1.59	0.199
Flight muscle mass (g)	59.4A	1.3	55.8A	1.5	54.9A	1.9	54.2A	1.5	2.70	0.051
Leg muscle mass (g)	26.2A	0.6	24.4AB	0.7	22.9A	1.0	23.4B	0.7	3.75	0.014
Kidney mass (g)	7.0A	0.3	6.9A	0.5	5.9A	0.7	6.4A	0.4	0.92	0.436

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Table 2.7. Continued.

	Male				Female					
	Adult (*n* = 28)		Juvenile (*n* = 23)		Adult (*n* = 9)		Juvenile (*n* =29)			
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Intestine mass (g)	28.3A	1.4	29.8A	1.1	28.0A	2.2	29.1A	1.3	0.33	0.802
Omental fat mass (g)	6.0A	1.0	8.0A	1.5	9.1A	1.9	7.1A	1.1	0.90	0.445
Mesentary fat mass (g)	5.0A	0.6	5.6A	0.9	6.0A	1.1	4.2A	0.6	0.94	0.426
Visceral fat mass (g)	0.7A	0.1	0.9A	0.3	0.4A	0.1	0.7A	0.2	0.58	0.628
Skin mass (g)	109.9A	8.2	105.8A	9.5	113.2A	13.0	100.0A	6.3	0.39	0.761

Table 2.8. Type III *F* and *P* values from analysis of variance of morphological features for ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in East Texas, 2003-2004 and 2004-2005.

			Source of variability					
	Overall model^1		Age^2		Sex^2		Age*Sex^2	
Morphological feature	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Total body mass (g)	22.06	<0.001	12.28	<0.001	14.68	<0.001	4.16	0.045
Plucked body mass (g)	17.99	<0.001	7.01	0.010	13.31	<0.001	4.18	0.044
Ingesta mass (g)	1.63	0.188	0.92	0.339	3.79	0.055	1.65	0.203
Corrected body mass (g)	20.37	<0.001	9.08	0.004	12.37	<0.001	5.90	0.018
Total body length (cm)	4.59	0.005	1.88	0.174	7.75	0.007	0.46	0.498
Wing chord (cm)	15.30	<0.001	1.97	0.164	16.88	<0.001	4.01	0.049
Culmen (cm)	0.76	0.521	0.00	0.949	1.91	0.171	0.94	0.335
Total bill length (cm)	1.08	0.364	0.11	0.737	2.50	0.118	0.18	0.676
Tarsus (cm)	1.57	0.202	0.20	0.652	0.07	0.787	3.32	0.072
Bill width (cm)	8.68	<0.001	11.01	0.001	2.23	0.139	0.81	0.370
Keel length (cm)	10.56	<0.001	1.85	0.177	17.54	<0.001	0.10	0.752
Esophagus-proventriculus length (cm)	2.98	0.036	0.40	0.529	3.23	0.076	0.83	0.364
Intestine length (cm)	0.40	0.756	0.15	0.702	0.83	0.365	0.56	0.458
Gizzard mass (g)	3.28	0.025	1.28	0.262	5.76	0.019	0.28	0.595
Heart mass (g)	4.05	0.010	0.38	0.541	6.07	0.016	0.42	0.517
Liver mass (g)	1.75	0.164	0.03	0.871	3.30	0.073	0.09	0.762

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Table 2.8. Continued.

	Source of variability							
	Overall model[1]		Age[2]		Sex[2]		Age*Sex[2]	
Morphological feature	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Esophagus-proventriculus mass (g)	5.35	0.002	0.04	0.849	13.27	0.001	0.22	0.639
Flight muscle mass (g)	18.55	<0.001	7.63	0.007	15.34	<0.001	3.60	0.061
Leg muscle mass (g)	3.88	0.012	10.67	0.002	0.02	0.884	1.49	0.226
Kidney mass (g)	1.87	0.141	0.06	0.800	4.93	0.029	0.99	0.323
Intestine mass (g)	1.87	0.141	1.71	0.195	2.09	0.152	2.41	0.125
Omental fat mass (g)	2.53	0.063	1.93	0.169	0.35	0.557	1.44	0.234
Mesentary fat mass (g)	1.90	0.136	1.83	0.180	0.58	0.447	2.35	0.129
Visceral fat mass (g)	0.47	0.705	0.77	0.382	0.22	0.642	0.03	0.856
Skin mass (g)	7.11	<0.001	4.01	0.049	1.15	0.287	4.84	0.031

[1] Initial model, where sex, age, and their interaction are pooled.

[2] Type III sums of squares *F* and *P* values.

Table 2.9. Means and Standard Errors (SE) of morphological features for ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Ring-necked Ducks							
	Male (n = 69)		Female (n = 17)		Adult (n = 70)		Juvenile (n = 16)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Total body mass (g)	743.0	6.9	654.8	8.9	741.3	7.0	656.6	9.4
Plucked body mass (g)	676.0	7.2	588.5	7.3	671.9	7.3	595.3	11.1
Ingesta mass (g)	16.4	0.9	13.9	1.8	15.6	0.9	17.3	9.6
Corrected body mass (g)	660.0	7.0	574.6	6.8	656.8	7.1	577.6	0.6
Total body length (cm)	38.0	0.3	35.8	0.4	37.9	0.3	36.3	0.1
Wing chord (cm)	20.4	0.1	19.3	0.1	20.4	0.1	19.6	<0.1
Culmen (cm)	4.6	<0.1	4.5	<0.1	4.6	<0.1	4.6	<0.1
Total bill length (cm)	4.7	<0.1	4.6	<0.1	4.7	<0.1	4.7	<0.1
Tarsus (cm)	3.5	<0.1	3.4	0.1	3.5	<0.1	3.4	<0.1
Bill width (cm)	2.2	<0.1	2.1	<0.1	2.2	<0.1	2.1	<0.1
Keel length (cm)	9.0	<0.1	8.6	0.1	8.9	<0.1	8.7	<0.1
Esophagus-proventriculus length (cm)	22.9	0.3	21.0	0.5	22.8	0.3	21.5	0.3
Intestine length (cm)	121.8	2.7	118.9	2.6	120.8	2.6	122.9	3.2
Gizzard mass (g)	45.9	1.3	37.9	2.2	45.3	1.3	39.7	2.2
Heart mass (g)	7.7	0.2	6.6	0.2	7.6	0.2	6.9	0.2
Liver mass (g)	19.2	0.5	16.9	0.8	18.9	0.5	17.8	0.7

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Table 2.9. Continued.

	Ring-necked Duck							
	Male (n = 69)		Female (n = 17)		Adult (n = 70)		Juvenile (n = 16)	
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Esophagus-proventriculus mass (g)	8.7	0.2	7.2	0.3	8.5	0.2	7.9	0.5
Flight muscle mass (g)	67.9	0.7	59.2	1.0	67.6	0.7	60.0	1.2
Leg muscle mass (g)	26.3	0.4	25.2	2.1	26.8	0.6	22.8	0.7
Kidney mass (g)	4.7	0.1	4.1	0.3	4.6	0.1	4.4	0.2
Intestine mass (g)	17.8	0.6	17.3	1.0	17.3	0.5	19.2	1.3
Omental fat mass (g)	4.9	0.4	3.6	0.6	5.1	0.4	3.2	0.6
Mesentary fat mass (g)	2.7	0.2	2.6	0.4	2.9	0.2	2.1	0.4
Visceral fat mass (g)	0.6	0.1	0.5	0.1	0.6	0.1	0.5	0.1
Skin mass (g)	97.7	3.2	77.8	4.2	98.5	3.1	74.4	4.3

Table 2.10. Means, Standard Errors (SE), and *F* and *P* values resulting from analysis of variance of morphological features for age-sex classes of wintering ring-necked ducks collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Male				Female					
	Adult (*n* = 60)		Juvenile (*n* = 8)		Adult (*n* = 9)		Juvenile (*n* =8)			
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Total body mass (g)	752.8A	6.78	670.0B	12.75	665.1B	11.99	643.2B	12.70	22.06	<0.001
Plucked body mass (g)	684.0A	7.17	609.0B	18.24	593.0B	7.81	583.4B	13.13	17.99	<0.001
Ingesta mass (g)	15.8A	0.95	21.1A	3.75	14.2A	2.83	13.4A	2.41	1.63	0.188
Corrected body mass (g)	668.7A	6.84	586.4B	15.81	578.9B	7.56	569.9B	11.96	20.37	<0.001
Total body length (cm)	38.1A	0.31	37.6A	0.92	36.6AB	0.61	35.1B	0.58	4.59	0.005
Wing chord (cm)	20.5A	0.10	19.8B	0.19	19.2B	0.15	19.3B	0.17	15.30	<0.001
Culmen (cm)	4.6A	0.04	4.7A	0.16	4.6A	0.04	4.5A	0.05	0.76	0.521
Total bill length (cm)	4.7A	0.04	4.7A	0.14	4.6A	0.04	4.6A	0.06	1.08	0.364
Tarsus (cm)	3.5A	0.04	3.3A	0.03	3.4A	0.03	3.5A	0.14	1.57	0.202
Bill width (cm)	2.2A	0.01	2.1B	0.02	2.2B	0.03	2.1B	0.03	8.68	<0.001
Keel length (cm)	9.0A	0.04	8.9AB	0.09	8.6BC	0.08	8.5C	0.10	10.56	<0.001
Esophagus-proventriculus length (cm)	23.0A	0.36	21.8AB	0.42	20.9B	0.83	21.2B	0.38	2.98	0.036
Intestine length (cm)	121.0A	2.97	128.0A	3.47	120.0A	2.43	117.7A	4.88	0.40	0.756
Gizzard mass (g)	46.1A	1.36	44.3AB	3.74	40.3AB	4.01	35.1A	1.07	3.28	0.025
Heart mass (g)	7.8A	0.18	7.3AB	0.19	6.6B	0.29	6.6B	0.29	4.05	0.010
Liver mass (g)	19.2A	0.53	18.7A	0.82	16.8A	1.06	16.9A	1.19	1.75	0.163
Esophagus-proventriculus mass (g)	8.7A	0.17	8.9A	0.92	7.3B	0.40	7.0B	0.38	5.35	0.002
Flight muscle mass (g)	68.8A	0.68	61.6B	2.01	59.8B	1.37	58.5B	1.38	18.55	<0.001
Leg muscle mass (g)	26.6A	0.41	23.8AB	0.71	28.1A	3.70	21.8B	1.10	3.88	0.012
Kidney mass (g)	4.6A	0.14	4.9A	0.25	4.2A	0.40	3.8A	0.32	1.87	0.141

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Table 2.10. Continued.

