C.2: Foraging, Nutrition, and Energetics of Waterfowl: The Foundations of Habitat Management (Organizers: Scott McWilliams, Bruce Dugger)

C.2.1: Heitmeyer

Energetics and Nutrition of Migrating and Wintering Dabbling Ducks – What Have We Learned in the Past 50 Years and Where Should Management Be Headed

Mickey E. Heitmeyer[1]*

[1] Greenbrier Wetland Services, Advance, MO 63730, USA, mheitmeyer@greenbrierwetland.com

The abundance and availability of food are among the most important drivers of waterfowl ecology, including the inherent abundance and distribution of populations. Consequently, is it no wonder that understanding food use and energetic/nutritional needs, and then attempting to produce presumed important foods, has been a major part of the history of waterfowl and wetlands management in migration and wintering areas of North America. Beginning with early studies of what ducks actually ate, biologists have greatly expanded our understanding of more comprehensive energetic and nutritional ecology of species, especially the integration of dynamics related to variable annual cycle events. This information has demonstrated the complex interactions of physiological, nutritional, and behavioral adaptations – and has helped provide a foundation for management of key resources used, and needed, by waterfowl during winter and migration periods. The majority of this information has been developed for dabbling ducks, and has strongly influenced habitat management across North America with several hundred million dollars spent annually trying to produce duck food. Despite advancements, management strategies remain constrained by a focus on energy (Kcals); a pre-disposition toward producing grains for mallards; indiscriminate emphasis on specific habitat types, such as moist-soil impoundments, in relation to season and locations; and flooding regimes that generally coincide with hunting seasons. Waterfowl conservation will be advanced further if future management strategies can more strongly and directly couple comprehensive nutritional needs of species with annual cycle events engaged in across continental landscape scales. Examples of landscape-scale understanding of the historical wetland community type, distribution, and dynamics that drove evolutionary form and function of waterfowl are starting to emerge from hydrogeomorphic (HGM) studies, for example in the Mississippi and Lower Missouri River Valleys, and should be a foundation for directing future habitat restoration and management strategies including revised NAWMP, SHC, LCC, and other continental- to local-scale programs.

C.2.3: Lovvorn

Are Detailed Energetics Studies Needed to Assess Habitat Requirements? Allometry, Mechanistic Models, and Other Confounding Factors

James R. Lovvorn[1]*, Susan E. W. De La Cruz[2], John Y. Takekawa[3], Samantha E. Richman[4]

[1] Department of Zoology, Southern Illinois University, Carbondale, IL 62903, USA, lovvorn@siu.edu
[2] U.S. Geological Survey, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, California, 94592, USA
[3] National Audubon Society–Science Division, 220 Montgomery Street, San Francisco, CA 94104, USA
[4] Department of Zoology and Physiology, University of Wyoming, Laramie, WY 82017, USA

From a habitat management perspective, one ultimate goal of energetics studies is to estimate the quality and extent of habitat needed to support a given number of animals. Allometry, or the metabolic theory of ecology, presumes that most aspects of energetics that affect food requirements F are subsumed within the single variable of body mass Mb in equations of the form F = a Mbx, derived from regressions including multiple taxa over a range of body masses. Such estimates of food requirements have been compared to all or some fraction of food stocks to evaluate the adequacy of existing or proposed habitat. If such estimates are realistic, they would be very powerful and inexpensive to implement. However, a number of issues such as threshold prey densities needed for profitable foraging, prey patch structure and associated search costs, and varying thermal regimes might cause important deviations from simple allometric relationships. Parameterizing models that account for such mechanisms is expensive and time-consuming, albeit more satisfying to functional ecologists. Seldom, however, have estimates from allometry versus mechanistic models been compared to assess the relative value of in-depth studies of the components of energy balance. This talk will describe the results of detailed mechanistic models of food and habitat needs of three diving duck species of differing body mass – lesser scaup, surf scoter, and greater scaup – when feeding on the same prey (Asian clams) in northern San Francisco Bay. I will compare these results to allometric estimates of metabolic requirements relative to prey standing stocks. I will also explore caveats to both these approaches, given that most mechanistic studies have found that diving ducks and a range of other taxa typically abandon feeding areas well before energetics models indicate that food has been depleted.

