Final Report

Monitoring the Effects of Climate Change on Waterfowl Abundance in the Mississippi Alluvial Valley: Optimizing Sampling Efficacy and Efficiency

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EXECUTIVE SUMMARY: Winter waterfowl surveys have been conducted across much of the United States since 1935. Aerial surveys conducted using stratified random sampling have the advantages of extensive coverage, increased accuracy, and the ability to calculate the variance of estimates. A statistically robust stratified random sampling design for aerial surveys of mallards in the Mississippi Alluvial Valley (MAV) was developed in the late 1980s and early 1990s; surveys based on this sampling design have been conducted by the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) in the Mississippi MAV since 2005 and by the Arkansas Game and Fish Commission (AGFC) in the Arkansas MAV since 2009. However, changes in land use since the survey was designed may have made modifications of the original design necessary. We refined strata boundaries in Arkansas using watersheds as a guide in determining strata boundaries and surveyed the Arkansas MAV four times during winter 2011-2012 using this modified design. To evaluate the performance of this new design we compared three sampling designs: 1) simple random, 2) expert opinion-based strata (original design), and 3) watershed-based strata (new design). For each of the four survey periods and each of the three sampling designs, we calculated %CV of the estimated number of mallards and total ducks by bootstrapping the surveyed transects in each survey period 10,000 times each under each of the three sampling designs. The %CV for all ducks and mallards was lower under the new watershed-based stratified random sample than under either the simple random or expert-based designs during all four survey periods. The watershed-based sampling design also estimates waterfowl abundance at a finer resolution using biologically meaningful strata.

We also wanted to improve the accuracy of population estimates by developing a protocol to account for biases related to observer and habitat effects on detection. We chose the double-observer method because its relative low cost and ease of implementation made this method the

most feasible for agency staff. The same AGFC personal that have conducted all waterfowl surveys in the Arkansas MAV since 2009 conducted a double-observer survey in February of 2012. These data were used to develop observer and habitat (closed or open canopy)-specific detection probabilities for the Arkansas MAV surveys. Detection in closed canopy habitats (obs1 =0.36, obs2=0.86) was lower than detection in open canopy habitats (obs1 =0.88, obs2=0.99). Adjusting estimates for detection increased estimates of mallard abundance by a mean of 27% (SE = 7%) and total ducks by 24% (SE = 7%). The large variability in the magnitude (range 7 – 71% for all ducks) of the effect of adjustment appeared to have been due to variation in the percentage of ducks observed in closed canopy habitat (range 3 to 32%). Because detection was lower in closed canopy habitat, counts in closed canopy habitat had more impact on the population estimate than the same size count in open canopy habitat.

Implementation of robust methods such as stratified random sampling can be time consuming for agency staff. Random transects are drawn for each survey and the process of determining randomly selected transects for each strata and each survey can take days of agency time. This time requirement may be a limiting factor for implementation of these methods, potentially threatening the conclusions and inferences from coordinated survey efforts, and the long-term viability of this monitoring program. However, recent development by the Arkansas Cooperative Fish and Wildlife Research Unit of a user-friendly, easily modifiable graphical user interface (GUI) that rapidly selects random transects by strata and generates files for input into computer programs and GPS units has greatly reduced the time staff spent preparing for the surveys. Furthermore, application of this protocol to waterfowl monitoring in adjacent states (e.g., Louisiana) has heretofore been limited, at least in part, by the support capacity for analysis.

This tool helps to eliminate that constraint and provide incentives for agencies to use a more robust protocol. Even with the improved system for survey preparation, there was an additional need to further develop the GUI to quickly process and analyze the collected survey data. Calculations of variance in stratified random sampling can be complex; implementation of these calculations in the GUI reduce the amount of time and statistical expertise required by users. The inclusion of a kernel density estimator in the GUI also avoids the need for access to a GIS with analysis capabilities. The increased speed of analysis allows for faster dissemination of survey data, which may allow managers to provide timely information to the public and to adjust habitat management in response to the most recent information on duck distributions. In addition, the GUI allows for easier expansion of surveys into new regions by the inclusion of an option for the user to upload new files from which to select random transects. Expansion of these surveys into neighboring regions would increase the capacity for distinguishing distribution shifts from population changes.