	Male				Female					
	Adult (*n* = 60)		Juvenile (*n* = 8)		Adult (*n* = 9)		Juvenile (*n* =8)			
Morphological feature	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	*F*	*P*
Intestine mass (g)	17.3A	0.59	21.3A	2.10	17.4A	1.65	17.1A	1.33	1.63	0.188
Omental fat mass (g)	5.3A	0.41	2.9A	0.89	3.7A	0.75	3.5A	0.97	2.53	0.063
Mesentary fat mass (g)	2.9A	0.21	1.5A	0.32	2.5A	0.51	2.6A	0.64	1.90	0.136
Visceral fat mass (g)	0.6A	0.06	0.5A	0.12	0.6A	0.11	0.4A	0.10	0.47	0.705
Skin mass (g)	101.3A	3.33	70.2B	4.69	77.1B	4.99	78.6B	7.23	7.11	<0.001

Table 2.11. Means and Standard Errors (SE) of total lipid content (%) and morphological body condition indices (BCI) for canvasbacks, lesser scaup, and ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Canvasback (*n* = 73)			Lesser scaup (*n* = 89)			Ring-necked duck (*n* = 86)		
	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range
Lipid content (%)	28.51B[1]	1.49	3.04-48.03	31.19A	1.35	3.39-52.94	26.68B	1.04	4.14-50.62
BCI1[2]	4.93A	0.05	3.56-5.62	3.40B	0.04	2.63-5.39	3.59B	0.03	2.89-4.21
BCI2[3]	16.47A	0.18	11.91-19.23	12.03B	0.14	9.14-15.92	12.55B	0.11	10.22-14.84
BCI3[4]	18.56A	0.21	14.10-21.53	17.00B	0.19	13.26-21.48	17.26B	0.22	13.42-20.40

[1] Means followed by the same letter within the same row are not different ($P > 0.05$).
[2] BCI1 = (total body mass (g)) / (wing chord (mm))
[3] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))
[4] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.12. Type III *F* and *P* values from analysis of variance of total lipid content (%) and morphological body condition indices (BCI) within canvasbacks (CANV), lesser scaup (LESC), and ring-necked ducks (RNDU) collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

		BCI1[1]		BCI2[2]		BCI3[3]		Lipid Content (%)	
Species	Source of variation	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
CANV	age	9.30	0.003	13.37	<0.001	15.51	<0.001	2.79	0.099
	sex	1.20	0.278	0.59	0.444	1.97	0.165	2.64	0.109
	age*sex	1.20	0.276	1.22	0.273	0.73	0.396	2.58	0.113
LESC	age	2.31	0.132	0.61	0.439	1.59	0.211	0.46	0.498
	sex	2.59	0.111	1.89	0.173	0.32	0.572	0.63	0.430
	age*sex	0.25	0.619	0.28	0.601	0.04	0.833	0.92	0.339
RNDU	age	7.23	0.009	3.59	0.062	2.40	0.126	0.68	0.412
	sex	2.90	0.092	2.72	0.103	0.15	0.704	0.70	0.405
	age*sex	0.95	0.333	4.42	0.039	1.93	0.168	5.20	0.025

[1] BCI1 = (total body mass (g)) / (wing chord (mm))

[2] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[3] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.13. Means and Standard Errors (SE) of morphological body condition indices (BCI) of adult and juvenile, and male and female canvasbacks, lesser scaup, and ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Body Condition Index								
	BCI1^1			BCI2^2			BCI3^3		
	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range	$\bar{x}$	SE	Range
Canvasback									
Adult (*n* = 51)	5.03A^4	0.05	4.20-5.62	16.89A	0.17	14.04-19.23	19.01A	0.22	15.42-21.53
Juvenile (*n* =22)	4.69B	0.10	3.56-5.37	15.49B	0.36	11.91-18.02	17.46B	0.36	14.10-20.52
Female (*n* = 34)	4.86a^5	0.08	3.56-5.59	16.26a	0.28	11.91-18.51	18.75a	0.31	14.31-21.45
Male (*n* = 39)	4.99a	0.06	3.91-5.62	16.66a	0.23	12.77-19.23	18.38a	0.28	14.10-21.53
Lesser scaup									
Adult (*n* = 37)	3.52A	0.08	2.78-5.39	12.23A	0.21	10.00-15.22	17.27A	0.32	13.26-21.48
Juvenile (n = 52)	3.32A	0.05	2.63-4.57	11.90A	0.18	9.14-15.92	16.82A	0.23	13.80-20.90
Female (n = 38)	3.29a	0.06	2.63-4.16	11.74a	0.20	9.14-15.22	17.04a	0.26	13.80-21.48
Male (n = 51)	3.48a	0.06	2.83-5.39	12.27a	0.18	10.10-15.92	16.97a	0.27	13.26-20.90
Ring-necked duck									
Adult (*n* = 69)	3.64A	0.03	2.89-4.21	12.73A	0.12	10.68-14.84	17.51A	0.26	14.83-20.40
Juvenile (*n* = 16)	3.36B	0.05	2.99-3.75	11.77A	0.21	10.22-13.25	16.21A	0.29	13.42-17.91
Female (*n* = 17)	3.39a	0.05	2.99-3.75	11.80a	0.17	10.68-13.13	16.56a	0.22	14.79-17.71
Male (*n* = 68)	3.63a	0.03	2.89-4.21	12.71a	0.12	10.22-14.84	17.44a	0.27	13.42-20.40

[1] BCI1 = (total body mass (g)) / (wing chord (mm))

[2] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[3] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

[4] Means followed by the same uppercase letter within the same column are not different ($P > 0.05$) within a species.

[5] Means followed by the same lowercase letter within the same column are not different ($P > 0.05$) within a species.

Table 2.14. Means and Standard Errors (SE) of total lipid content (%) of adult and juvenile, and male and female canvasbacks, lesser scaup, and ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Lipid content (%)		
	$\bar{x}$	SE	Range
Canvasback			
Adult (*n* = 51)	29.89 A[1]	1.82	3.04-48.03
Juvenile (*n* =22)	25.49 A	2.56	6.09-46.01
Female (*n* = 34)	31.57 a[2]	1.96	6.09-48.03
Male (*n* = 39)	25.61 a	2.15	3.04-44.29
Lesser scaup			
Adult (*n* = 37)	31.63 A	2.12	3.39-48.88
Juvenile (n = 52)	30.87 A	1.78	3.52-52.94
Female (n = 38)	31.89 a	2.11	3.52-52.37
Male (n = 51)	30.68 a	1.78	3.39-52.94
Ring-necked duck			
Adult (*n* = 69)	27.45 A	1.07	8.24-45.65
Juvenile (*n* = 16)	23.30 A	3.07	4.14-50.62
Female (*n* = 17)	25.72 a	2.59	4.14-50.62
Male (*n* = 68)	26.91 a	1.15	5.91-45.65

[1] Means followed by the same uppercase letter within the same column are not different (*P* > 0.05) within a species.

[2] Means followed by the same lowercase letter within the same column are not different (*P* > 0.05) within a species.

Table 2.15. Means and Standard Errors (SE) of total lipid content and morphological body condition indices (BCI) among age-sex classes for canvasbacks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Adult Male			Juvenile Male			Adult Female			Juvenile Female		
	n	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Lipid content (%)	28	25.66B[1]	2.56	8	25.45B	3.96	20	35.82A	1.84	14	25.51B	3.43
BCI1[2]	31	5.03A	0.06	8	4.83 AB	0.16	20	5.03A	0.08	14	4.61B	0.13
BCI2[3]	31	16.85A	0.23	8	15.92AB	0.59	20	16.97A	0.24	14	15.24B	0.46
BCI3[4]	31	18.63B	0.29	7	17.30C	0.65	20	19.60A	0.30	14	17.54C	0.45

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[1] Means followed by the same letter within the same row are not different ($P < 0.05$).

[2] BCI1 = (total body mass (g)) / (wing chord (mm))

[3] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[4] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.16. Ranges of total lipid content (%) and morphological body condition indices (BCI) among age-sex classes for canvasbacks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Adult Male		Juvenile Male		Adult Female		Juvenile Female	
	n	Range	*n*	Range	*n*	Range	*n*	Range
Lipid content (%)	28	3.04-44.29	8	8.12-40.72	20	14.03-48.03	14	6.09-46.01
BCI1[1]	31	4.20-5.62	8	3.91-5.37	20	4.46-5.59	14	3.56-5.34
BCI2[2]	31	14.09-19.23	8	12.77-18.02	20	14.04-18.51	14	11.91-17.86
BCI3[3]	31	15.42-21.53	7	14.10-19.64	20	16.74-21.45	14	14.31-20.52

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[1] BCI1 = (total body mass (g)) / (wing chord (mm))

[2] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[3] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.17. Means and Standard Errors (SE) of total lipid content (%) and morphological body condition indices (BCI) among age-sex classes for lesser scaup collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Adult Male			Juvenile Male			Adult Female			Juvenile Female		
	n	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Lipid content (%)	27	30.30A[1]	2.54	22	31.15A	2.51	9	35.62A	3.66	27	30.64A	2.53
BCI1[2]	27	3.57A	0.10	23	3.38A	0.08	9	3.37A	0.12	29	3.27A	0.06
BCI2[3]	25	12.30A	0.23	23	12.22A	0.30	9	12.04A	0.50	29	11.65A	0.21
BCI3[4]	25	17.18A	0.37	22	16.74A	0.38	9	17.50A	0.64	29	16.89A	0.28

[1] Means followed by the same letter within the same row are not different ($P < 0.05$).