C.2.4: Webb

An Empirical Evaluation of Landscape Energetic Models: Mallard and American Black Duck Space Use During the Non-breeding Period

William S. Beatty[1], Elisabeth B. Webb[2*], Dylan C. Kesler[3], Luke W. Naylor[4], Andrew H. Raedeke[5], Dale D. Humburg[6], John M. Coluccy[7], Gregory J. Soulliere[8]

[1] U.S. Geological Survey, Alaska Science Center, Anchorage, AK, 99508, USA, w_beatty@hotmail.com
[2] U.S. Geological Survey, Missouri Cooperative Fish and Wildlife Research Unit, 302 Anheuser-Busch Natural Resources Building, Columbia, Missouri 65211, USA, webbli@missouri.edu
[3] Department of Fisheries and Wildlife Sciences, University of Missouri, 302 Anheuser-Busch Natural Resources Building, Columbia, Missouri 65211, USA
[4] Arkansas Game and Fish Commission, 2 Natural Resources Drive, Little Rock, Arkansas 72205, USA
[5] Missouri Department of Conservation, 3500 East Gans Road, Columbia, Missouri 65201, USA
[6] Ducks Unlimited, 1 Waterfowl Way, Memphis, Tennessee 38120, USA
[7] Ducks Unlimited, 1220 Eisenhower Place, Ann Arbor, Michigan, 48108, USA
[8] Upper Mississippi River and Great Lakes Region Joint Venture, U.S. Fish and Wildlife Service, 2651 Coolidge Road, Suite 101, East Lansing, Michigan 48837, USA

A subset of Bird conservation Joint Ventures has developed energetic carrying capacity models (ECCs) to translate regional waterfowl population goals into habitat objectives during the non-breeding period. Energetic carrying capacity models consider food biomass, metabolism, and available habitat area to estimate waterfowl carrying capacity within regional landscapes. Thus, ECCs provide a method to generate non-breeding waterfowl habitat restoration targets. To evaluate Joint Venture ECCs in the context of waterfowl space use, we monitored 33 female mallards (*Anas platyrhynchos*) and 55 female American black ducks (*A. rubripes*) using global positioning system satellite telemetry in the central and eastern United States. To quantify space use, we measured first-passage time (FPT: time required for an individual to transit across a circle of a given radius) at biologically relevant spatial scales for mallards (3.46 km) and American black ducks (2.30 km) during the non-breeding period, which included autumn migration, winter, and spring migration. We developed a series of models to predict FPT using Joint Venture ECCs and compared them to a biological null model that quantified habitat composition and a statistical null model, which included an intercept and random terms. Energetic carrying capacity models predicted mallard space use more efficiently during autumn and spring migrations, but the statistical null was the top model for winter. For American black ducks, ECCs did not improve predictions of space use; the biological null was top ranked for winter and the statistical null was top ranked for spring migration. Thus, existing ECCs provided limited insight into predicting waterfowl space use, especially for black ducks, during the non-breeding period. Refined estimates of spatial and temporal variation in food abundance, habitat conditions, and anthropogenic disturbance will likely improve ECCs and benefit conservation planners in linking non-breeding waterfowl habitat objectives with distribution and population parameters.

*Speaker; ^Student

C.2.5: Johns^

Influences of Individual Quality and Energetic Carry-Over Effects on Reproductive Success: Evidence from Dabbling Ducks

David W. Johns[1]*^, Robert G. Clark[1,2]

[1] Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan, S7N 5E2, Canada, david.johns@usask.ca
[2] Environment Canada, Saskatoon, Saskatchewan, S7N 0X4, Canada

Individual quality is an important component in determining timing of breeding and reproductive success in waterfowl. While measures of quality have typically focused on age or indices of body condition, an individual's intrinsic quality may not be fixed but responsive to varying energetic demands or environmental conditions. As migratory species winter and breed in distant locations, demands in one season may ultimately influence intrinsic quality and performance of individuals in subsequent seasons. (i.e., carry-over effects). In birds, the hormone corticosterone is deposited in feather tissue (CORTf) during feather growth and represents an integrated record of an individual's energetic response over periods of days to weeks which persists until the feather is molted. Collection of feathers grown prior to breeding enables retrospective insight into energetic responses and investigations of potential carry-over effects that may influence future reproductive performance. While negative relationships between CORTf from the wintering period and subsequent survival have been demonstrated in arctic-nesting eiders, investigations in other systems are lacking. Incorporating information gained from captive experimental work on the relationships between energetic response and CORTf, we can further inform and refine investigations of extrinsic (i.e. landscape, habitat) influences on reproductive success. Our objective was to determine how individual quality, in terms of current (measured upon capture; age, body condition, behavior, and timing of breeding) and antecedent (CORTf from previous breeding and wintering periods) periods, affects waterfowl reproductive success. During 2011 and 2012, 104 female pintails were captured, radio-marked and monitored during brood rearing in southern Saskatchewan. We collected wing and body feathers from captured pintails as well as indexed body morphometrics, age and behavior during capture and brood-rearing. Feather samples were analyzed for CORTf and stable isotopes of hydrogen (δ^2 H), sulfur (δ^34 S), nitrogen (δ^15 N) and carbon (δ^13 C). Using a combination of direct band recovery information, Bayesian probabilistic and multi-isotope assignment approaches, we estimated likely origins of pintails during the previous post-breeding period (wing molt) and winter provenance (body molt). Using structural equation modeling we tested whether reproductive success (number of fledged young) was influenced by past (CORTf) and current (scaled body mass) quality, with respect to known (hatch date) and hypothesized (behavior) sources of variation in waterfowl reproductive success. Based on isotopic assignment the majority of pintails molted wing feathers in the prairies, followed by arctic and boreal regions. Body feathers were likely grown in mid-latitude locations during migration between known breeding and putative wintering locations. Pintail body condition was dependent on wing molt location with boreal origin birds having reduced body condition in the following year. CORTf values did not differ between likely wing molt locations but CORTf in body feathers was higher for pintails wintering in non-agricultural settings. We did not find evidence of direct influences of intrinsic quality on pintail fledging success. The use of intrinsic biomarkers such as feathers provides an integrated method for assessing retrospective quality and its future use will provide a novel method to enhance our understanding of reproductive variation in migratory birds.

