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True Metabolized Energy of Submersed Aquatic Vegetation in Semi-Permanent Marshes for Dabbling Ducks in the Upper Midwest

Annual Performance Report

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INTRODUCTION

Many species of waterfowl depend on wetlands and vegetation communities produced therein for food and cover. Dabbling ducks (*Anatini*) consume vegetation, seeds, and invertebrates in different proportions depending upon factors such as species, age, sex, or time of year (Combs and Fredrickson 1996, Miller et al. 2000). During migration, wetlands in the upper Midwest provide resources that allow ducks to migrate and prepare for the energetically-demanding winter and breeding seasons (Straub et al. 2012, Davis et al. 2014, Hagy et al. 2014*a*). The amount of food and habitat available for waterfowl at migration stopovers has decreased as wetlands have been lost and converted to other land uses, and the quality of remaining wetlands has been degraded by a myriad of factors (Anteau and Afton 2009, Dahl 2011, Hagy et al. 2014*b*).

Waterfowl habitat destruction and degradation is a well-documented and pervasive problem within the Midwestern United States (Bellrose et al. 1983, Sparks 1995). Illinois has lost approximately 85% of historical wetlands in the last two hundred years (Dahl 1990). Draining and tiling wetlands for agriculture, dredging and channelizing rivers for navigation, and constructing dams and levees for flood control are among the primary anthropogenic activities that have historically and continue to remove wetlands from the landscape (Sparks 1995). Consequently, remaining wetlands are subject to increased sedimentation from altered hydrology and flow, decreased light penetration due to suspended sediment, and drastic changes in nutrient loads due to agricultural runoff and other point source pollution (Moore et al. 2010). All of these factors make it difficult for submersed aquatic vegetation (SAV) to thrive in wetlands, especially those with connections to large rivers with unnatural hydrology (Jackson and Pringle 2010, Moore et al. 2010). Stafford et al. (2010) found that the percentage of wetland area in the Illinois River Valley (IRV) covered in submersed aquatic and floating leaf vegetation declined from 26.1% during 1938–1942 to <0.1% during 2005−2006.

As wetland area and quality decreased, it has become imperative that wetland managers understand the resources necessary to sustain healthy populations of wetland-dependent organisms. Havera (1999) estimated that the Upper Mississippi River supports 36% of all continental migrating waterfowl, making ducks and geese significant consumers of wetland resources in the Midwest. The wetlands of the IRV provide approximately 7.5 million mallards (*Anas platyrhynchos*) use-days during fall migration each year (2012–2015, A. Yetter, Illinois Natural History Survey, unpublished data). Mallards are the most abundant duck species in North America, and are considered among the most generalist of dabbling duck species, both in habitat and diet selection (Baldassarre 2014). Mallards are opportunistic omnivores that utilize abundant food sources, even commonly feeding in crop fields containing corn, soybeans, and other grains (Anderson 1959, Combs and Fredrickson 1996, Dabbert and

Martin 2000). During autumn migration, the primary food of mallards is plant material e.g., seeds and leaves of aquatic vegetation; Anderson 1959, Fredrickson and Reid 1988, Callicutt et al. 2011). Hitchcock (2009) found that mallards consumed both invertebrates and seeds in proportion to their availability.

Current conservation planning for dabbling ducks in the Midwest is based on the assumption that food energy may be a limiting factor during migration. The basic principle of this food limitation hypothesis is that food availability during nonbreeding periods is related to demographic rates and by increasing food, survival, productivity, or other rates will increase (Williams et al. 2014). Wetland managers need three pieces of information to determine the energetic carrying capacity of a wetland using a daily ration model, including 1) the daily energetic requirement of ducks using a wetland, 2) the amount of food available in the wetland, and 3) the energetic value of the available foods for ducks (Soulliere et al. 2007). Daily energetic requirements are estimated using mass and resting metabolic rates from available equations (Miller and Eadie 2006). Food availability within a wetland complex often is estimated by core and box sampling (Sychra and Adamek 2010, Hagy and Kaminski 2012). The energetic value an organism obtains from a food (i.e., true metabolizable energy) has become of great interest to wetland and waterfowl managers for its direct applicability in conservation planning.

