SEED YIELD PREDICTION MODELS OF TWO COMMON MOIST-SOIL PLANT SPECIES IN EAST-CENTRAL TEXAS

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Extended Abstract: Moist-soil management techniques typically encourage germination and growth of native, annual-seed producing plant species that provide essential nutritive value (i.e., carbohydrates, amino acids, and proteins; Loesch and Kaminski 1989, Bowyer et al. 2005) to waterfowl during winter and migration.

Moist-soil managed wetlands can be primary foraging habitats and have the potential to elevate waterfowl carrying capacity during winter, even in spatially limited habitats (Anderson and Smith 1999, Kross 2006). By means of manipulating managed wetland seed bank structure (i.e., disking, mowing, and inundation) and hydrology (via regulated drawdown and inundation) managers can influence moist-soil plant production by creating germination conditions suitable for desirable moist-soil wetland plants (Fredrickson and Taylor 1982). Consequently, maximizing annual moist-soil plant seed production is typically a high management priority, whereby obtaining accurate estimates of seed production (i.e., seed yield) is desirable for waterfowl habitat evaluation (Laubhan and Fredrickson 1992, Gray et al. 1999\textsuperscript{b, c}, Sherfy and Kirkpatrick 1999).

Methods have been developed (i.e., phytomorphological and dot grid methods) to predict seed yield of desirable moist-soil plant species using regression modeling approaches (Laubhan and Fredrickson 1992, Gray et al. 1999\textsuperscript{b,c}, Sherfy and Kirkpatrick 1999, Anderson 2007)
Our research was designed to (1) estimate and (2) compare seed production estimates developed using phytomorphological and dot grid methods on barnyard grass (*Echinochloa crus-galli*) and wild millet (*Echinochloa walterii*), produced in moist-soil managed wetlands in east-central Texas.

Initial species specific linear regression analyses using phytomorphological characteristics showed barnyard grass, total plant height, total number of seed heads, and mean seed head mass predicted seed production well ($P < 0.001$, $R^2 = 0.52$) and for wild millet, total number of seed heads and mean seed head mass predicted seed production well ($P < 0.001$; $R^2 = 0.56$).

Initial species specific linear regression analyses using the dot grid method showed barnyard grass and wild millet production using obscured dots was ($P < 0.001$, $R^2 = 0.47$) and ($P < 0.001$, $R^2 = 0.74$) respectively.

Seed yield prediction models developed during this study were consistent with other research (Gray et al. 1999b,c, Laubhan and Fredrickson 1992, Sherfy and Kirkpatrick 1999, Anderson 2007), where both the phytomorphological and dot grid techniques satisfactorily explained much of the variation in seed biomass of focal plant species.

Literature Cited:


Developing an agent-based models to inform habitat planning for wintering waterfowl in California

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Extended Abstract: Winter Joint Ventures typically use a bioenergetics approach to estimate the amount of habitat needed to support a target population of wintering waterfowl (e.g., duck-use days). A limitation of this approach is that it provides only broad estimates of energy needs versus energy available for foraging waterfowl, and it does so at a fairly large spatial scale.

As part of a study examining the impact of water policy on waterfowl wintering in California, we developed an agent-based model to simulate how changes in the amount and distribution of wetland habitat affect the energetics and carrying capacity of waterbirds. Agent-based models (ABMs) provide a behaviorally based, bottom-up approach that models the actions of individual waterfowl “agents” foraging on a landscape.

We have developed an initial prototype of a spatially-explicit waterbird agent-based modeling program (SWAMP) to determine the carrying capacity and energy budgets of waterfowl foraging on moist-soil managed wetlands and flooded ricoland during winter in the Central Valley. We modeled 80,000 Northern Pintail-sized ducks as individual, spatially-embodied agents within the MASON ABM framework. These agents foraged on simulated 100 km² landscape with a refuge area in the center and specified number of foraging patches interspersed throughout the environment. Agents left the refuge at the start of each day and acquired food energy based upon the density of the remaining food resources on a patch as modeled by Holling’s disc equation. Intake capacity was limited by a combination of time constraints, gut capacity, and maximum lipid storage. Agents used energy in proportion to their individual activity budgets, supplementing shortfalls from lipid reserves or converting any excess calories into lipids; thus our model incorporates behavior and time budgets to determine daily energy requirements (whereas a bioenergetic approach assumes fixed DER).