C.2.6: Williams

Improving Bioenergetic Carrying Capacity Estimates by Including Morphometrics in Cost of Thermoregulation

Christopher K. Williams[1]*, Mark C. Livolsi[1], Scott R. McWilliams[2]

[1] Department of Entomology and Wildlife Ecology, University of Delaware, Newark, DE 19716, USA, ckwillia@udel.edu
[2] Department of Natural Resource Science, University of Rhode Island, Kingston, RI 02881, USA

Bioenergetics modeling is a popular tool used by waterfowl biologists to estimate carrying capacity based on food energy availability and daily energy expenditure (DEE). For wintering waterfowl, estimates of DEE may incorporate a cost of thermoregulation (CT) component, which accounts for metabolic heat production when ambient temperatures fall below a species-specific Lower Critical Temperature (LCT). Typically, DEE estimates have utilized either a fixed CT component or a simple CT model based solely on the magnitude of the difference between ambient temperature and LCT. Using a more complex CT model that accounts for differential heat loss from individual body regions due to temperature, wind speed, and contact with air or water may provide more detailed estimates of CT and in turn, carrying capacity. However, such models required detailed morphometrics as model inputs in addition to environmental data. We present morphometrics for 8 dabbling duck species for use in thermoregulation models, as well as regression equations that may substitute for measurements of unmeasured species. We compared CT values produced via simple and complex CT models for American Black Ducks (*Anas rubripes*) wintering on the Delaware Bayshore, 2011–2013. We found that the complex CT model produced significantly higher CT estimates (5.38 ± SE 0.38 kJ/bird/hr) compared with the simple model (1.26 ± 0.04 kJ/bird/hr). Applying these CT values to bioenergetics models for American Black Ducks wintering in southern New Jersey suggested that this disparity in CT could produce substantial differences in estimated carrying capacity. Thus, we recommend that researchers consider incorporating detailed CT models into their estimates of DEE to reduce bias in carrying capacity estimates.

D.2: Foraging, Nutrition, and Energetics of Waterfowl: The Foundations of Habitat Management (Organizers: Scott McWilliams, Bruce Dugger)

D.2.1: Guillemain

Foraging, Nutrition, and Energetics of Waterfowl: A European Perspective

Matthieu Guillemain[1]*, Claire A. Pernollet[1,2], Céline Arzel[3], Johan Elmberg[4], John Eadie[5]

[1] Office National de la Chasse et de la Faune Sauvage, Arles, 13200, France, matthieu.guillemain@oncfs.gouv.fr
[2] Centre de Recherche de la Tour du Valat, Arles, 13200, France
[3] Turku University, 20014 Turku, Finland
[4] Kristianstad University, Kristianstad, 29188, Sweden
[5] University of California, Davis, CA 95616-8627, USA