True metabolizable energy (TME) values are commonly used in conservation planning because they account for fecal and urinary energy of non-food origin (Miller and Reinecke 1984). True metabolizable energy studies began in the 1970s with agricultural grains and domestic poultry (Sibbald 1976), and methods have since been adapted for wild waterfowl and natural foods to support conservation planning (Miller and Reinecke 1984, Hoffman and Bookhout 1985, Jorde and Owen 1988, Kaminski and Essig 1992). To date, nearly all available TME values for waterfowl are from moist-soil seeds and agricultural grains collected from a limited number of duck species (Checkett et al. 2002, Kaminski et al. 2003, Ballard et al. 2004). Seeds are considered relatively high in fat and low in ash, resulting in high digestibility (Fredrickson and Reid 1988, Ballard et al. 2004). True metabolizable energy values of moist-soil seeds across duck species range from 1.08 kcal/g for Pennsylvania smartweed (*Polygonum pensylvanicum*, Hoffman and Bookhout 1985) to 3.47 kcal/g for wild rice (*Zizania aquatica*, Sherfy 1999). Vegetation contains less energy than seeds because it is low in fat and high in fibrous, inorganic, and indigestible material (Hoffman 1983, Fredrickson and Reid 1988). Two previously assayed vegetation species (shoalgrass, *Halodule wrightii*, TME: 0.82 ± .03 kcal/g, Ballard et al. 2004; widgeon grass, *Ruppia maritima*, TME: 1.10 ± 0.14 kcal/g, Coluccy et al. 2014) have low TME values relative to seeds. Until recently, SAV has been largely undervalued as a potentially significant source of energy for dabbling ducks and few comparisons have been made across species

(Ballard et al. 2004, Straub 2008, Coluccy et al. 2014). Many dabbling duck species have omnivorous diets similar to mallards (Baldassarre 2014), but other species that are primarily herbivorous, especially gadwall (*Anas strepera*), may differ in their digestion efficiency of SAV (Barnes and Thomas 1987).

Our primary objectives were to 1) estimate true metabolizable energy of common species of submersed aquatic vegetation in semi-permanent marsh habitats of the Upper Midwest for gadwall and mallard during autumns 2015–2017, and 2) use current and historic estimates of semi-permanent marsh vegetation communities during autumn within the IRV to document the net change in energetic carrying capacity for dabbling ducks and compare with habitat use by waterfowl using long-term aerial surveys of the Illinois Natural History Survey. We assayed six species of SAV common in the Midwest and that have been previously documented as waterfowl foods: coontail (*Ceratophyllum demersum*), wild celery (*Vallisneria americana*), Canadian waterweed (*Elodea canadensis*), southern naiad (*Najas guadalupensis*), Eurasian watermilfoil (*Myriophyllum spicatum*), and sago pondweed (*Stuckenia pectinate*; Anderson 1959, Stewart 1962, Bergman 1973, Havera 1999, Benedict and Hepp 2000, Hitchcock 2009, Baldassarre 2014). Understanding the energetic value of SAV for dabbling ducks will allow wetland managers to accurately evaluate wetland management practices and conservation planners to develop more accurate energetic carrying capacity models. We predicted that the energetic carrying capacity of semi-permanent marshes containing SAV will be slightly less than if the same wetlands were managed for moist-soil vegetation (Bowyer et al. 2005). We hypothesized that the TME of SAV per unit biomass will be less than that of moist-soil seeds and agricultural grains. Further, we hypothesized that the TME values derived from male and female mallards and between time periods (week of trial) will be similar.

METHODS

We captured wild mallards during August 2015 and gadwall during March 2016 using rocket nets and swim-in traps baited with corn in central Illinois. Wild ducks were used in trials due to variation in TME values between game-farm mallards and wild ducks (Kaminski and Essig 1992). We kept birds in captivity and conducted all feeding trials at Forbes Biological Station near Havana, Illinois. We collected SAV from Emiquon Preserve in Fulton County, Illinois, Sue and Wes Dixon Waterfowl Refuge at Hennepin and Hopper Lakes in Putnam County, Illinois, and Big Basin of the Des Plaines River in Will County, Illinois. Vegetation was collected by hand prior to feeding trials, transported to the Forbes Biological Station, and transferred into aquaria in a climate-controlled laboratory for maintenance. Freshly collected vegetation was used in feeding trials while available before senescence and tank-maintained vegetation was used subsequently. We maintained water temperatures near 28°C

using in-tank water heaters and photoperiod at 14 hours of light daily (0600–2000 hrs) using 40 watt T12 fluorescent bulbs. We fed SAV to ducks ad libitum throughout the fall migration period (September–December), using freshly-collected vegetation when available and laboratory-maintained after natural senescence occurred in our study area. We assumed no differences between laboratory-maintained and fresh-collected vegetation, and will confirm this assumption by conducting proximate analysis on both fresh and laboratory-maintained vegetation in later years.