[2] BCI1 = (total body mass (g)) / (wing chord (mm))

[3] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[4] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.18. Ranges of total lipid content (%) and morphological body condition indices (BCI) among age-sex classes for lesser scaup collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Adult Male		Juvenile Male		Adult Female		Juvenile Female	
	n	Range	*n*	Range	*n*	Range	*n*	Range
Lipid content (%)	27	3.39-48.04	22	8.37-52.94	9	17.23-48.88	27	3.52-52.37
BCI1[1]	27	2.83-5.39	23	2.88-4.57	9	2.78-4.16	29	2.63-3.88
BCI2[2]	25	10.10-15.02	23	10.19-15.92	9	10.00-15.22	29	9.14-13.85
BCI3[3]	25	13.26-20.34	22	13.90-20.90	9	14.38-21.48	29	13.80-19.40

[1] BCI1 = (total body mass (g)) / (wing chord (mm))
[2] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))
[3] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.19. Means and Standard Errors (SE) of total lipid content (%) and morphological body condition indices (BCI) among age-sex classes for ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Adult Male			Juvenile Male			Adult Female			Juvenile Female		
	n	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE
Lipid content (%)	56	28.03A[1]	1.17	8	19.13A	2.93	9	23.90A	2.17	7	28.06A	5.36
BCI1[2]	60	3.67A	0.03	8	3.38B	0.06	9	3.46B	0.06	8	3.33B	0.08
BCI2[3]	60	12.86A	0.13	8	11.70B	0.31	8	11.77B	0.19	8	11.83B	0.29
BCI3[4]	57	17.65A	0.29	8	15.91B	0.43	9	16.60AB	0.26	8	16.51AB	0.38

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[1] Means followed by the same letter within the same row are not different ($P > 0.05$).

[2] BCI1 = (total body mass (g)) / (wing chord (mm))

[3] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[4] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.20. Ranges of total lipid content (%) and morphological body condition indices (BCI) among age-sex classes for ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Adult Male		Juvenile Male		Adult Female		Juvenile Female	
	n	Range	*n*	Range	*n*	Range	*n*	Range
Lipid content (%)	56	8.24-45.65	8	5.91-30.39	9	15.93-35.57	7	4.14-50.62
BCI1[1]	60	2.89-4.21	8	3.19-3.75	9	3.24-3.75	14	2.99-3.59
BCI2[2]	60	11.08-14.84	8	10.22-13.25	8	10.68-12.49	14	10.74-13.13
BCI3[3]	57	14.83-20.40	8	13.42-17.91	9	15.52-17.54	14	14.78-17.71

[1] BCI1 = (total body mass (g)) / (wing chord (mm))
[2] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))
[3] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.21. Means and Standard Errors (SE) of total lipid content (%) and morphological body condition indices (BCI) between seasons for canvasbacks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Season 1[1]				Season 2[2]			
	n	$\bar{x}$	SE	Range	*n*	$\bar{x}$	SE	Range
Lipid content (%)	56	28.59A[3]	1.68	3.63-48.03	14	28.17A	3.33	3.04-41.36
BCI1[4]	58	4.92A	0.05	3.56-5.62	15	4.94A	0.10	4.20-5.49
BCI2[5]	58	16.46A	0.20	11.91-19.23	15	16.54A	0.38	14.04-18.28
BCI3[6]	57	18.47A	0.23	14.10-21.53	15	18.88A	0.47	14.94-21.12

[1] Season 1 = 8 November 2003 - 23 January 2004

[2] Season 2 = 3 November 2004 - 2 March 2005

[3] Means followed by the same letter within the same row are not different ($P > 0.05$).

[4] BCI1 = (total body mass (g)) / (wing chord (mm))

[5] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[6] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.22. Means and Standard Errors (SE) of total lipid content (%) and morphological body condition indices (BCI) between seasons for lesser scaup collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Season 1[1]				Season 2[2]			
	n	$\bar{x}$	SE	Range	*n*	$\bar{x}$	SE	Range
Lipid content (%)	77	31.48A[3]	1.48	3.39-52.94	8	28.46A	2.22	20.61-41.53
BCI1[4]	80	3.39A	0.05	2.63-5.39	8	3.49A	0.08	3.20-3.81
BCI2[5]	78	12.01A	0.15	9.14-15.92	8	12.25A	0.26	11.38-13.24
BCI3[6]	78	16.92A	0.19	13.26-21.48	7	17.90A	0.57	15.34-19.28

[1] Season 1 = 8 November 2003 - 23 January 2004

[2] Season 2 = 3 November 2004 - 2 March 2005

[3] Means followed by the same letter within the same row are not different ($P > 0.05$).

[4] BCI1 = (total body mass (g)) / (wing chord (mm))

[5] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[6] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.23. Means and Standard Errors (SE) of total lipid content and morphological body condition indices (BCI) between seasons for ring-necked ducks collected during winter on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 2003-2004 and 2004-2005.

	Season 1[1]				Season 2[2]			
	n	$\bar{x}$	SE	Range	*n*	$\bar{x}$	SE	Range
Lipid content (%)	60	25.69A[3]	1.20	4.14-50.62	20	29.63A	2.06	12.01-45.65
BCI1[4]	65	3.57A	0.03	2.99-4.21	20	3.64A	0.07	2.89-4.19
BCI2[5]	64	12.40A	0.13	10.22-14.84	20	13.00A	0.22	11.47-14.77
BCI3[6]	62	17.23A	0.19	14.78-20.41	20	17.33A	0.30	13.42-19.23

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[1] Season 1 = 8 November 2003 - 23 January 2004

[2] Season 2 = 3 November 2004 - 2 March 2005

[3] Means followed by the same letter within the same row are not different ($P > 0.05$).

[4] BCI1 = (total body mass (g)) / (wing chord (mm))

[5] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[6] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.24. Significant ($P < 0.05$) variables, R^2 values, and lipid prediction equations resulting from simple linear regression analyses using only body condition index (BCI) data (model A), a combination of BCI and external morphology data (model B), or all BCI, external and internal morphology data (models C & D) for each canvasback age-sex class collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas during November - January 2003-2004 and October – February 2004-2005.

Model	Age-sex class	*n*	R^2	Equation
	Adult males			
A	BCI2[1]	28	0.63	Y = -108.68 + 7.96(BCI2)
B	BCI2 + Culmen	28	0.72	Y = -55.00 + 8.77(BCI2) + -10.79(Culmen)
C	Skin mass (SM)	26	0.88	Y = -21.02 + 0.29(SM)
D	Body length (BL)+ gizzard mass (GM) + skin mass (SM)	26	0.93	Y = 53.37 + -1.24(BL) + -0.24(GM) + 0.27(SM)
	Juvenile males			
A	BCI2	7	0.74	Y = -63.56 + 5.56(BCI2)
B	BCI2 + tarsus length(TL)	7	0.92	Y = -210.85 + 6.52(BCI2) + 30.42(TL)
B	BCI2 + body mass(BM) + tarsus length (TL)	7	0.99	Y = -196.24 + 15.77(BCI2) + -0.14(BM) + 30.79(TL)
C	Skin mass (SM)	7	0.86	Y = -6.50 + 0.20(SM)
D	Body length (BL)+ skin mass (SM)	7	0.96	Y = 141.57 + -2.95(BL) + 0.17(SM)
	Adult females			
A&B	BCI2	20	0.68	Y = -70.15 + 6.24(BCI2)
C	Skin mass (SM)	20	0.81	Y = 4.09 + 0.17(SM)
D	Bill length (Bill) + skin mass (SM)	20	0.88	Y = 95.92 + -14.73(Bill) + 0.15(SM)
	Juvenile females			
A&B	BCI1[2]	14	0.68	Y = -78.19 + 22.50(BCI1)
C	Skin mass (SM)	14	0.83	Y = -7.91 + 0.23(SM)
D	Wing cord (WC) + heart mass (HM) + skin mass (SM)	14	0.93	Y = 72.39 + -4.49(WC) + 3.16(HM) + 0.16(SM)

[1] BCI2 = (total body mass (g)) / (total body length (cm) + wing cord (cm))

[2] BCI1 = (total body mass (g)) / (wing cord (mm))

Table 2.25. Significant ($P < 0.05$) variables, R^2 values, and lipid prediction equations resulting from simple linear regression analyses using only body condition index (BCI) data (model A), a combination of BCI and external morphology data (model B), or all BCI, external and internal morphology data (models C & D) for male, female, adult, and juvenile canvasbacks collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas during November - January 2003-2004 and October – February 2004-2005.