Much attention has historically been devoted to feeding ecology of waterfowl, providing an extensive research record for Europe and North America alike. However, research in this field has gradually followed different paths on the two continents. American scientists have adopted a more applied perspective, often aiming at assessing the extent to which food requirements of waterfowl can be fulfilled in different habitats, and how management of these can increase carrying capacity. As opposed to this “energetic” approach, European scientists have rather framed their studies in a “behavioral” perspective, using waterfowl as model species for more theoretical approaches to foraging ecology. Consequently, while North American research has most often been carried out at the scale of waterfowl populations, the individual bird has more frequently been the scale of study in Europe. We present three examples of such European studies: first, a detailed analysis of the trade-offs made by dabbling ducks between foraging and anti-predator vigilance, leading to divergent strategies to face gradual food depletion during the winter. Second, we do a flyway-scale analysis of duck foraging needs and behavior, from Mediterranean wintering grounds to breeding sites in the Boreal, and point out the main hurdles faced by these birds across their annual cycle. Such detailed European studies can provide useful parameter values to fuel modern agent-based models of habitat use and carrying capacity developed in North America, hence cross-fertilizing the approaches on the two continents. This is exactly what our third example is about; namely adapting the SWAMP model developed in California to better understand and predict the use of harvested rice fields by wintering ducks in southern France.

D.2.3: Alisauskas

Diet and Nutrition of King Eiders and Long-tailed Ducks Arriving to Breed at Karrak Lake, Nunavut

Ray T. Alisauskas[1]*, Dana K. Kellett[1]

[1] Wildlife Research Division, Environment Canada, Prairie and Northern Wildlife Research Centre, 115 Perimeter Rd, Saskatoon, Saskatchewan, S7N 0X4, Canada, ray.alisauskas@ec.gc.ca

The relative contribution of nutrient reserves vs. exogenous nutrients for egg formation has implications for cross-seasonal effects on reproduction and recruitment to sea duck populations. We studied body composition, and diet of both King Eiders, *Somateria spectabilis*, and Long-tailed Ducks, *Clangula hyemalis*, shot as they arrived to breed at Karrak Lake, about 60 km inland from the south shore of Queen Maud Gulf in Canada’s central arctic. From 13 to 21 June in each of 2009 to 2011, we shot 28 (19 female, 9 male) King Eiders and 43 (18 female, 25 male) Long-tailed ducks shortly after their arrival at Karrak Lake, where they nest at relatively high densities. Ten morphometric measurements were recorded. Major organs of all birds were dissected and weighed, and proximate analysis of carcasses was done to determine whole body fat, protein, and mineral. Esophageal contents were removed and sorted to Genus and Species, where possible, but at least to Order (Diptera, Trichoptera, Coleoptera, Plecoptera, Aranea) or Family (most common were Anthomyiidae, Chrinomidae, Tipulidae, Limnephilidae, Nemouridae, Circulionidae, and Syrphidae) in most cases. The number of individuals in each identifiable taxonomic group found in each esophagus was counted and aggregate mass of such groups was recorded, followed by proximate analysis. Finally, we conducted stable Carbon and Nitrogen isotope analysis of liver, breast muscle, abdominal fat (Carbon only), oviduct, developing follicle (lipid and lean dry portion, separately), and any oviducal eggs (albumen, yolk lipid and lean dry yolk, separately); as well, stable isotope analysis was done on identifiable taxonomic groups of esophageal contents separately for lipid and lean dry fractions. Final stable isotope results have not been received from the contracted laboratory, but program SIAR will be used to compare the relative estimated contributions of endogenous nutrients toward various egg components in both King Eiders and Long-tailed Ducks.

*Speaker; ^Student

D.2.4: Perry

Geographic and Interspecific Variation of Seaduck Food Habits in Northeastern North America

Matthew C. Perry[1]*, Peter C. Osenton[1], Alicia M. Wells-Berlin[1]

[1] USGS Patuxent Wildlife Research Center, 12100 Beech Forest Road, Laurel, Maryland 20708 USA, mperry1209@verizon.net

Food selection was determined among four species of seaducks (n = 716) collected by hunters during 1999-2008 from three areas of the Atlantic Coast (Maritime Provinces, Massachusetts, and Chesapeake Bay). Objectives were to determine geographic and interspecific differences in food and compare to data from historic food habits file (1890-1985). Scoters (black, surf, and white-winged) and common eiders fed mainly mussels and clams, which varied greatly among locations and species. Aerial waterfowl surveys, in general, suggest that the four species of seaducks were more commonly located in the meso- to polyhaline areas of the coast where the food collected from the ducks is typically found. Three species of mussels (*Ischadium recurvum, Mytilus edulis, Modiolus modiolus*) and four species of clams (*Gemma gemma, Mulinia lateralis Ensis directus, Spisula solidissima*) constituted 62% of the food, with a north to south increase in clam and a decrease in mussel composition. No major differences were noticed between the sexes in regard to food selection in any of the wintering areas for any of the seaduck species. Comparisons of recent data to historic food habits data failed to detect major temporal differences in all areas. However, several invertebrate species recorded in historic samples were not found in current samples and two invasive species (*Rangia cuneata* and *Carcinas maenas*) were recorded in modern samples, but not in historic samples. Benthic sampling in areas where seaducks were collected showed a close correlation between consumption and availability. Concurrent energetic studies done with captive scoters in large 2-meter deep dive tanks compared energy value from the dominant mussel and the dominant clam eaten by scoters in Chesapeake Bay. The mussel provided greater energetic value, which could be problematic as mussel beds are declining in the Bay, and possibly other areas of the Atlantic coast.