Following capture and during the 10-day rest period after each trial, we maintained ducks on a commercial poultry ration (Nutrena Country Feeds Layer 16%, 16% protein, 2.5% fat, 8% fiber; and Nutrena Country Feeds All Flock, 18% protein, 2.5% fat, 8% fiber; Checkett et al. 2002, Kaminski et al. 2003, Ballard et al. 2004, Dugger et al. 2007, Coluccy et al. 2014) and supplemented this stock food with scratch grains (Nutrena Country Feeds Scratch Grains, 7.5% protein, 2.5% fat, 8% fiber) and provided a mixture of SAV (largely coontail and milfoil) at least once a week. Poultry ration provides a low-protein, balanced maintenance diet and helps prevent physiological issues (e.g., weight loss, angel wing) resulting from maintaining birds in captivity. We added SAV to diets to maximize the likelihood that gut morphology of captive birds is accustomed to processing vegetation efficiently during feeding trials (Miller 1975, Checkett et al. 2002).

Outside of trails, ducks were maintained in a large (1.22 m wide × 6.1 m long × 0.91 m tall or 1.68 m wide × 9.75 m long × 0.91 tall) aviary elevated approximately 1 m above the ground with a 0.6 m × 0.91 m basin of water that is continually refreshed. Within a trial season, ducks were kept in 2 adjacent trial pens consisting of a similarly constructed aviary (2.44 m wide × 3.05 m long × 0.61 m tall) with individual compartments (2 ducks/compartment; 1.07 m wide × 1.22 m long). Trial pairs (i.e., one male, one female) were randomly assigned and housed together in each compartment. Each duck was banded with a numbered, removable, plastic tarsal band for identification and the right primary feathers were clipped to prevent flight inside holding pens.

Trial pens and aviaries were constructed with 2.5-cm vinyl-coated hardware cloth with up to two-thirds of each pen covered in outdoor carpet. Each pen contained a bowl (35 cm diameter × 9 cm depth) of water that was continually replenished with fresh water (Fig. 1) and feeders made of 7.6-cm polyvinyl chloride pipe and located on the opposite corner of the pen from the water to decrease chances of splashing water into feed. Ducks fed from a wye joint connected to a 0.8-m long pipe, which acted as a gravity feeder (Fig. 2). Caps on each feeder extended above the top wire to facilitate refilling of feeders without opening the main doors of the pens. Pens were rinsed with fresh water daily during trial season. We continuously monitored feeders and refilled when needed. At least every two weeks, we removed, cleaned and sanitized, and refilled feeders and water bowls.

Feeding trials were preceded by a fasting period of 48 hours to clear the digestive tracts of trial birds. We removed birds from trial pens and weighed each using an Ohaus balance (1 g; Ohaus Corporation, Parsippany, NJ), cleaned each pen and water bowl with fresh water, and removed the feeder to ensure no access to food during the fasting period. Throughout the fasting period, birds had access to water ad libitum. After 48 hours, we reweighed each duck, precision fed each duck a quantity of SAV of approximately 1% of their body mass, and placed each duck in a metabolic cage (20 × 20 × 30 cm, 1-cm welded wire mesh) placed within an open-top plastic tub to catch excreta (Fig. 3). Precision feeding consisted of consolidating small amounts (<1 cm diameter) of vegetation and pressing it down the esophagus of each bird using a gloved finger. A typical feeding consisted of 3–10 replications of this process and took approximately 5 minutes. Ducks were removed from metabolism cages after 48 hrs and retuned to trial pens with access to food and water ad libitum. Each individual duck served as their own control to reduce effects of individual metabolism (Sherfy et al. 2005). During the control trials, an individual was fasted throughout the entire 4-day trial period.

We collected excreta by rinsing contents of the plastic tubs into a 1-gal Ziploc bag. We removed feathers, regurgitated SAV, and any other debris by hand from the samples and then froze samples until subsequent laboratory processing and analysis. We also froze fresh vegetation samples of each of the six species throughout feeding trials for comparison with digested samples. Within 180 days of trials, we thawed samples, dried samples in an oven at 60° C to remove excess water, grinded samples with a mortar and pestle into a fine powder, weighed ground material to the nearest 0.1 mg (Mettler Toledo, Columbus, OH), pressed material into individual pellets using a Parr pellet press (Parr Instrument Company, Moline, IL), and combusted pellets in a Parr 6050 compensated jacket calorimeter to determine gross energy of the sample. True metabolizable energy (TME) was calculated using the following equation:

$$TME = \frac{(GE_f \times W_f) - (EE_f - EE_c)}{W_f}$$

where GE_f is the gross energy of vegetation, W_f is mass of vegetation fed to each bird, EE_f is the gross energy of excreta collected during feeding trial, and EE_c is the gross energy of excreta collected during control trial (Sibbald 1976, Coluccy et al. 2014).