SWAMP models the time-budget, foraging activities, and metabolic state of each bird individually throughout the season. While the rules governing patch selection and foraging behavior are user-defined (e.g. forage for 12 hours or until limited by gut capacity), variation in the habitat configuration and individual behavior (e.g. in patch selection and corresponding flight times) lead to interesting emergent
dynamics. For example, as the model runs, time budgets start to depend heavily on food availability, and under many scenarios and foraging rules, birds may not be able to forage long enough (or effectively enough) to sustain themselves.

SWAMP also allows users to directly examine the energy intake and lipid reserve of each individual bird and compare that to the amount of energy it can attain at a given point in the season. Importantly, our results show that birds can be in metabolic deficit—that is, beginning to starve to death—while there is still food on the landscape, because birds are limited by efficiency and foraging time. In fact, many simulations indicate that entire populations of birds can perish when there is still as much as 30 days worth of food on the landscape. The model output can predict the expected number of days a target population can be sustained depending on the amount and composition of available foraging habitats, whether flooded rice, managed moist-soil wetlands, or other landscape types (Fig. 1).

Our model shows that water allocation among various resource types can have a profound influence on sustaining target populations and so it is these types of biological outputs that we will next integrate with the water predictions from the Central Valley WEAP model. We are currently proceeding from proof-of-concept stage to Phase II, in which digital maps based on real landscapes and water-allocation plans will be integrated into the model.

**Figure 1.** Predicted time to energy deficit (total metabolic demand of the population exceeds caloric intake) for different proportions of forageable landscape and the proportion of that habitat that comprises moist-soil wetlands. These simulations show that the ability to sustain waterfowl populations is strongly influenced by both: (a) the proportion of the total landscape that comprises foraging habitat (each line in the figure, ranging from 20% to 35%); and (b) the proportion of that habitat that is comprised of moist-soil versus rice habitat; x-axis). SWAMP will allow managers to evaluate the influence of different wetland conservation policies and determine how changes in the amount and composition of habitat—as affected by water policy, climate change and land-use patterns—will impact the number of birds that can be sustained for a desired time period.
Cost-effective Moist-soil Management in the Sacramento Valley of California

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Extended Abstract: The incorporation of moist-soil management techniques has become an increasingly important component in the management of wintering areas for migrating waterfowl. In California, the availability of wetlands continues to decline, water is being spread thinner amongst an increasing urban population, new models suggest that the extent of wetlands necessary to sustain waterfowl populations could be 37-50% higher than previously predicted (Miller and Eadie 2006), and recent research suggests the Central Valley is producing less food than previously assumed (Naylor 2002). All of these factors highlight the need to maximize the benefits provided by wetlands to ensure that the energetic needs of wintering waterfowl are met. We addressed this issue by experimentally evaluating several moist-soil management strategies used by wetland managers in California.

Disking and summer irrigations have been identified as two of the most effective management practices for increasing moist-soil seed production (Naylor 2002). Our evaluation focused on the influence of irrigation schedules on moist-soil seed production and the costs associated with those irrigations. We examined the effects of timing and duration of summer irrigations on moist-soil seed production using large scale (1.5 acre) replicated plots. We contrasted two sets of treatments focusing on the duration (7, 14 and 28 days) and frequency (1, 2 or 3) of summer irrigations (Figure 1). Response variables included: 1) vegetative structure and species composition, 2) moist-soil seed production, 3) water management and mosquito abatement costs, and 4) the cost-effectiveness of these practices.