Model	Age/Sex	*n*	R^2	Equation
	Males (adults and juveniles combined)			
A	BCI2[1]	35	0.59	Y = -87.06 + 6.75(BCI2)
B	BCI2 + culmen (CUL)	35	0.66	Y = -39.88 + 7.38(BCI2) + -9.22 (CUL)
C	Skin mass (SM)	33	0.86	Y = -17.30 + 0.27(SM))
D	Body length (BL) + gizzard mass (GM) + skin mass (SM)	33	0.92	Y = 59.33 + -1.28(BL) + -0.27(GM) + 0.25(SM)
	Females (adults and juveniles combined)			
A	BCI1[2]	34	0.73	Y = -74.45 + 21.83(BCI1)
B	BCI1 + bill length (Bill)	34	0.79	Y = 19.03 + 21.98(BCI1) + -15.49(Bill)
C	Skin mass (SM)	34	0.84	Y = -3.16 + 0.20(SM)
D	Bill length (Bill) + heart mass (HM) + skin mass (SM)	34	0.88	Y = 37.48 + -8.66(Bill) + 1.36(HM) + 0.19(SM)
	Adults (males and females combined)			
A	BCI2 + BCI3[3]	48	0.63	Y = -108.71 + 4.73(BCI2) + 3.08(BCI3)
B	BCI2 + wing cord (WC) + culmen (CUL)	48	0.73	Y = 41.24 + 8.07(BCI2) + -3.90(WC) + -9.04(CUL)
C	Skin mass (SM)	46	0.83	Y = -13.41 + 0.25(SM)
D	Body length (BL) + gizzard mass (GM) + skin mass (SM)	46	0.91	Y = 63.47 + -1.31(BL) + -0.25(GM) + 0.23(SM)
	Juveniles (males and females combined)			
A&B	BCI3	21	0.64	Y = -73.84 + 5.65(BCI3)
C	Skin mass (SM)	21	0.83	Y = -7.65 + 0.22(SM)
D	Tarsus length (TL) + omental fat (OF) + skin mass (SM)	21	0.90	Y = 57.09 + -14.38(TL) + 0.53(OF) + 0.17(SM)

[1] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

[2] BCI1 = (total body mass (g)) / (wing chord (mm))

[3] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

Table 2.26. Significant ($P < 0.05$) variables, R^2 values, and lipid prediction equations resulting from simple linear regression analyses using only body condition index (BCI) data (model A), a combination of BCI and external morphology data (model B), or all BCI, external and internal morphology data (models C & D) for each lesser scaup age-sex class collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas during November - January 2003-2004 and October – February 2004-2005.

Model	Age-sex class	*n*	R^2	Equation
	Adult Males			
A&B	BCI3[1]	21	0.72	Y = -78.24 + 6.32(BCI3)
C	Skin mass (SM)	21	0.85	Y = -3.58 + 0.33(SM)
D	BCI3 + skin mass (SM)	21	0.88	Y = -33.91 + 2.30(BCI3) + 0.24(SM)
	Juvenile Males			
A&B	BCI3	21	0.43	Y = -42.22 + 4.37(BCI3)
C	Skin mass (SM)	18	0.70	Y = 10.47 + 0.21(SM)
D	BCI2[2] + skin mass (SM)	18	0.83	Y = 42.51 + -2.97(BCI2) + 0.25(SM)
	Adult Females			
A&B	BCI1[3]	9	0.46	Y = -32.68 + 20.26(BCI1)
C	Omental fat mass (OF)	9	0.71	Y = 20.46 + 1.66(OF)
D	Bill (Bill)+ gizzard mass (GM) + omental fat mass (OF)	9	0.97	Y = 100.03 + -21.90(Bill) + 0.68(GM) + 1.71(OF)
	Juvenile Females			
A	BCI1	27	0.25	Y = -36.83 + 20.74(BCI1)
B	BCI1 + bill width (BW)	27	0.46	Y = 75.30 + 23.61(BCI1) + -53.63(BW)
C	Skin mass (SM)	26	0.71	Y = -1.07 + 0.33(SM)
D	Leg muscle mass (Leg) +skin mass (SM)	26	0.82	Y = 20.21 + -0.96(Leg) + 0.34(SM)

[1] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

[3] BCI1 = (total body mass (g)) / (wing chord (mm))

[2] BCI2 = (total body mass (g)) / (total body length (cm) + wing chord (cm))

Table 2.27. Significant ($P < 0.05$) variables, R^2 values, and lipid prediction equations resulting from simple linear regression analyses using only body condition index (BCI) data (model A), a combination of BCI and external morphology data (model B), or all BCI, external and internal morphology data (models C & D) for male, female, adult, and juvenile lesser scaup collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas during November - January 2003-2004 and October – February 2004-2005.

Model	Sex/age	*n*	R^2	Equation
	Males (adults and juveniles combined)			
A&B	BCI3[1]	43	0.57	$Y = -60.64 + 5.39(BCI3)$
C	Skin mass (SM)	39	0.75	$Y = 3.60 + 0.26(SM)$
D	Bill length (Bill) + skin mass (SM)	39	0.79	$Y = 68.09 + -13.50(Bill) + 0.26(SM)$
	Females (adults and juveniles combined)			
A	BCI1[2]	36	0.30	$Y = -37.49 + 21.14(BCI1)$
B	BCI1 + bill width (BW)	36	0.46	$Y = 56.41 + 21.84(BCI1) + -42.24(BW)$
C	Skin mass (SM)	35	0.70	$Y = 2.07 + 0.30(SM)$
D	Bill length (Bill) + omental fat mass (OF) + skin mass (SM)	35	0.84	$Y = 81.34 + -16.29(Bill) + 0.71(OF) + 0.21(SM)$
	Adults (males and females combined)			
A&B	BCI3	31	0.63	$Y = -66.55 + 5.71(BCI3)$
C	Skin mass (SM)	30	0.81	$Y = -0.66 + 0.30(SM)$
D	Bill length (Bill) + leg mass (Leg) + kidney mass (KM) + skin mass (SM)	30	0.90	$Y = 83.70 + -18.14(Bill) + 0.70(Leg) + 1.65(KM) + 0.26(SM)$
	Juveniles (males and females combined)			
A	BCI1	48	0.30	$Y = -33.79 + 19.55(BCI1)$
B	BCI1 + Bill length (Bill)	47	0.45	$Y = 55.41 + 24.93(BCI1) + -22.73(Bill)$
C	Skin mass (SM)	44	0.67	$Y = 5.84 + 0.26(SM)$
D	Body mass (BM) + log-body mass (LBM) + skin mass (SM)	44	0.84	$Y = -1791.18 + -0.54(BM) + 761.30(LBM) + 0.37(SM)$

[1] BCI3 = (total body mass (g)) / (bill length (cm) * keel length (cm))

[2] BCI1 = (total body mass (g)) / (wing chord (mm))

Table 2.28. Significant ($P < 0.05$) variables, R^2 values, and lipid prediction equations resulting from simple linear regression analyses using only body condition index (BCI) data (model A), a combination of BCI and external morphology data (model B), or all BCI, external and internal morphology data (models C & D) for each ring-necked duck age-sex class collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas during November - January 2003-2004 and October – February 2004-2005.

Model	Age-sex class	*n*	R^2	Equation
	Adult males			
A	BCI1[1]	53	0.30	Y = -36.89 + 17.70(BCI1)
B	Log body mass (LBM) + tarsus length (TL)	52	0.42	Y = -486.16 + 186.94(LBM) + -6.62(TL)
C	Skin mass (SM)	50	0.76	Y = -1.75 + 0.29(SM)
D	Esophagus proventriculus mass (EPM) + skin mass (SM)	50	0.79	Y = 7.13 + -1.13(EPM) + 0.30(SM)
	Juvenile males			
D	Kidney mass (KM)	8	0.59	Y = -24.24 + 8.90(KM)
	Adult females			
D	Skin mass (SM)	8	0.89	Y = -4.12 + 0.34(SM)
	Juvenile females			
D	Heart mass (HM)	7	0.80	Y = 125.90 + -14.96(HM)

[1] BCI1 = (total body mass (g)) / (wing chord (mm))

Table 2.29. Significant ($P < 0.05$) variables, R^2 values, and lipid prediction equations resulting from simple linear regression analyses using only body condition index (BCI) data (model A), a combination of BCI and external morphology data (model B), or all BCI, external and internal morphology data (models C & D) for male, female, adult, and juvenile ring-necked ducks collected on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas during November - January 2003-2004 and October – February 2004-2005.

Model	Sex/age	*n*	R^2	Equation
	Males			
A	BCI1[1]	61	0.34	$Y = - 43.88 + 19.49(BCI1)$
B	Log-body mass (LBM)+ tarsus length (TL)	60	0.45	$Y = - 485.93 + 186.93(LBM) + -6.72(TL)$
C	Skin mass (SM)	58	0.69	$Y = - 0.70 + 0.28(SM)$
D	Esophagus proventriculus mass (EPM) + omental fat (OF) + skinmass (SM)	58	0.76	$Y = 11.86 - 0.97(EPM) + 1.03(OF) + 0.19(SM)$
	Females			
C	Esophagus proventriculus mass (EPM)	15	0.51	$Y = 72.99 + -6.66(EPM)$
D	Esophagus proventriculus mass (EPM) + intestine mass (IM)	15	0.65	$Y = 72.52 + -7.63(EPM) + 0.52(IM)$
	Adults			
A	BCI1	61	0.32	$Y = - 37.34 + 17.78(BCI1)$
B	Log-body mass (LBM) + tarsus length (TL)	60	0.42	$Y = - 416.61 + 162.56(LBM) + -6.36(TL)$
C	Skin mass (SM)	58	0.77	$Y = - 1.03 + 0.29(SM)$
D	Esophagus proventriculus mass (EPM) + skin mass (SM)	58	0.80	$Y = 7.66 + -1.16(EPM) + 0.30(SM)$
	Juveniles			
D	Mesentery fat mass (MFM)	15	0.45	$Y = 12.54 + 5.15(MFM)$

[1] BCI1 = (total body mass (g)) / (wing chord (mm))

APPENDIX A

LITERATURE REVIEW OF WINTERING WATERFOWL ECOLOGY, BEHAVIOR, AND BODY CONDITION

Estimation of waterfowl body condition

Nutrient reserves in waterfowl are a combination of lipids, carbohydrates, protein, and other sources of stored energy (Haukos et al. 2001). Lipids (i.e., fats) are the main form of stored energy and are used to provide birds with energy during stressful conditions, especially food shortages, whereas carbohydrates are utilized when birds are inactive or not exposed to low ambient temperatures. Proteins are not used as energy, but are mobilized during reproductive and molting periods (Blem 1990, Baldassarre and Bolen 1994). Throughout winter, lipid levels will fluctuate as a result of both exogenous and endogenous pressures, while protein content generally remains relatively stable (Baldassarre and Bolen 1994). Documenting changes in total lipid and protein contents during winter are critical to assess body condition, which indicates an individual's ability to meet current and future energy demands (Owen and Cook 1977).