Given the potential for changes to wildlife distribution and abundance under various climate change scenarios, there is a need to better understand the effects of climate on waterfowl distributions. We evaluated the cumulative winter severity index (WSI) developed by Schummer et al. (2010) to predict waterfowl abundance using data collected in Arkansas during winters 2009-2011. For dabbling ducks other than mallards, no model performed better than the null and only models containing year had strong support for diving ducks. The best model for predicting mallard abundance contained the WSI for the Arkansas MAV (w_i = 0.88). Mallards occurred in higher numbers when the weather conditions within the MAV were more severe. Number of all ducks combined also had a positive relationship with the WSI in the MAV but evidence for this relationship was not as strong (w_i = 0.48) and was likely driven by the inclusion of mallards. For mallards, there were a predicted 0.5 (95% CI 0.0 to 1.1) million mallards present within the Arkansas MAV with the mildest WSI and a predicted 2.7 (95% CI 2.1 to 3.3) million mallards during the most severe WSI. Further evaluation of the Schummer et al. (2010) model and additional climate variables will help to clarify the relationships between waterfowl distribution and climate.

Introduction

Given the potential for changes to wildlife distribution and abundance under various climate change scenarios, there is a need to effectively and efficiently collect indices of these metrics for wildlife populations. Wintering waterfowl, in particular, provide an excellent bellwether for the effects of climate change as changes in their abundance and distribution reflect both a direct response to climatic variables (e.g., temperature and precipitation) and an indirect response to climate change mediated through habitat alterations. The mallard (*Anas platyrhynchos*) is the most abundant (and arguably most popular for sport) duck in North America, and their numbers are often used as a surrogate to gauge the health of other waterfowl populations and in making management decisions (U. S. Dep. Int. and Envrion. Canada 1986, Drilling et al. 2002). The Mississippi Alluvial Valley (MAV) is an area of continental significance for migrating and wintering waterfowl under the auspices of the North American Waterfowl Management Plan (NAWMP 2012), and the single most important region for wintering mallards (Reinecke et al. 1989). Therefore, MAV-wide monitoring of mallards and other duck species has the potential to provide some of the earliest indications of climate change impacts on wildlife.

Winter waterfowl surveys have been conducted across much of the United States since 1935. Many different counting techniques have been used, but aerial waterfowl surveys have the advantages of 1) the ability to survey areas difficult to access by ground, 2) the ability to rapidly survey large regions, and 3) the elimination of double counting by traveling faster than waterfowl can fly. However, sampling designs have generally relied on professional judgment of areas believed to be important to waterfowl rather than statistical probability to establish "representative" samples, making inferences and comparisons of estimates within and among years and geographic regions difficult. In response to these challenges, Reinecke et al. (1992) developed a statistically-robust, stratified random sampling design for aerial surveys of mallards in the MAV during the late 1980s and early 1990s. Surveys in the MAV conducted using stratified random sampling of aerial fixed-width strips can be used to estimate population size and precision of estimates for large regions; these estimates can be compared among regions and over time. Using a stratified design rather than a simple random design allows the researchers to allocate more effort to areas with expected higher numbers of ducks and larger variances; whereas, areas with low numbers of ducks and little variance are sampled at a lower rate. Beginning in 2005, the Mississippi Department of Wildlife, Fisheries and Parks, in cooperation with Mississippi State University, has annually conducted aerial surveys following a modification of this protocol and estimated abundance and distribution of mallards four times each winter (Pearse et al. 2008a, 2008b). Based on that success, the Arkansas Game and Fish Commission (AGFC) adopted the Reinecke et al. (1992) protocol for its aerial surveys of the Arkansas portion of the MAV and, beginning in November 2009, conducted four waterfowl surveys each winter.

However, these waterfowl surveys are complicated by the high degree of variability associated with the clumped distribution of birds and the often ephemeral nature of the habitats they use; precipitation and wetland conditions vary within and among years leading to highly dynamic usage of habitat by waterfowl (Reinecke et al. 1992). Additionally, not all birds present within the surveyed region are detected during aerial surveys and the proportion of birds not seen may vary by habitat type, group size, and observer (Smith et al. 1995, Pearse et al. 2008a). These challenges can result in population indices with high variances, making it difficult to detect changes in population size or distribution. Pearse et al. (2008a,b) refined the sampling design of Reinecke et al. (1992) and Smith et al. (1995) to better reflect the current landscape conditions in the MAV, including distribution of waterfowl and waterfowl habitat (e.g., established a high-density strata where new waterfowl habitat exists that was not present 20 years prior). This refinement has allowed for more efficient allocation of sampling effort and provides precise estimates of waterfowl abundance in the Mississippi MAV. Similar landscape changes have likely occurred across the MAV, particularly in Arkansas and Louisiana, since the original sampling design was developed, creating the need to reevaluate the current sampling design in the Arkansas MAV and revisit the original design in the Louisiana MAV.