Several key results emerged from our analyses: (1) An irrigation early in the growing season (approximately 6 weeks after drawdown) was extremely important to aid in the control of undesirable vegetation. (2) Plant height was driven primarily by duration of irrigation rather than frequency of irrigation when 35 days are provided between irrigations and plots have been irrigated 6 weeks after drawdown. (3) No
more than 2 irrigations were needed to maximize seed yield of barnyard grass (Figure 2). (4) The capabilities of water delivery systems can significantly influence costs associated with mosquito abatement.

(5) Finally, we found that the most cost-effective strategy for irrigating barnyardgrass was 2 irrigations of 7 days (Figure 3). These results should help managers of California’s critically important wetlands maximize the production of desirable food plants for waterfowl, while minimizing water use and reducing the potential financial costs of mosquito control.

Figure 1. Irrigation treatments on 21 experimental plots. Treatments were randomly assigned to the 1.5 acre plots (7 treatments with 3 replicates per treatment), each with independent water control. The first number of each treatment value indicates the number of irrigations provided, and the second indicates the duration of that irrigation (e.g. “2x14” refers to a treatment with 2 irrigations lasting 14 days).

Figure 2. Barnyardgrass seed yield by treatment and year. Seed yield estimates were taken in late-September and early-October, immediately prior to fall flood-up.

Figure 3. Total cost per 100 pounds hulled barnyardgrass seed by treatment for 2007 and 2008 field seasons under slow flood scenario (takes greater than 3 days for water to cover unit). Costs include those related to summer water use and mosquito abatement. All costs assume $20 per acre-ft for water, and that mosquito abatement thresholds were met under all treatments.

Literature Cited:


First Steps in Wetland Management ARM: Developing a Decision-Support Tool

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Extended Abstract: We developed a decision-support tool that allows managers to document management decisions and outcomes in a standardized format. This tool enables managers to more efficiently collect and use information when making decisions and offers the possibility of managers learning from the decisions of others. This will be the first step in a longer term process of shifting the culture of wetland management to more actively use information when making decisions, explicitly address management assumptions and uncertainties, and engage in an iterative, shared learning process maintained through wetland reviews. This shift in wetland management culture will lead to an improved understanding of wetland systems and lead to more effective and efficient wetland management.

Due to the scarcity of wetland habitat, rising management costs, and growing demands for water, managers must consider many tradeoffs (e.g., costs vs. ecological benefits, resource benefits vs. public use, and water for in-stream communities vs. water for wetland/floodplain communities). For nearly a decade, wetland reviews in Missouri have provided a format to involve wetland managers and an interdisciplinary team in developing an adaptive approach to address these trade-offs and more efficiently and effectively manage wetland resources. The wetland review process focused on developing objectives, models, and management alternatives. This process successfully improved managers’ abilities to set objectives and understand the relationship between management actions and system processes. However, wetland review participants achieved limited success in integrating ARM into their everyday management decisions and actions, and as a consequence we have missed learning opportunities that would improve management and our understanding of wetland systems. The decision-support tool will enable managers to collect, archive, analyze, and use information to make repeated decisions about water management, disturbance regimes, and vegetation management. Collecting information in a standardized fashion will then allow us to begin addressing management uncertainties.

We have developed the initial components of a decision-support tool to aide managers in collecting and analyzing information in a similar fashion. We will add geo-spatial components and develop an interface between the decision-support tool and the
True-met model (Dugger et al. 2009). Managers identified improved elevation information as a necessary ingredient to improve water management decisions. Our goal is to integrate elevation data into the decision-support tool such that it allows managers to evaluate the effects of their decisions and how they relate to resource availability at a local scale. Based upon pool elevations we can use GIS to estimate flooded acres within a range of shallow water depths (0-6 inches, 6-12 inches, 12-18 inches, and >18 inches, Figure 1, Nelson 2008).

Additionally, we have implemented a vegetation monitoring process to estimate moist soil production in a manner that is accurate and yet not overly time consuming for managers.