D.2.5: Coluccy

True Metabolizable Energy of Waterfowl Foods: Our Current Understanding and Implications for Conservation Planning

John M. Coluccy[1]*, Matt T. DiBona[2], Bruce D. Dugger[3], Mark C. Livolsi[4], Mark J. Petrie[5], Kevin M. Ringelman[6], Chris K. Williams[4]

[1] Ducks Unlimited Inc., 1220 Eisenhower Place, Ann Arbor, MI 48108, USA, jcoluccy@ducks.org
[2] Delaware Department of Natural Resources and Environmental Control, Division of Fish & Wildlife, Dover, DE 19901, USA
[3] Oregon State University, 104 Nash Hall, Corvallis, OR 97331, USA
[4] Department of Entomology and Wildlife Ecology, University of Delaware, 250 Townsend Hall, Newark, DE 19716, USA
[5] Ducks Unlimited, Inc., 1101 SE Tech Center Drive, Vancouver, WA 98683, USA
[6] Department of Renewable Natural Resources, Louisiana State University AgCenter, 310 Renewable Natural Resources Building, Baton Rouge, LA 70803, USA

Bioenergetic models are the primary tools used to estimate habitat requirements for non-breeding waterfowl. Determining the carrying capacity of any landscape requires knowledge of both the types and amounts of different foods available and their energetic value. Despite the importance of food energy content in estimating carrying capacity, true metabolizable energy (TME) values are currently only available for 5 agricultural seeds, 5 acorns, 15 species of animals, the parts of 6 plants, and the seeds of 16 moist soil plants known to be consumed by waterfowl. These TME values are often based on a single study, represent a small fraction of the foods consumed by waterfowl, are skewed towards a few species of waterfowl, and largely represent foods available in a limited number of geographies. In the face of limited TME data, conservation planners have had to had to improvise: for example, by using a single TME value to represent a broad assortment of similar food types (e.g., seeds, invertebrates, etc.), or by estimating unknown TMEs using values from taxonomically-related foods. Many Joint Ventures have used a mean TME value of 2.5 kcal/g for moist-soil seeds. However, this approach could substantially over- or underestimate carrying capacity depending on the dominant seed species present within the planning area of interest. In addition, inherent uncertainty in TME values is rarely acknowledged or addressed when estimating carrying capacity. Even relatively small variation in TME values can produce highly variable estimates of carrying capacity for a given landscape. Finally, our current energy-based conservation planning approach addresses a single nutritional requirement for waterfowl while ignoring other nutritional needs (e.g., protein, mineral, etc.). The quality of foods can best be judged when information on nutritional composition is considered along with energy. In this paper, we will review the state of knowledge regarding TME values, ramifications for conservation planning, how uncertainty in TME values compares to uncertainty associated with other bioenergetics model inputs and recommendations for future research directions.

D.2.6: Krapu

Effects of Recent Trends in Agriculture on Waterfowl Nutrition and Energetics

Gary L. Krapu[1]*

[1] USGS Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, North Dakota 58401 USA, gkrapu@usgs.gov

Agriculture in North America over the past 15 years has become more intensive with the introduction and widespread planting of GMO crops and increased planting of row crops, the latter influenced by passage of the Renewable Fuel Standard (RFS) by Congress in 2005. Taken together, these actions have changed agricultural landscapes in ways that have reduced availability of key foods sought by many species of migrant and breeding waterfowl. Increased efficiency of corn harvest combined with soybean expansion has reduced capacity of geese to store fat on some major spring staging areas in mid-continent North America potentially affecting reproductive success. The diets of prairie-breeding ducks generally require a high level of protein during egg production and early brood-rearing with most of this nutrient need supplied by macro-invertebrates taken from shallow wetlands. Drawing upon insight gained from recent scientific studies and other sources, I discuss ways intensification of land use in the Prairie Pothole Region affects the distribution and abundance of foods required by breeding waterfowl and follow by considering implications to reproductive success. I conclude by briefly discussing possible measures beyond existing federal programs to enhance wetland habitat for waterfowl and other water birds breeding in prairie pothole landscapes.