In addition to redeveloping strata design, addressing the issue of incomplete detection, that is, waterfowl present in the surveyed transects but not detected by observers, may reduce variance and improve the accuracy of the population estimates. It is well established that bias may result from incomplete detection during aerial surveys (Caughley 1974, Caughley 1977). Smith et al. (1995) and Pearse et al. (2008a) recognized that surveying waterfowl in the MAV was complicated by differences in visibility due to habitat types, primarily forested wetlands versus croplands, and due to group sizes of ducks counted. Visibility Correction Factors (VCFs) were developed by Pearse et al. (2008a) to account for these biases but those VCFs were survey-specific because of variation in habitat and observer effects. Given limited funds and staff time, a simple and cost effective means of estimating detection is needed that can be used by agency staff to adjust population estimates. A double-observer approach (Nichols et al. 2000) is one potential cost-effective solution that has been used in waterfowl surveys (Koneff et al. 2008, Vrtiska and Powell 2011).

One draw-back of the implementation of robust methods such as stratified random sampling is the time required by agency staff to process files for input and the compile and analyze the collected data. New random transects are drawn for each survey and the process of determining randomly selected transects for each strata and each survey can take days of agency time. The transects selected must also be processed in order to be read into computer programs and GPS units. The time required of agency staff to implement these survey protocols may limit use of this survey method, potentially threatening the conclusions and inferences from coordinated survey efforts, and the long-term viability of this monitoring program. However, recent development by the Arkansas Cooperative Fish and Wildlife Research Unit of a user-friendly, easily modifiable graphical user interface (GUI) that rapidly selects random transects by strata and generates files for input into computer programs and GPS units has greatly reduced the time staff spent preparing for the surveys. Furthermore, application of this protocol to waterfowl monitoring in adjacent states (e.g., Louisiana) has heretofore been limited by the scientific support capacity for analysis. This tool helps to eliminate that constraint and provide incentives for agencies to use a more robust protocol. There is additional need to develop the GUI to quickly process and analyze the collected survey data. Calculations of variance in stratified random sampling can be complex; implementation of these calculations in the GUI would reduce the amount of time and statistical expertise required by users. Examples of these calculations include bootstrapping estimates of variance and the production of kernel density estimates. The development of an analysis component to the GUI will allow agency staff to determine duck abundance and distribution within surveyed regions shortly after observers tabulate the survey data. Faster dissemination of survey results will better inform managers of current waterfowl distributions, allow quicker dissemination of information to the public and may allow managers to better respond to waterfowl needs.

Waterfowl survey data collected in the MAV can be used to complement ongoing work to develop models of future duck distributions using weather severity thresholds and long-term changes in weather severity (Schummer et al. 2010). The data collected under a coordinated MAV waterfowl monitoring framework would be valuable for cross-validation of these model predictions. These data also would be useful in combination with ongoing efforts to model the impacts of precipitation, climate, and land use on the surface-water system within select MAV watersheds by providing an index of waterfowl population response to hydrologic variables presumed to be key drivers of waterfowl distribution and abundance.

Objectives:

1) Refine strata boundaries in Arkansas and expand surveys to other states in the MAV. Precisely (coefficient of variation [CV] ≤ 15%) estimate populations of wintering ducks (i.e., mallards, other dabbling ducks, diving ducks) during winter 2011-2012.
2) Assess the feasibility of developing a reliable and cost-effective method for estimating detection during waterfowl aerial surveys.
3) Develop a rapid method of estimating populations and using GIS for displaying waterfowl distribution and abundance from aerial survey data.
4) Evaluate the Schummer et al. (2010) model for predictive ability using the data collected in Arkansas during winters 2009-2011.