Reaching agreement about information needs and implementing the use of a decision-support tool and the True-met model will be the first steps in changing wetland management culture. These steps will raise Department comfort in acknowledging what we do not know, increase participation in a shared learning process, and lead to the use of management to improve our understanding and effectiveness at restoring wetland systems. La Peyre et al. (2001) note that tracking management actions and outcomes are one of the keys to implementing adaptive management frameworks. At present, most managers record information about water and vegetation management, but not in a standardized or assessable format to help evaluate management outcomes or address management uncertainties. Incorporation of information from past management decisions along with information about elevation and other abiotic factors will enable managers to learn from past water management activities and to make more efficient and cost-effective water management decisions in the future. Using standardized data collection methods, in conjunction with the True-Met Model and geospatial data, will facilitate addressing uncertainties at multiple scales. It will lead to improved information transfer, smoother staff transitions, more accountability, and ultimately more effective wetland and riverine/floodplain system restoration.

**Literature Cited:**


Body Composition of Common Eider (Somateria mollissima dresseri) Changes During Winter: a Validation of the Deuterium Dilution Method with Ecological Implications

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Extended Abstract: Thousands of sea ducks migrate to and from southern New-England (SNE) during winter. Common eider (Somateria mollissima dresseri), hereafter eider, are one of the most abundant and heavily harvested sea ducks wintering in the Northeastern United States (Raftovich et al. 2011). Recently, the near-shore and offshore waters of SNE have been considered for potential offshore wind-power development. Anthropogenic disturbances introduced into habitat used by wintering eider have the potential to negatively impact their body condition, migration, and reproductive success.

Many factors affect the body composition of wintering waterfowl, including migration, food availability, habitat quality and weather conditions on the wintering grounds. The ability of wintering waterfowl to maintain protein and energy stores may impact their breeding performance (Heitmeyer and Frederickson 1981, Kaminski and Gluesing 1986). The introduction of anthropogenic disturbances in the form of offshore wind power development has the potential to displace birds from preferred habitats (Peterson et al. 2006) and increase daily commuting distances (Masden et al. 2009) which in turn could negatively impact the body composition of wintering sea ducks.

We validated a non-lethal, deuterium dilution method for accurately measuring body composition of wintering eider. This method was used successfully for Barnacle Geese (Eichhorn and Visser, 2008) as well as for various songbirds (Karasov and Pinshow 1998, McWilliams and Whitman 2012) but has not yet been validated for any species of duck.

During winter 2011/2012, we captured eider using floating mist nets. We injected heavy water into 17 adult eider spanning a wide range of body weights (ca. 1600 - 2300 g), and then 90 min later blood samples were drawn. Birds were euthanized and stored frozen until carcass analysis. Total body water, protein and fat were directly measured using standard analysis procedures. Total body water was
also estimated from plasma concentrations of deuterium measured using an isotope ratio mass spectrophotometer. We built predictive models for estimating lean and fat mass using a subset of birds (the calibration birds) and then used the models to predict lean and fat mass in another subset of birds that were not used to develop the predictive models (the validation birds) so that we quantified the accuracy and precision of our estimates. We then used these models to estimate body composition of wintering adult eider in SNE that were collected at three intervals (ca. 30 at each interval) during winter 2011/2012.

Patterns of body composition change in free-living ducks during winter provide important information for conservation and management of this resource. Anthropogenic disturbances such as shoreline development and offshore wind power facilities may reduce access to resources and thus protein and energy reserves of wintering seaducks. Body composition of wintering seaducks may be related to disease susceptibility and help to explain the timing and virulence of the newly described orthomyxovirus (Wellfleet Bay Virus) that has been linked to the recent deaths of thousands of eider in SNE.