Owen and Cook (1977) defined nutritional condition as the ability of an animal to meet present and future energy demands. Body condition indices are usually measures of fat and other energy stores, and are indicative of nutritional condition (Ankney and MacInnes 1978), and are developed to predict relative health of live birds using dead birds. To build these indices and predictive body condition models, total available fat and protein must be measured. Models are then constructed using various combinations of body mass and linear morphological measures in a regression setting. The "best" condition models are those in which body mass and linear morphological measures most clearly predict known fat and protein content. The goal of these indices is to estimate relative bird health in a non-destructive fashion.

Historically, body mass alone was used to predict nutritional status; however, such indices are biased by structural size of the animal (Ringelman and Szymczak 1985). To eliminate these biases, wing length and wing chord measurements are commonly used to standardize for structural size in live birds (Owen and Cook 1977, Whyte and Bolen 1984, Ringelman and Szymczak 1985, Haukos et al. 2001, DeVault et al. 2003). However, total body length, tarsus length, bill length, keel length, tail length, culmen length, and various combinations of each also have been used (Wishart 1979, Chappell and Titman 1983, Hohman and Taylor 1986, Hohman 1993).

Other condition indices have been developed for live birds using fat scoring and total body electrical conductivity (TOBEC) (Conway et al. 1994, Harder and Kirkpatrick 1996). Conway et al. (1994) evaluated five methods (fat scoring, regression residuals of body mass versus morphological measurements, quotients of body mass divided by morphological measurements, TOBEC, and water content) to assess lipid reserves in wood thrushes (*Hylocichla mustelina*) in Rhode Island. They found that water content and fat score were highly correlated with extracted lipid mass and percentage lipid content and were the most useful indices of body fat and overall condition; TOBEC was not an accurate predictor of lipid in that species.

For dead birds, condition indices have been developed by using water content, organ mass, bone marrow fat, gizzard fat, omental fat, and other fat depot estimates (Hohman and Taylor 1986, Austin and Fredrickson 1987, Servello and Kirkpatrick 1987). Historically, the best method to estimate fat stores in birds is the measurement of whole body fat through extraction in a Soxhlet apparatus (Harder and Kirkpatrick 1996), a costly and time consuming procedure. Other methods such as pressurized solvent extraction using an accelerated solvent extractor (ASE) instrument have been used to estimate total lipids in poultry meat. Use of the ASE instrument reduces extraction time and solvents (Toschi et al. 2003).

Many different condition assessment techniques and indices have been developed for waterfowl. Published body condition indices of greater white-fronted geese (*Anser albifrons*) were compared using a meta-analysis technique by Johnson et al. (1985). They found lipid extraction was the best method to estimate fat stores, and water extraction was a simple laboratory method that provided an accurate body condition index. Body mass alone was a poor index because of structural differences among individuals, but standardizing using morphological measurements greatly improved the index value. In American wigeon (*Anas americana*), body length + wing length can be used as a structural index (SI) and body weight/SI was a good body condition index (Wishart 1979). Similarly, the best predictors of lipid and protein reserves were abdominal fat mass + skin fat mass and carcass mass/SI, respectively (Wishart 1979). For the same species, DeVault et al. (2003) found omental fat mass was the best predictor of total body fat. Hohman and Taylor (1986) developed indices of ash-free lean dry body mass and body fat for ring-necked ducks using linear regression models. They found the best predictor of ash-free lean dry body mass was the model that incorporated eviscerated carcass mass, wet leg mass, breast muscle mass, and bill length. Wet mass of omental fat and sheared skin tissues were the best predictors of total fat.

Condition through the annual cycle

Many studies have focused on waterfowl body condition during the annual cycle. For example, postbreeding female lesser scaup had the lowest body mass during wing molt and highest during early fall migration (Austin and Fredrickson 1987); lipid reserves remained constant during the preflightless to postflightless period, and increased during migration. Protein reserves were lowest during the flightless period and gradually increased over the postflightless and migratory periods with breast muscle mass following similar patterns. The loss of protein reserves and breast muscle mass during the flightless period was attributed to mobilization of proteins for feather production (Austin and Fredrickson 1987). Low body mass and low lipid reserves during molt may not be caused by energetic or nutritional stresses, but from a postbreeding strategy to reduce energy demands, which in turn reduces the length of the flightless period. Similar body and lipid mass patterns were observed for female mallards (*Anas platyrhynchos*) during prealternate and prebasic molts (Heitmeyer 1988).

On stopover sites along the upper Mississippi River, canvasback (*Aythya valisineria*) body mass increased during fall migration, and stopover duration varied inversely with fat reserves during fall migration (Serie and Sharp 1989). Fat levels attained during fall stopover were hypothesized to be adaptive for improving survival during winter (Serie and Sharp 1989). Gammonley and Heitmeyer (1990) observed that body weights were near mid-winter levels for spring-migrating buffleheads (*Bucephala albeola*) and lesser scaup (*Aythya affinis*) using stopover sites in the Klamath Basin, but were lower than weights observed upon arrival in northern breeding areas.

Although each period (i.e., breeding, migration, and winter) during the annual cycle will impact waterfowl survival, some recent research has focused on the importance of waterfowl body condition dynamics during winter. Waterfowl body condition usually fluctuates through winter, where lipid reserves increase from fall to mid-winter, decrease during late winter, and increase before spring migration, with some variation among age and sex classes. For example, in the Southern High Plains (SHP) of Texas, mallard lipid reserves for both age and sex classes were lowest in autumn, increased 49-62% for adults and 21-30% for juveniles by mid-winter, decreased 9-15% for adult and juvenile females from mid-winter to late winter, increased 20% for juvenile males from mid-winter to late winter, and increased for both sexes and ages before spring migration (Whyte et al. 1986). Baldassarre et al. (1986) found similar patterns for green-winged teal (*Anas crecca*) wintering in the SHP and hypothesized that declines in body mass and lipid reserve during late winter was an adaptation to winter conditions. It should be adaptive for waterfowl to mobilize lipid reserves gradually throughout colder portions of the year rather than trying to maintain high lipid reserves because the energetic costs outweigh the benefits associated with high lipid maintenance.

Within a species, winter body condition patterns may vary geographically because local environmental conditions, such as ambient temperatures and food availability, vary (Hohman and Weller 1994). For example, adult male American black ducks (*Anas rubripes*) wintering at Chincoteague, Virginia had lipid index (LI = grams lipid/grams nonlipid dry carcass x 100) values that were relatively high throughout winter. Females of both age classes had LI values that were low in early winter, peaked by midwinter, and remained high into late winter; protein mass did not vary, throughout the winter, however (Morton et al. 1990). Conversely, in Maine, where environment conditions are generally severe, lipid and protein reserves decreased during winter in female American black ducks (Reinecke et al. 1982). Morton et al. (1990) hypothesized that these differences in fluctuations of body condition may be explained by differences in winter severity and diet.

Time-activity Budgets

Animals perform a variety of activities, each requiring an expenditure of time and energy to survive and reproduce (Verner 1965). Those individuals with activity budgets that closely resemble the hypothetical "best" time budget will theoretically experience the greatest fitness (Verner 1965). Time-activity studies of wintering waterfowl provide insight on behavioral activities, seasonal habitat use (Rave and Baldassarre 1989, Baldassarre and Bolen 1994), and the effects of hunting pressure, habitat changes, unseasonable temperatures, and other disturbances (Baldassarre and Bolen 1994). Finally, waterfowl time-activity budget studies provide information for managing waterfowl populations and identifying future research needs (Paulus 1988).

Activity budgets may be defined as a quantitative description of how animals apportion their time for feeding and other activities (Baldassarre and Bolen 1994). In general, non-breeding waterfowl spend most of their time feeding and loafing, although time allocated to these activities varies among species (Paulus 1988). Time allocated to other activities such as locomotion, preening, social display, alert, and agonistic behaviors are generally similar among species during the nonbreeding season (Paulus 1988). Deviations from normal activity budgets may severely affect energy uptake and expenditure, therefore affecting individual survival and productivity (Burton and Hudson 1978).

Time-activity budgets may be influenced by food choices and availability, habitat conditions, disturbance, environmental factors, gender, and individual pair status (Baldassarre and Bolen 1994). Food availability and foraging activities generally have a strong affect on waterfowl time-activity budgets. For example, green-winged teal expended an average of 33% of their time feeding on natural foods in coastal wetlands in Louisiana (Rave and Baldassarre 1989), whereas teal using corn in Texas expended 15-20% of their time on feeding (Quinlan and Baldassarre 1984). The differences between agricultural and natural wetland habitats and food sources caused teal to alter their activity budgets to meet energy requirements (Rave and Baldassarre 1989). As foods in agricultural habitats were easily acquired and higher in energy content than natural foods in coastal wetlands, teal were able to decrease time spent feeding and still meet energy requirements (Baldassarre and Bolen 1984).

Species that feed on leafy aquatic vegetation and algae generally have activity budgets dominated by feeding. Such foods have a high water and fiber content with relatively low nutrition and energy value, which explains the disproportionate amount of time, spent feeding by species that prefer these foods (Baldassarre and Bolen 1994). Gadwall (*Anas strepera*), whose diet consists of 95% leafy aquatic vegetation and algae, expended an average of 64% of their time feeding, and 11% resting in coastal southwestern Louisiana (Paulus 1984). American wigeon (*Anas americana*) have a diet similar to that of gadwalls. On the Eufaula National Wildlife Refuge in east-central Alabama, American wigeon spent 45-71% of their time feeding, whereas mallards that fed mainly on corn in managed waterfowl impoundments spent most of their time resting (Turnbull and Baldassarre 1987).