Study Area

The MAV is the floodplain of the lower Mississippi River, covering 10 million ha of primarily agricultural habitats. Portions of seven states lie within the boundaries of the MAV but four states (Arkansas (3.7 million ha), Louisiana (2.9 million ha), Mississippi (1.9 million ha), and Missouri (1.0 million ha)) comprise over 96% of the total area. Historically, the MAV was dominated by bottomland hardwood forest and flooded frequently during the spring and fall (Reinecke et al. 1989). Extensive clearing during the 19th and 20th centuries have transformed this region into an area dominated by agriculture; in addition, flood control projects have greatly altered natural hydrology (Galloway 1980). Despite these alterations, the MAV remains a continentally important region for migrating and wintering waterfowl, particularly mallards (Reinecke et al. 1989). Currently, flooded agricultural fields (primarily rice and soybeans) provide much of the foraging habitat for waterfowl in the region (Stafford et al. 2006). The mallard is the most abundant duck species in the MAV during winter. Other dabbling duck species common in the region during winter include, roughly in order of abundance, northern pintail (*Anas acuta*), northern shoveler (*A. clypeata*), gadwall (*A. strepera*), American green-winged teal (*A. crecca*), blue-winged teal (*A. discors*), American wigeon (*A. americana*), and wood duck (*Aix sponsa*) (L.W. Naylor, Arkansas Game and Fish Commission, personal communication). Diving ducks are much less abundant than dabbling ducks in the MAV and primarily use lakes, rivers, and aquaculture ponds rather than flooded agricultural fields. Common species of diving duck in the MAV during winter include bufflehead (*Bucephala albeola*), canvasback (*Aythya valisineria*), hooded merganser (*Lophodytes cucullatus*), ringnecked duck (*Aythya collaris*), and lesser scaup (*Aythya affinis*) (L.W. Naylor, Arkansas Game and Fish Commission, personal communication).

Methods

Refine strata boundaries in Arkansas and expand surveys to other states in the MAV. One of our main objectives was the reduction of %CV of the waterfowl surveys. With Luke Naylor (AGFC), we redesigned the Arkansas MAV strata based on cataloguing unit-level watershed boundaries (hydrologic unit code 8) in the region. The original five strata boundaries (Figure 1) were based on expert opinion given the best information available at the time (Reinecke et al. 1992); major rivers were also used as guides in determining strata boundaries. Because waterfowl are closely associated with surface water availability and surface water availability is likely to be similar within watersheds, we developed an alternative design of eleven strata based on watershed boundaries (Figure 2). We used this new strata design during the winter 2011-2012 seasons. We used a similar watershed-based method in determining new strata boundaries for Louisiana although the new watershed-based strata boundaries were similar to the original boundaries created by Reinecke et al. (1992) with the exception that the northern two strata in the old design were combined into one in the watershed-based design (Figure 3).

To evaluate the performance of this new design we compared three sampling designs: 1) simple random, 2) expert opinion-based strata (original design; Figure 1), and 3) watershed-based strata (new design; Figure 2). We used the data collected during winter 2011-2012 for the comparison. For each of the four survey periods and each of the three sampling designs, we calculated %CV of the estimated number of mallards and total ducks. We bootstrapped the surveyed transects in each survey period 10,000 times each under each of the three sampling designs. We set the total sampling effort (the total length of transects sampled) equal among the sampling designs. For the random sample, the strata within which the data were collected were resampled such that all areas within the Arkansas MAV had the same coverage (i.e. 8.3% coverage in all strata). For the expert-opinion-based design, each transect in the surveys was reassigned to one of the original strata. Because strata in the new design were generally nested within strata in the old design this process was generally straightforward but in the event that a transect crossed strata boundaries of the old design it was assigned to the transect in which it had the most length. The transects were then resampled using the same relative sampling effort among strata as in the expert design but setting the total sampling effort identical to that of the random design. For the watershed-based design we resampled the transects 10,000 times. For each sampling design and each survey we calculated the median %CV value out of the 10,000 bootstraps.

Detection Probabilities and Corrected Population Estimates. To assess the impact that missed birds have on estimated waterfowl numbers, we assisted the AGFC in designing a survey to estimate detection rates by observer and canopy cover. Detection rates in this case are the probability of observers recording a duck, given that it is: 1) present in the surveyed region, and 2) available for detection. These detection rates may overestimate true detection because they do not account for birds that are present but unavailable (e.g. ducks obscured by habitat such that they are not visible from the plane). Previous work has established the importance of observer to detection probabilities during aerial surveys (Koneff et al. 2008). In addition, we believed habitat could influence the ability of observers to detect ducks (Smith et al. 1995, Pearse 2008b).