**Literature Cited:**


Using Satellite Telemetry to Evaluate the Effectiveness of the Waterfowl Breeding Population and Habitat Survey for Counting Lesser and Greater Scaup in North America

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Extended Abstract: The U.S. Fish and Wildlife Service (USFWS), Canadian Wildlife Service, and numerous cooperators conduct the Waterfowl Breeding Population and Habitat Survey (WBPHS) annually during May and June to determine abundance and trends for waterfowl populations and habitat availability throughout North America. During the WBPHS, numbers of waterfowl and ponds are counted from fixed-wing aircraft and helicopters along strata-specific survey transects located within the traditional and eastern survey areas. Annual variation in migration chronology, potential for differential migration between sexes, and the tendency of scaup to pair late during migration (April – May) may introduce bias into breeding population estimates for scaup (combined Lesser Scaup; Aythya affinis: LESC, and Greater Scaup; Aythya marila; GRSC, populations; Afton and Anderson 2001). Further, annual timing of the WBPHS is based on mallard migration and settling patterns and, thus may not effectively count scaup (Smith 1995). The last comprehensive review of estimation procedures was completed in 1995, and USFWS recently initiated another review of operational and analytical procedures in 2010. Thus, additional independent evaluations of the effectiveness of the WBPHS are timely and information that helps refine breeding population estimates may be useful to managers. We implanted satellite transmitters in LESC on southern spring stopover areas south of the WPBHS area in the Mississippi (Pool 19 of the Mississippi River) and Atlantic Flyways (Lake Erie) and GRSC on wintering areas in the Atlantic Flyway (Lake Ontario). We monitored movements of satellite
transmitter-marked individuals to increase understanding of their spring migration chronology and evaluate effectiveness of the WBPHS for counting scaup. Our objectives were to track migrations of marked scaup into and through the WBPHS traditional and eastern survey areas to determine: 1) proportions located within WBPHS strata when aerial surveys were conducted; 2) proportions located within multiple WBPHS strata and available to be sampled on > 1 aerial survey (i.e., assess potential for double-counting); 3) proportions settling in inferred breeding sites within WBPHS strata when surveys were conducted there and 4) proportions settling in inferred breeding sites outside WBPHS strata. Nearly all lesser scaup migrating from Pool 19 during the WBPHS (May – June) traveled through the Traditional Survey Area. Lesser scaup migrating from Lake Erie used both the Traditional and Eastern Survey Areas as migration corridors. Forty-one percent (16 of 39) and 22% (10 of 46) lesser scaup from Lake Erie and Pool 19 (respectively), did not settle to breed within an area counted during the WBPHS (Fig. 1). The majority of lesser scaup breeding in Quebec did not settle into a surveyed area of the WBPHS, suggesting that numbers of these ducks may be under-represented. Analyses are ongoing and estimates of proportions of the scaup population surveyed by the WBPHS will be instrumental in determining the accuracy of scaup breeding population estimates which are used in setting of harvest regulations.

Figure 1. Inferred breeding areas of lesser scaup marked at Pool 19 and Lake Erie, 2005 – 2010.

Literature Cited:


Extended Abstract: Wear and potential loss of bands are important concerns for waterfowl managers as they assess population vital rates derived from band recovery data. For long-lived species such as diving ducks, these effects may be substantial enough to result in meaningful overestimates of mortality and subsequent underestimates of survival rates (Seguin and Cooke 1983, Coluccy et al. 2002). Aluminum leg bands applied to diving ducks experience heavy wear that often requires etching to read the numbers on recovered aluminum bands (D. Bystrak, USGS Bird Banding Lab [BBL], pers. comm., Haramis et al. 1982). Currently, the BBL recommends, but does not require, the use of hard metal bands for diving ducks due to their greater resistance to salt water corrosion. Consequently, few banders have used hard metal bands, likely due to the greater handling time they require, or they were unaware of problems with aluminum bands when applied to diving ducks. Our objectives herein were:

1) Investigate the effects of band material on wear and legibility of inscription information on bands placed on lesser scaup (LESC; Aythya affinis) and redheads (REDH; A. Americana) and, 2) Estimate relative recovery rates for singly and doubly banded LESC and REDH.