Habitat also will impact waterfowl time activity budgets. Rave and Baldassarre (1989) observed that green-winged teal activity budgets significantly varied among 6 habitats in coastal Louisiana. The dominant activity in the brackish tidal flats, impounded marshes, and fresh water unimpounded marsh habitats was feeding. Resting was the most common activity in brackish water impounded marshes, brackish water impounded created by weirs, and brackish water unimpounded marshes. Time activity differences among these habitats were hypothesized to be due to dynamic water levels and habitat structure (Rave and Baldassarre 1989). At Catahoula Lake (CL) in Louisiana, canvasback spent 13% of their time feeding, 29% in locomotion, and 13% in comfort behaviors. Conversely, at a study site on the Mississippi River Delta (MRD) in Louisiana, canvasback spent 23% of their time feeding, 19% in locomotion, and 9% in comfort behaviors (Hohman and Rave 1990). Canvasbacks at CL fed in flocks and dove to obtain food, while those on the MRD fed in shallow water by tipping. Hohman and Rave (1990) believed that differences in time budgets were due to differences in foraging strategies.

Human disturbance such as sport fishing, recreational boating, and hunting will affect waterfowl time-activity budgets. Many studies have shown that when waterfowl are continuously disturbed, they will increase locomotion activities and spend less time feeding (Pedroli 1982, Paulus 1984, Knapton et al. 2000). When canvasbacks were frequently disturbed at CL, they increased time spent in locomotion and comfort activities (Hohman and Rave 1990). Tamisier (1976) observed that 76% of a green-winged teal population would fly when disturbed by Northern harriers (*Circus cyaneus*); flight time due to such disturbances averaged 101 seconds per day. However, greater proportions of teal would flush, and the birds would fly for longer periods in response to human disturbances. Thornburg (1973) observed that diving ducks (i.e., canvasback, ring-necked duck (*Aythya collaris*), lesser scaup) on the Mississippi River would move at dawn from the heavily hunted middle and upper sections of the Keouk Pool to the less disturbed lower section where they loafed throughout the day. The upper and middle sections of the pool had the greatest abundance of benthic organisms and the ducks switched from a diurnal to a nocturnal foraging strategy.

Environmental factors will also impact waterfowl time-activity budgets (Hohman and Rave 1990). Waterfowl usually increase time spent feeding as temperature decreases, but reduce activities when temperatures are < 0 °C as energetic costs from foraging may exceed benefits of additional food consumption (Baldassarre and Bolen 1994). Green-winged teal wintering on the SHP of Texas increased resting activities to conserve energy when temperatures were cold (Quinlan and Baldassarre 1984). Time spent resting by American black ducks increased as the wind chill index decreased during fall and winter on Prince Edward Island (Hickey and Titman 1983). High winds can also affect waterfowl foraging in open water, because high winds increase water turbulence and hindered birds from locating submerged food (Paulus 1984).

Age, sex, and social status also influence waterfowl time budgets. Lesser scaup and ring-necked duck females fed more than males during the diurnal period (Bergan et al. 1989); Hohman and Rave (1990) observed a similar trend in canvasbacks, where females fed more than males in early and late winter, but most other activities comprised similar proportions of the time budget. Female Northern pintails (*Anas acuta*) were observed feeding and loafing more than males from November through March in the Sacramento Valley, California (Miller 1985). Increased feeding by females during this period was thought to provide nutrients for feather production, fat storage for migration, and egg production. In contrast, some studies have found no differences between sexes in time budgets in green-winged teal and Northern pintail (Tamisier 1976, Quinlan and Baldassarre 1984), and gadwall (Paulus 1984).

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APPENDIX B

CHRONOLOGY OF WINTERING DIVING DUCK OCCURRENCE ON EAST TEXAS RESERVOIRS 2003-2004 AND 2004-2005

METHODS and RESULTS

All individuals of focal species observed on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs were identified and counted between 19 November 2003 -13 March 2004 (study year 1) and 8 November 2004 - 18 February 2005 (study year 2) on days spent collecting behavioral data for developing time-activity budgets (see Chapter I). As behavior data were collected on each reservoir ≥ 1 day/week during each study year, depending upon weather and environmental conditions, additional survey data were collected opportunistically during those same sampling periods. When focal species were located, flock (i.e., raft) size and species composition was recorded. No data were recorded for non-focal species during this study.

The total number of canvasbacks, lesser scaup, and ring-necked ducks observed during this study were summed within each study year and month. Chronology of occurrence was developed for each species by calculating the proportion (%) of each species observed within each month as compared to the total number of observations within a year.

Chronology of Occurrence

During this study, 41,890 canvasbacks, lesser scaup, and ring-necked ducks were observed (excluding focal samples) on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs (Table B1). Between 19 November 2003 and 13 March 2004 (i.e., study year 1), > 19,000 canvasbacks, lesser scaup, and ring-necked ducks were counted during 76 surveys; 31 at Toledo Bend, 31 at Sam Rayburn, and 14 at B. A. Steinhagen Reservoirs (Table B1). Between 8 November 2004 and 18 February 2005 (i.e., study year 2), > 22,000 canvasbacks, lesser scaup, and ring-necked ducks were counted during 111 surveys; 40 at Toledo Bend, 41 at Sam Rayburn, and 30 at B. A. Steinhagen Reservoirs (Table B1). Although total numbers of individuals of canvasbacks, lesser scaup, and ring-necked ducks were similar between years (Table B1), there were distinct differences between years when most individuals were observed, despite general consistency between study years in survey effort among months (Figure B1). In study year 1, most individuals of each species were observed during November and December, whereas between 60-70% of each species was observed during January in study year 2 (Figure B1).

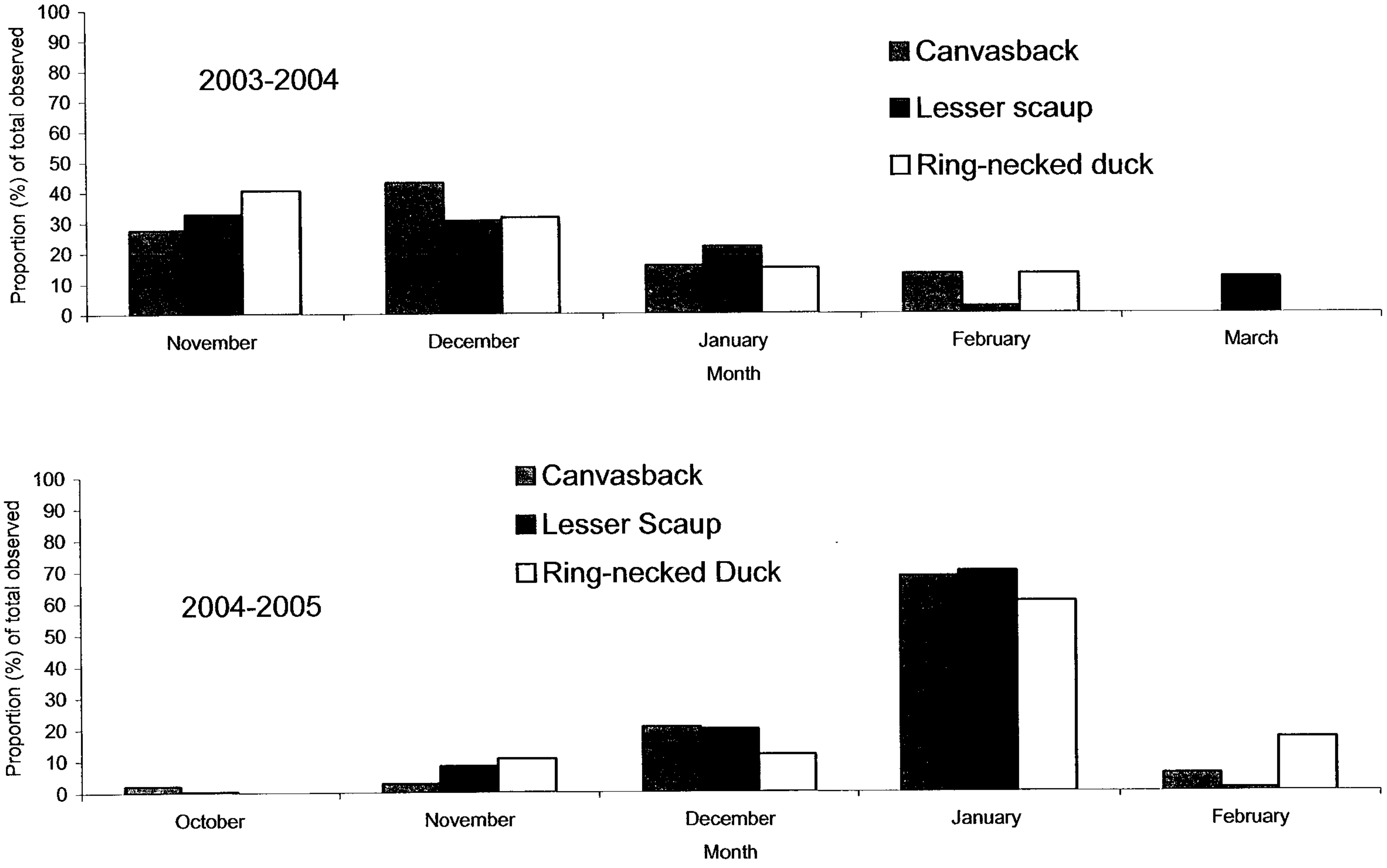

Figure B1. Chronology of occurrence of diving ducks wintering on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs 19 November 2003 - 13 March 2004 and 8 November 2004 – 18 February 2005.

Table B1. Numbers of canvasbacks (CANV), lesser scaup (LESC), and ring-necked ducks (RNDU) observed on Toledo Bend, Sam Rayburn, and B.A. Steinhagen Reservoirs in east Texas, 19 November 2003 -13 March 2004 (study year 1) and 8 November 2004 - 18 February 2005 (study year 2).