Therefore, our goal was to develop a sampling protocol that allowed us to estimate detection rates by observer and habitat type.

We used a double-observer survey with on-the-fly-reconciliation to estimate detection (Koneff et al. 2008, Vrtiska and Powell 2011). An earlier attempt at double sampling using two separate planes raised issues of reconciling observations in habitat where ducks did not occur in clearly delineated groups. In addition, it was difficult for the pilots of the two separate planes to survey exactly the same 250-m strip of habitat. Also, birds may have moved during the lag time between the two planes passing over the same location. In the double-observer method, both observers were in the same plane simultaneously surveying the same habitat. These two observers were the same observers who had conducted all the surveys in the Arkansas MAV during the winter 2009 to 2011 surveys and who had been conducting aerial waterfowl surveys since 2005 and 2008. To the extent possible, survey methodologies were the same in this double-observer survey as during the regular winter surveys. At the start of each transect, one observer took on the role of the primary observer. The primary observer called out all ducks (mallards, divers, teal, and non-mallard dabblers) observed in the same manner as he would normally record them using the United States Fish and Wildlife Service (USFWS), aka Hodges, "Record" program. The primary observer called out the species or group, number observed, and habitat. The secondary observer then recorded the observations called out by the primary observer. In addition, the secondary observer recorded whether he also observed the group and recorded any additional ducks he detected that were not called out by the primary observer. The primary observer could not hear what the secondary observer was recording. Observers switched roles for each transect, so that they served as primary and secondary observers an equal number of times.

AGFC personal surveyed a subset of the Arkansas MAV that was representative of the overall habitat using one of the same planes used in the 2009 to 2011 winter surveys.

In addition to observer, other covariates could influence the detection of ducks. Although there are a variety of habitat types within the MAV, based on previous research, we believed that canopy cover was likely to have the strongest effect on detection (Smith et al. 1995, Pearse et al. 2008a). To account for other possible sources of heterogeneity in detection probabilities we also included species group (mallard, teal, other dabbling ducks, or diving ducks) and group size as covariates in the candidate model set (Table 1). We ran all models using the 'multinomPois' function in the 'unmarked' package (Fiske and Chandler 2011) within program R (R Core Team 2012). This function fits a multinomial-Poisson mixture model to data collected using double observer sampling and allows us to compare multiple possible sources of heterogeneity in detection probabilities. Models were ranked using AIC and the detection estimates from the top-ranked model were used to calculate bias-corrected population estimates for the Arkansas MAV. To determine the impact of using the bias-corrected population estimate, we calculated the correlation coefficient (r) value of the bias-correction population estimate relative to the uncorrected population estimates (or Population Index).

We used bootstrap resampling (Efron 1979) to estimate 95% confidence intervals, an accepted procedure for computing variance in complex surveys. The bootstrap uses multiple independent resamples from a sample to estimate properties of the population from which the sample was drawn (Efron and Tibshirani 1993). We resampled transects using the original and detection-adjusted counts 5,000 times; the lower and upper 95% confidence intervals of estimated population sizes were taken from the lowest 125th and highest 4,875th of the estimated population sizes.

Develop a rapid method of using GIS for displaying waterfowl distribution. We modified a previously created GUI in R that could quickly select random transects for surveys and also quickly analyze the collected data. The advantages of using a GUI are that: 1) no special statistical programming knowledge is required by users, and 2) the software involved is open-source, meaning that it can be easily installed on any system without requiring expensive software licenses. Estimates of variance in stratified random sampling can also be computational complex so use of this GUI reduces the amount of time and statistical expertise required by users. We added additional features to the GUI such as the ability to create kernel density estimates, a data check to locate errors in data input, the ability to estimate abundance and variance by species group (e.g., all ducks combined), the ability to correct numbers of ducks observed for detectability, and generated a shapfile of the transects when new random transects were selected. We also added the Louisiana strata design to the GUI and added an option for the user to upload new transect files for new survey designs.