We asked banders in Alberta (AB), Saskatchewan (SK), Manitoba (MB), North Dakota (ND), South Dakota (SD; REDH) and at Pool 19 on the Mississippi River (LESC) to cooperate in the study. We double banded LESC and REDH with a size 6 incoloy and a size 6 aluminum band on each leg, respectively. Suffixes of paired bands either matched completely or at least the last 3 digits. We banded every fourth bird of each species using a single size 6 aluminum band; however, we continued to use single bands if supplies of double bands were exhausted. We then contacted hunters who harvested double-banded birds that had survived ≥ 2 hunting seasons and asked them if they would cooperate in the study by sending us their bands for wear assessment.

We weighed a random selection of new bands to determine their mass (g) for comparison to recoveries of paired bands. Upon receipt of bands from hunters, we then weighted bands and separately scored wear on band suffix and prefix using a scale from 1 to 9, and on band contact information from 1 to 10.
A total of 3,393 and 2,801 LESC were double and single-banded, respectively, at Pool 19 during spring of 2009. A total of 1,429 and 2,139 REDH were double and single-banded, respectively, by permit holders participating in the study across AB, MB, ND SD and SK during preseason banding operations in 2009 and 2010.

A total of 151 and 119 LESC have been recovered that were double and single-banded, respectively, at Pool 19. Additionally, 133 and 124 REDH that were double and single-banded, respectively, by cooperating permit holders have been recovered.

Thus far, we have assessed wear on indirect recoveries of paired bands from 30 LESC and 13 REDH. We found that 15.8% and 36.4% of paired aluminum LESC bands that had survived 2 and 3 hunting seasons, respectively, had contact information that was completely illegible. Wear on contact information for bands placed on REDH appears to be slightly delayed as compared to LESC where 70% of paired aluminum REDH bands that survived 2 hunting seasons still had all legible contact information, but were very faded. However, the 2 of 3 REDH bands that survived 3 hunting seasons had contact information that was partially readable. Paired aluminum bands for both species combined lost 8.2% (95% CL = 6.2% - 10.2%) of their mass after 2 hunting seasons survived and 15.7% (95% CL = 13% - 18.5%) of their mass after 3 hunting seasons survived. All paired incoloy bands from LESC and REDH showed no signs of wear on prefix, suffix, or contact information or loss of mass.

Direct recovery rates (found dead or shot) for double-banded REDH (6.37%) were approximately twice as high as those for single-banded REDH (3.04%). However, direct recovery rates for double (1.71%) and single-banded (1.65%) LESC were nearly identical.

Wear varied over time for aluminum bands, but was often extreme over a relatively short time period (< 3 years). Although it is too early in our study to determine whether band loss will occur, we believe that illegibility of contact information and band numbers will create heterogeneity in reporting rates throughout the time frame that a band could be recovered. We suggest that the BBL consider requiring LESC and REDH to be banded with hard metal bands in the future.

**Literature Cited:**


A Watershed-based Aerial Survey to Estimate Wintering Duck Abundance

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Extended Abstract: Winter waterfowl surveys have been conducted across much of the United States since 1935. Many different survey techniques have been used, but aerial waterfowl surveys can quickly cover areas difficult to access by ground. However, areas surveyed are often only those deemed important to waterfowl by biologists. The reliance on professional judgment in survey design rather than on statistical probability to establish representative samples makes comparisons of estimates among years and regions difficult. In response to these challenges, a stratified random sampling design using fixed-width strips was developed for aerial surveys of mallards in the Mississippi Alluvial Valley (MAV; Reinecke et al. 1992). Surveys conducted using stratified random sampling have the advantages of extensive coverage (i.e., all areas within the study region have the potential to be included in the survey); increased accuracy by counting on fixed strips rather than traditional “cruise” surveys only counting waterfowl on large concentration areas; and, the ability to calculate the sampling error of estimates.