	Study year 1 (*n* = 19,814)				Study year 2 (*n* = 22,076)			
Reservoir	CANV	LESC	RNDU	Totals	CANV	LESC	RNDU	Totals
B.A. Steinhagen	5,052	293	2	5,347	6,123	402	179	6,704
Sam Rayburn	3,015	1,673	26	4,714	3,658	644	68	4,370
Toledo Bend	8,193	514	1,046	9,753	8,002	2,300	700	11,002
Totals	16,260	2,480	1,074	19,814	17,783	3,346	917	22,076

APPENDIX C

COMPARISON OF SOXHLET AND ACCELERATED SOLVENT EXTRACTION TECHNIQUES FOR ESTIMATING TOTAL BODY LIPID CONTENT IN DIVING DUCKS

INTRODUCTION

Directly quantifying lipid content is an important element in understanding a species' basic ecophysiology, estimating an individual's and/or population's nutrient/reserve status and dynamics, and generating data for lipid prediction models used to estimate general body condition of a given individual, species, or population. Literally hundreds of studies have performed lipid extractions in order to address questions regarding body condition and nutrient reserve dynamics. As such, this approach is well founded, substantiated, and relevant to ecophysiological, behavioral, nutritional, and management oriented research questions for many vertebrate and invertebrate taxa.

Most published research examining lipid content in wild animals use well entrenched and well established petroleum ether Soxhlet extraction procedures (see Dobush et al. 1985 for detailed explanation). Regardless of taxa, this procedure generates comparable data among studies, is relatively straightforward technically, requires no technologically advanced computers or software, and is relatively inexpensive (i.e., < $10,000 to obtain glassware and associated equipment). However, the procedure uses large volumes of petroleum ether, is fairly time-consuming, in that most have performed extraction washes for 24-48 hr (depending upon source) per sample, and the number of samples extracted simultaneously is constrained by glassware, heating elements, and the number of condensing units. For example, if using six-300 ml flasks, a minimum of 1.8 L of petroleum ether would be used per 48 hr wash, although variably more would be used to replace evaporating ether during washing. Moreover, if using the same six-300 ml flasks on a heating apparatus with 6 condensing units, a maximum of approximately 18 tissue samples could be extracted simultaneously. If washed for 48 hr, then approximately 36 samples could be processed in a typical 5-day work-week, excluding drying and measuring time.

Recent technological advances in automated extraction sample processing, particularly in terms of large sample number, have allowed development of accelerated solvent extraction (ASE) apparati. Such equipment allows for accelerated sample extractions using liquid solvents at high pressure and temperature, which effectively cuts wash time into a fraction of traditional Soxhlet techniques (Dionex 1999). As compared to traditional Soxhlet procedures, which are limited by solvent boiling points and require evaporation and subsequent condensation of the solvent to wash samples, ASE procedures decrease the volume of solvent used (approximately 20 ml) and time to complete an extraction (approximately 20 min. per sample), as pressurization allows for extraction using solvents well beyond their characteristic boiling point (Dionex 1999). Moreover, using a Dionex 200 ASE, 24 samples can be simultaneously extracted. Excluding preparation and cleaning time, an estimate of 48 sample extractions per day would be a conservative estimate of daily productivity using such equipment. The primary constraint on using such equipment, as opposed to Soxhlet procedures, is the inordinate cost of such equipment (i.e., > $50,000 per machine) and associated costs of maintenance and repair. However, in situations where either commercial or nonindustrial analytical laboratories have such equipment available, the number of samples processed can be increased exponentially as compared to Soxhlet procedures over the same time period.

The purpose of this portion of this study was to verify that the extraction procedures using a Dionex ASE 200 were comparable with traditional Soxhlet extraction procedures for diving ducks. To my knowledge, no published studies examining lipid content in waterfowl have used an ASE. As such, it is critical to verify that data generated using this equipment is accurate and any variability is due to homogenate (i.e., within carcass homogenate) variability, not extraction procedures, equipment, nor techniques.

METHODS

Collection and Sample Preparation

Canvasback, lesser scaup, and ring-necked duck were collected from 8 November 2003 - 23 January 2004 and from 3 November 2004 - 2 March 2005 on Toledo Bend, Sam Rayburn, and B. A. Steinhagen Reservoirs. After retrieval, each bird was aged and sexed, frozen (Haramis et al. 1982, Carney 1992), and stored at Stephen F. Austin State University. For this portion of this study, I randomly selected 46 birds (16 canvasbacks, 11 lesser scaup, and 19 ring-necked ducks) to perform an additional set of ASE extractions (see Chapter II) and traditional Soxhlet extractions (Table C1). All sample preparation procedures were identical to those used previously (see Chapter II). The same whole bird homogenates in which subsamples were removed for previous extractions were used in this portion of the study (see Chapter II).

Lipid extraction: Accelerated Solvent Extraction

After drying, 5-g samples of each homogenized 30-g subsample were ground with a mortar and pestle, and placed into a 22 ml extraction cell, and then subjected to lipid extraction using petroleum ether in an Accelerated Solvent Extractor (ASE) (Dionex 1999). Extractions were performed at 125° C, at 10.3 Mpa (1500 psi), for 6 min. equilibration, extracted for 2 min., flushed with 60% petroleum ether, and purged for 60 s with Nitrogen (Dionex 1999). This cycle was performed twice for each 5-g subsample. After extraction, each cell and its contents were removed and oven dried at 65° C to constant mass (i.e., 12-14 h). Once dry, each subsample mass was measured to the nearest 0.01 g to obtain subsample lean dry mass.

Lipid Extraction: Soxhlet Extraction

Prior to lipid extraction using a Soxhlet apparatus, cellulose thimbles were lined with 1-2 g of fiberglass and washed in petroleum ether in a Soxhlet apparatus for 2 h, removed, and oven dried at 65° C to constant mass (i.e., 12-24 h). Once dry, mass was measured for each thimble (with fiberglass) to nearest 0.0001 g using an electronic scale (College B154/Mettler Toledo) to record the sample free mass of the thimble and fiberglass (i.e., thimble/fiberglass). After thimble/fiberglass mass was measured, approximately 5-g of homogenate was added to each thimble, lined with fiberglass, to prevent spilling of homogenate sample during extraction, and measured to nearest 0.0001 g using an electronic scale (College B154/Mettler Toledo) to record the pre-extraction sample mass (i.e., thimble/fiberglass/sample – thimble/fiberglass). Thimbles with samples were exposed to Soxhlet extractions using petroleum ether under the following conditions. As opposed to continuous washing for 24-48 hours with the same (dirty) ether, samples were first washed 3 times with the same ether. After the third wash, all ether was removed and fresh ether replaced the dirty ether. This procedure was repeated until samples were washed until clean (i.e., ether color was clear). Each sample was washed approximately 9 times, although number of washes varied per sample. However, extraction time generally ranged between 8-20 hours per sample. After extraction, all thimbles with samples were removed and oven dried at 65° C to constant mass (i.e., 24-48 hr). Once dry, each thimble/fiberglass/sample mass was measured to the nearest 0.01 g to obtain subsample lean dry mass including thimble and fiberglass (i.e., pre-extraction thimble/fiberglass/sample mass – post-extraction thimble/fiberglass/sample mass).

Total Body Lipid Estimation

Lipid content (%) of each subsample (n = 3 for each bird) was calculated by dividing subsample dry mass after extraction by subsample dry mass before extraction and multiplying by 100. If one subsample deviated ≥ 10 % of the calculated lipid content for the other 2 subsamples, new subsamples from the carcass homogenate were exposed to ether extraction procedures until all lipid content (%) of all subsamples for an individual bird were < 10 % from one another. Lipid content (%) of each carcass was calculated by averaging all subsamples.

Data Analysis

A simple univariate analysis of variance was used to examine differences in total lipid content data generated using ASE and using Soxhlet extraction procedures within each species (i.e., canvasback, lesser scaup, and ring-necked duck). All data (see Table C1) were used in this analysis, where all subsample data were averaged for each individual bird for each extraction technique. Due to sample size inconsistencies, no further analyses were performed within age/sex classes within each species.

RESULTS and DISCUSSION

In general, total lipid content data generated during this portion of the study were very similar between extraction techniques (Table C1, C2, C3). Moreover, in no instance did total lipid content vary between ASE and Soxhlet procedures for any species {canvasback: $F = 0.03$, 1, 30 d.f.; $P = 0.856$; lesser scaup: $F = 0.110$; 1, 20 d.f.; $P = 0.743$; ring-necked duck: $F = 0.124$; 1, 36 d.f.; $P = 0.730$}. For canvasback, mean total lipid content estimated using ASE was 30.34% (SE = 2.79) and using Soxhlet extraction procedures was 31.06% (SE = 2.79). For lesser scaup, mean total lipid content estimated using ASE was 24.69% (SE = 3.45) and using Soxhlet extraction procedures was 26.37% (SE = 3.69). For ring-necked duck, mean total lipid content estimated using ASE was 22.95% (SE = 1.62) and using Soxhlet extraction procedures was 23.73% (SE = 1.55). Although there were no differences ($P > 0.05$) in total lipid content generated from ASE or Soxhlet procedures, there was a general trend for Soxhlet lipid content values to be slightly higher, indicating that this extraction technique, as performed in this portion of the study, to be somewhat more thorough extracting lipids.

As the objective of this portion of the study was to verify that ASE and Soxhlet procedures are comparable, I believe use of ASE in the larger portion of the study (see Chapter II) generated accurate and reliable results. As the ASE data were corroborated and verified by Soxhlet data, I believe that this technique may provide future researchers, with access to such equipment, the ability to process large numbers of samples accurately and efficiently.

Table C1. Estimated whole body lipid content (%) of canvasbacks (CANV), lesser scaup (LESC), and ring-necked ducks (RNDU) exposed to accelerated solvent extractions and traditional Soxhlet extraction procedures.