Additionally, we determined gross energy, percent water, ash, crude protein, fat, fiber, and nitrogen-free extract for each sample using proximate analysis and other techniques. Percent water and ash were analyzed according to standardized procedures (Association of Official Analytical Chemists (AOAC), 2006; methods 934.01 and 942.05). Crude protein was calculated from LECO (models FP2000 and TruMac; LECO Corp., St. Joseph, MI) and total nitrogen values (AOAC, 2006; method

992.15). Crude fat of each food was determined according to the methods of the Association of Official Analytical Chemists (2006; method 2003.06). Acid and neutral detergent fiber contents was determined by the method of Jeraci and Van Soest (1990). We calculated nitrogen free extract as (100% – [%water + %crude fiber + %ash + %fat + %crude protein]) where crude fiber is ADF x 0.80 (Petrie et al. 1998). Crude protein also will be determined for all excreta samples, which we will apply using a nitrogen correction factor to account for energy of non-food origin, following the recommendation of Sibbald and Morse (1982).

We compared TME values of the six species of SAV using general linear models in a mixed model framework (Proc Mixed in SAS v9.4). True metabolizable energy was the dependent variable and vegetation species, time of trial, and sex were independent variables. We included body mass as a random effect to account for any variation in digestibility difference during the fall migration period. We built all-possible models using different combinations of fixed effects and biologically-plausible interactions and used Akaike's Information Criteria (AIC) to determine the best model (AIC <2; Burnham and Anderson 2002). We examined residuals for normal distribution and use transformations as needed (Zar 2009). We calculated effect sizes from raw data or use back-transformations as appropriate. We model averaged parameter estimates or effects sizes as appropriate among competitive models (Burnham and Anderson 2002).

We used a daily ration model to estimate energetic carrying capacity of wetlands (i.e., duck energy days [DED]) within the IRV using a combination of published data and those generated in our previous analyses:

$$\text{DED} = \sum \left(\frac{\text{Food available (g dry weight) x TME of food (kcal/g dry weight))}}{\text{Species specific daily energy requirement (kcal/day)}} \right.$$

(Checkett et al. 2002, Kaminski et al. 2003, Dugger et al. 2007, Williams et al. 2014). We used 358 kcal/day as the daily energy requirement of mallards as estimated by Souilliere et al. (2007).

RESULTS AND DISCUSSION

During October–December 2015, we conducted 12 trials using 22 different mallards (11 females and 11 males) resulting in 84 samples. These trials resulted in collection of 20 control, 8 sago pondweed, 14 coontail, 12 Eurasian watermilfoil, 10 Canadian waterweed, 10 wild celery, and 14 southern naiad samples. Although our goal was 12–16 samples of each species, issues with tank-maintained vegetation limited samples sizes for several species. We submitted samples for nutrient

analysis through the University of Illinois at Urbana-Champaign during summer 2016 and are still waiting on full results to adjust raw TME values for energy of non-food origin in fecal samples. Unadjusted TME estimates were 1.56 kcal/g for coontail, 2.32 kcal/g for Canadian waterweed, 1.85 kcal/g for southern naiad, -2.37 kcal/g for Eurasian watermilfoil, 0.89 kcal/g for sago pondweed, and 2.69 kcal/g for wild celery. Assuming nitrogen adjustments will be minor (e.g., 2–5%) similar to Adeola et al. (1997), our estimates for most species were less than most seeds (Kaminski et al. 2003) but greater than most invertebrates and several previously reported species of SAV (Sherfy 1999, Ballard et al. 2004, Dugger et al. 2007). In future segments of this project, we will report results from other species of vegetation and ducks and results of nutrient analyses as they become available. We will also model energetic carrying capacity of wetlands in the IRV when more data are available. Additional trials with mallards and gadwall are planned for fall and winter 2016–2017 and 2017–2018.

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Figure 1. Trial pen compartment at Forbes Biological Station in Havana, IL during autumn 2015.

Figure 2. Trial pens with feeders located at Forbes Biological Station in Havana, IL during autumn 2015.

Figure 3. Metabolism cage and tubs used during trials at Forbes Biological Station in Havana, IL during autumn 2015.

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