Following the success of the implementation of the Reinecke et al. (1992) protocol and a revised protocol (Pearse. 2007) in Mississippi, the Arkansas Game and Fish Commission (AGFC) adopted the Reinecke et al. (1992) sampling design for the Arkansas portion of the MAV and, beginning in November of 2009, conducted four waterfowl surveys each winter. However, these counts had relatively high variances due to the clumped distribution of birds and the ephemeral nature of waterfowl habitats. In addition, habitat distribution likely has changed in the nearly two decades since the original protocol was developed. With the goal of increasing precision of estimates of wintering ducks in the Arkansas portion of the MAV under contemporary conditions, we proposed reddefining the strata boundaries. Ideally, in a stratified random sample, samples vary among strata but samples within each stratum are homogenous. The original 5 strata boundaries were based on expert opinion given the best information available at the time. Because waterfowl are closely associated with surface water availability and surface water availability is tied to watersheds, we developed an alternative design of eleven strata based on watershed boundaries.
To evaluate the performance of this new design we compared three sampling designs: 1) simple random, 2) expert opinion based strata (original design; Figure 1A), and 3) watershed-based strata (new design; Figure 1B). Data used in the comparison were collected during winter 2011-2012. Using these data, we calculated the standard error of the estimated number of mallards and total ducks for each of the four survey periods and each of the three sampling designs. This was accomplished through bootstrapping; the surveyed transects were resampled 10,000 times each under each of the three sampling designs.

![A] Expert-based ![B] Watershed-based

Figure 1. Stratified sampling designs for aerial waterfowl surveys in the Arkansas portion of the Mississippi Alluvial Valley overlain on kernel density estimate of all ducks during the 2012 midwinter survey.

The SE for all ducks was lower under the new watershed-based stratified random sample for all four survey periods. For mallards, in two survey periods the expert-based design had the lowest SE and in two surveys the watershed-based design had the lowest SE (Table 1). Future sampling will further elucidate patterns of precision by sampling design.

<table>
<thead>
<tr>
<th>Survey</th>
<th>Design</th>
<th>Mallards</th>
<th>All ducks</th>
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<tbody>
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<td>Nov.</td>
<td>SR</td>
<td>141 (24)</td>
<td>614 (72)</td>
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<tr>
<td></td>
<td>EX</td>
<td>145 (23)</td>
<td>671 (72)</td>
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<tr>
<td></td>
<td>WS</td>
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<td>671 (67)</td>
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<td>Dec.</td>
<td>SR</td>
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<td>2,037 (164)</td>
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<tr>
<td></td>
<td>WS</td>
<td>1,510 (116)</td>
<td>2,191 (148)</td>
</tr>
<tr>
<td>MWS</td>
<td>SR</td>
<td>907 (117)</td>
<td>1,378 (162)</td>
</tr>
<tr>
<td></td>
<td>EX</td>
<td>834 (112)</td>
<td>1,283 (154)</td>
</tr>
<tr>
<td></td>
<td>WS</td>
<td>825 (83)</td>
<td>1,300 (121)</td>
</tr>
<tr>
<td>Jan.</td>
<td>SR</td>
<td>735 (87)</td>
<td>1,238 (122)</td>
</tr>
<tr>
<td></td>
<td>EX</td>
<td>903 (84)</td>
<td>1,438 (127)</td>
</tr>
<tr>
<td></td>
<td>WS</td>
<td>904 (91)</td>
<td>1,457 (118)</td>
</tr>
</tbody>
</table>

In addition to having a lower SE in six out eight comparisons, the watershed-based sampling design allows for a finer resolution of waterfowl abundance estimation by being able to precisely estimate abundance in eleven biologically meaningful strata. Watersheds are delineated across the U.S. at multiple scales, enabling this sampling design to be readily adapted by other waterfowl researchers. Strata-specific population estimates can also be used to evaluate the impacts of landuse characteristics and hydrologic processes on waterfowl abundance at the watershed level.

Literature Cited:
Pearse, A.T. 2007. Design, evaluation, and applications of an aerial survey to estimate abundance of wintering waterfowl in Mississippi. Dissertation, Mississippi State University, Mississippi State, USA.