			Accelerated Solvent Extraction			Soxhlet Extraction		
			Sample A	Sample B	Sample C	Sample A	Sample B	Sample C
Species	Sex	Age	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)
CANV	Female	Adult	36.9570	36.2874	40.1897	39.1213	36.3555	39.4498
CANV	Female	Adult	43.5640	44.5134	44.4416	44.5662	46.1906	47.4586
CANV	Female	Adult	35.0599	36.2721	38.1328	38.4132	36.0773	35.3100
CANV	Female	Adult	37.4343	38.4514	37.7094	38.1156	39.5577	39.8235
CANV	Female	Adult	40.6811	41.0343	40.8554	41.5365	39.5026	41.5593
CANV	Female	Juvenile	25.5206	24.8096	25.0855	26.1793	26.0529	26.2774
CANV	Female	Juvenile	6.1603	6.7187	6.0142	6.8521	6.8058	5.7122
CANV	Female	Juvenile	10.5413	12.2099	10.8049	12.1156	14.3803	13.5447
CANV	Female	Juvenile	31.9729	31.4884	29.5386	33.8760	31.0597	31.3287
CANV	Male	Adult	28.8297	28.6414	28.5763	31.8590	31.1039	31.0749
CANV	Male	Adult	43.5455	45.0347	40.0064	41.9253	44.1035	42.7915
CANV	Male	Adult	28.4726	30.8696	28.3735	29.4243	31.1274	31.3145
CANV	Male	Adult	31.9365	30.4171	31.1376	32.0941	31.2218	31.3857
CANV	Male	Adult	33.5353	29.8148	33.2591	34.1191	31.8726	33.4013

Continued on next page.

Table C1. Continued.

			Accelerated Solvent Extraction			Soxhlet Extraction		
			Sample A	Sample B	Sample C	Sample A	Sample B	Sample C
Species	Sex	Age	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)
CANV	Male	Juvenile	35.5644	35.2068	37.6234	34.2936	36.1596	33.3806
CANV	Male	Juvenile	12.5898	15.0762	15.1549	15.2431	14.1385	11.5402
LESC	Female	Adult	41.1507	41.9097	36.7466	37.8952	42.4175	45.0601
LESC	Female	Adult	17.1405	16.9082	17.3288	16.9269	16.7700	18.1973
LESC	Female	Adult	24.3131	22.2567	22.4862	23.9197	23.9153	25.5016
LESC	Female	Juvenile	6.3813	5.6540	6.3814	7.7351	7.0394	7.6346
LESC	Female	Juvenile	25.2430	26.7977	25.5967	27.3784	28.3704	28.4399
LESC	Female	Juvenile	3.4391	4.7171	3.6100	3.7916	3.8414	4.7884
LESC	Female	Juvenile	29.5211	30.0865	30.6776	34.1429	34.2402	33.6979
LESC	Male	Adult	29.9088	25.1412	25.6710	28.5038	26.2972	30.0121
LESC	Male	Adult	29.8901	31.5371	31.3701	30.4642	30.6975	30.5253
LESC	Male	Juvenile	32.4454	32.4290	34.7450	36.1826	33.9451	32.0302
LESC	Male	Juvenile	33.9134	34.6564	34.8525	41.4965	41.6762	36.8238
RNDU	Female	Adult	17.7426	20.5133	19.8642	20.6314	20.2907	19.2449
RNDU	Female	Adult	19.2921	16.3648	15.4874	19.8240	21.2121	23.9721

Continued on next page.

Tabel C1. Continued.

			Accelerated Solvent Extraction			Soxhlet Extraction		
			Sample A	Sample B	Sample C	Sample A	Sample B	Sample C
Species	Sex	Age	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)	Lipid (%)
RNDU	Female	Adult	16.8786	20.8013	19.4859	24.9015	23.4952	20.4222
RNDU	Female	Adult	26.3423	28.0350	29.7354	33.2409	31.9300	29.7011
RNDU	Female	Juvenile	28.9392	29.2336	26.9930	30.0312	28.4300	30.8949
RNDU	Female	Juvenile	31.5675	32.7138	34.0910	34.4442	33.8865	32.2956
RNDU	Male	Adult	9.7342	8.1532	8.3228	9.7372	9.5710	8.1639
RNDU	Male	Adult	26.1550	27.3824	26.0698	28.2213	22.6240	29.7341
RNDU	Male	Adult	15.9459	16.3608	15.9149	16.5593	16.1737	18.7211
RNDU	Male	Adult	28.9056	28.1548	29.2814	30.1067	29.4630	27.2948
RNDU	Male	Adult	24.5645	24.0810	24.8189	25.1313	9.2443	.
RNDU	Male	Adult	16.0124	15.0338	16.3142	19.9405	19.3275	19.9593
RNDU	Male	Adult	35.3743	37.8028	35.5702	34.4442	33.8865	32.2956
RNDU	Male	Adult	28.8525	30.0718	29.9641	28.2213	22.6240	29.7341
RNDU	Male	Adult	19.9583	22.2279	21.1587	20.4222	.	24.9015
RNDU	Male	Adult	19.5882	17.3854	17.5045	19.7537	19.3637	20.8981
RNDU	Male	Juvenile	24.1509	21.4585	21.3016	22.5271	22.8149	24.9897
RNDU	Male	Juvenile	26.9867	29.4383	27.6828	26.2180	.	33.8811
RNDU	Male	Juvenile	14.1318	16.5857	15.4338	.	16.0119	15.1878

Table C2. Means and Standard Errors (SE) of whole body lipid content (%) of canvasbacks (CANV), lesser scaup (LESC), and ring-necked ducks (RNDU) grouped according to age/sex class, exposed to accelerated solvent extractions and traditional Soxhlet extraction procedures.

			Accelerated Solvent Extraction						Soxhlet Extraction					
			Sample A		Sample B		Sample C		Sample A		Sample B		Sample C	
			Lipid (%)		Lipid (%)		Lipid (%)		Lipid (%)		Lipid (%)		Lipid (%)	
Species	Sex	Age	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
CANV	Female	Adult	38.74	1.51	39.31	1.57	40.20	1.20	40.35	1.21	39.53	1.82	40.72	1.97
CANV	Female	Juvenile	18.55	6.09	18.81	5.67	17.86	5.61	19.76	6.22	19.57	5.51	19.22	5.85
CANV	Male	Adult	33.26	2.74	32.96	3.04	32.37	2.13	33.88	2.14	33.86	2.55	33.99	2.24
CANV	Male	Juvenile	24.08	11.48	25.14	10.06	26.39	11.23	24.77	9.52	25.14	11.01	22.46	10.92
LESC	Female	Adult	27.53	7.11	27.02	7.60	25.52	5.81	26.25	6.16	27.70	7.64	29.59	8.02
LESC	Female	Juvenile	16.15	6.57	16.81	6.74	16.57	6.78	18.26	7.39	18.37	7.59	18.64	7.28
LESC	Male	Adult	29.89	0.01	28.34	3.19	28.52	2.85	29.48	0.98	28.50	2.20	30.27	0.25
LESC	Male	Juvenile	33.18	0.73	33.54	1.11	34.79	0.05	38.83	2.65	37.81	3.87	34.42	2.39
RNDU	Female	Adult	20.06	2.16	21.42	2.42	21.14	3.03	24.65	3.07	24.23	2.65	23.34	2.35
RNDU	Female	Juvenile	30.25	1.31	30.97	1.74	30.54	3.55	32.24	2.21	31.16	2.73	31.59	0.70
RNDU	Male	Adult	22.51	2.42	22.67	1.73	11.49	2.58	23.25	2.32	20.25	2.73	23.52	2.50
RNDU	Male	Juvenile	21.76	3.89	22.49	3.74	21.48	3.53	24.37	1.84	19.41	3.40	24.69	5.39

Table C3. Means and Standard Errors (SE) of whole body lipid content (%) of canvasbacks (CANV), lesser scaup (LESC), and ring-necked ducks (RNDU), grouped by sex, exposed to accelerated solvent extractions, and traditional Soxhlet extraction procedures.

			Accelerated Solvent Extraction						Soxhlet Extraction					
			Sample A		Sample B		Sample C		Sample A		Sample B		Sample C	
			Lipid (%)		Lipid (%)		Lipid (%)		Lipid (%)		Lipid (%)		Lipid (%)	
Species	Sex	*n*	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
CANV	Female	9	29.76	4.40	30.19	4.36	30.31	4.59	31.19	4.46	30.66	4.27	31.16	4.59
CANV	Male	7	30.63	3.57	30.72	3.36	30.59	3.06	31.28	3.05	31.39	3.39	30.69	3.54
LESC	Female	7	21.03	4.98	21.19	5.05	20.40	4.60	21.68	4.86	22.37	5.32	23.33	5.41
LESC	Male	4	31.53	0.99	30.94	2.04	31.66	2.15	34.17	2.93	33.15	3.24	32.34	1.55
RNDU	Female	6	23.46	2.57	24.61	2.57	24.27	2.90	27.18	2.58	26.54	2.33	26.09	2.29
RNDU	Male	13	22.34	1.99	22.62	2.20	22.26	2.08	23.44	2.93	20.10	2.26	23.81	2.18

VITA

Shaun L. Crook was born on 19 August 1975, son of Bill B. and Donna J. Crook. Shaun attended Lindale High School in Lindale, Texas and graduated in May of 1993. He graduated from Stephen F. Austin State University in May 2003 with a Bachelor of Science degree in Forestry. Shaun then entered the Graduate School at Stephen F. Austin State University in August 2003. He received a Master of Science degree in May 2007. Shaun is currently employed by the Texas Parks and Wildlife Department as the Area Biologist over Old Sabine Bottom Wildlife Management Area.

Permanent Address: 10595 County Road 429
Tyler, TX 75704

This thesis was typed by Shaun L. Crook.