Random Placement Models Predict Duck Species-Area Relationships

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The classic species-area relationship (SAR) is ubiquitous (Preston 1962), having been described for taxa ranging from bacteria to many vertebrates, and is considered a fundamental law in community ecology. Explanations for the processes underlying SARs have focused on separating putative biological mechanisms that correlate with area, such as habitat heterogeneity or dispersal limitation, from sampling effects caused by habitats with more individuals containing more species than habitats with fewer individuals. But, there is no consensus for why SARs emerge. The number of species occupying a habitat patch may be influenced by patch characteristics other than its size, such as habitat diversity or isolation. Species richness (SR) within patches may also be related to species-specific niche breadths, direct interactions among species such as competition, or by combinations of patch and species-related attributes.

Breeding duck communities in the northern hemisphere have been the subject of numerous attempts to assess the role of interactions among species, especially competition, in determining habitat use and community structure (Elmberg et al. 1997, Nudds 1992). It has often been suggested that duck species of a similar body size should avoid each other, as should species with similar bill morphology. There remains much debate, however, about the importance of interspecific competition in structuring duck communities (Gurd 2008).

Random placement models (i.e., null models) provide a powerful way to distinguish between the mechanisms behind SARs. Use of random placement models to date has been limited, largely owing to the need for complete community-wide census information. Here, we used null models to test if random placement processes can explain variation in duck species richness between wetlands. Alternatively, interactions within or between species may be important in determining SARs. For ducks, observed SARs may differ from those expected at random because of dispersal limitation, species sorting among different habitats, or conspecific aggregation, which would produce lower SR on a given wetland than expected. On the other hand, social avoidance among conspecifics (e.g., due to territoriality) or heterospecific attraction would produce higher SR than expected.

We counted pairs of seven species of dabbling ducks and seven species of diving ducks on the 385-ha St. Denis National Wildlife Area, Saskatchewan, Canada, during 2007-2009. Anticipating guild- and year-specific differences, we used generalized linear models to derive SARs for all ducks combined and for two guilds (dabblers, divers) for each year. We modeled the observed relationship between pond area and species richness using all possible combinations of logged and unlogged pond area and SR, resulting in four GLMs for each guild-year combination. We used $R^2$ values and diagnostic plots to discriminate among models and chose the...
best-approximating model to explore the effect of year and the possible year-area interaction in an information theoretic framework and to test null models of species richness. Then, for each guild-year combination, we used the empirically-derived SARs from the previous step to conduct random placement modeling to test whether observed SARs differed from those expected by chance. We used an individual-based random placement model (Guadagnin et al. 2008) suitable for waterfowl which distributed duck pairs randomly between wetlands, while constraining total pair abundance on each wetland to its observed value.

For each guild-year combination, the SR~log(Area) model explained the most amount of variation in SR (>60% of the variation in a given year for all ducks). Hence, that model was used to explore the effect of year, and a possible year-area interaction, on duck species richness. That analysis resulted in a model incorporating a year effect, but no year-area interaction. Most importantly, random-placement models revealed no difference between the null and observed slope and intercept from the SR~log(Area) model (Figure 1) for each guild-year combination. Thus, our null models accurately reproduced SARs in different years for all species, and for different guilds, of ducks.

Our study, conducted in the wetland and waterfowl-rich prairies, provides the first demonstration that SARs for waterfowl can be predicted by random placement models. Results suggest that, at a local scale, duck pairs act in an independent manner when selecting breeding sites, and that interactions within or between species are of little importance. This result implies that interspecific competition may not have a detectable effect on species richness, although competition among ducks for food or other resources could influence breeding success, or be more pronounced during periods of resource limitation (e.g., drought).

Figure 1. Observed (circles, solid line) and null (squares, dashed line) species-area curve for all ducks in 2007. Plots for all ducks, dabbers and divers, in all years, are similar.

Literature Cited