Evaluate the Schummer et al. (2010) model. We developed models predicting the relationships between duck abundance in the Arkansas MAV and Winter Severity Index (WSI) (Schummer et al. 2010). We used the detection-corrected estimates of population of mallards, dabbling ducks other than mallards, diving ducks, and all ducks combined in the 12 surveys conducted between Nov 2009 and Jan 2012 as the response variable. Weather data were obtained from Historical Climate Network (Williams et al. 2006) weather stations across the MAV (Corning, Pocahontas, Newport, Brinkley, and Pine Bluff, Arkansas) and at weather stations at a latitude of ~38 to 39ºN (Kansas City and St. Louis Missouri and Louisville, Kentucky). We chose this latitude because it had previously been shown to influence wintering ducks in the MAV (Pearse 2007). We initially included ambient temperature, difference in ambient temperature between MAV and northern region, and difference in WSI between MAV and northern region. After examining the explanatory variables for correlation, only the difference between WSI in the MAV and northern region had a correlation below 0.7 with WSI in the MAV so only these two variables and month and year were included in the candidate set. We fit linear models in program R and compared them using Akaike's Information Criteria adjusted for small sample sizes (AIC_c ;Akaike 1973).

Results

Evaluate, design and conduct aerial surveys. The mean %CV for all ducks in the Arkansas MAV was lower during the four surveys conducted during winter 2011-2012 under the new strata design (14.0 %CV (SE 1.18)) than it had been under the eight surveys conducted under the old design (23.5 %CV (SE 3.42)) during winters 2009-2010 to 2010-2011. The mean %CV for mallards was also lower under the new design (17.4 %CV (SE 2.57)) during winter 2011-2012 than under the older design (26.3 %CV (SE 3.30); Figure 4) during winters 2009-2010 to 2010-2011. However, estimates of variance can vary among surveys for many reasons and sampling effort was slightly higher under the new design. Using the bootstrapping procedure to explicitly test the effect of sampling design, the %CV for all ducks and mallards was lower under the new watershed-based stratified random sample than under either the simple random or expert-opinion-based designs during all four survey periods (Table 2).

Due to constraints in the availability of personal and flight time, only one survey was conducted in Louisiana during the winter 2011-2012 during early January 2012. There were an estimated 372,990 (SE 33,449 95% CI 211,524 – 614,960) ducks in the Louisiana portion of the MAV. The most common duck species was the mallard with an estimated 139,998 (SE 3,980 95% CI 76,810 to 221,381) mallards in the region.

Detection Probabilities and Corrected Population Estimates. Arkansas Game and Fish personal surveyed 24 transects totaling 452 km in length using the double observer method on 21 February 2012. Observers recorded 166 duck groups (Table 3) of which 24 were in closed canopy habitat, primarily bottomland hardwood forest, and the remaining 142 were in open canopy habitat. The mean group size was 30.9 (SE 3.80) ducks with a mean group size of 35.0 (SE 4.34) ducks observed in open canopy habitat and a mean group size of 6.6 (SE 1.54) ducks observed in closed habitat. The variables observer and canopy cover had strong support (Table 4). Not surprisingly, detection in closed canopy habitat was lower than detection in open canopy habitat (0.86 and 0.36 in closed canopy vs. 0.99 and 0.88 in open canopy for observers 1 and 2, respectively; Table 5).

Adjustment using observer and habitat-specific detection probabilities increased estimates of mallard abundance by a mean of 27% (SE = 7%), other dabbling ducks by 23% (SE = 7%), diving ducks by 12% (SE = 1%), and total ducks by 24% (SE = 7%; Table 6). The degree of increase was related to the number of ducks observed in forested wetlands (closed canopy habitat) during the surveys. For mallards, there was a wide range in the percent of ducks observed in closed canopy habitat from a low of 3% in November of 2009 to a high of 32% in

December of 2010 (see Appendix A for additional habitat use information). For overall duck observations the results were similar, with a low of 3% of ducks observed in closed canopy habitat during the November 2009 survey to a high of 27% of all ducks observed in closed canopy habitat during December of 2010. Although there was substantial variation in the magnitude of the impact of the detection-adjustment among surveys, for mallards, other dabbling ducks, diving ducks, and all ducks combined, there was a high degree of overlap in the 95% confidence intervals around both the population index and the detection-adjusted population estimate for all surveys (Figures 5, 6, 7, and 8).

Develop a rapid method of using GIS for displaying waterfowl distribution. We created a GUI in R that could quickly select random transects for surveys and also quickly analyze collected data (Appendix B). The GUI includes the option of creating user-defined duck groups (e.g, all ducks combined) that can then be used for kernel density estimates and/or for estimating strata and MAV-level populations. The GUI also includes the option of adjusting observed ducks for observer and habitat (open or closed canopy)-level detection probabilities. The detection probabilities from the double observer trial in the Arkansas MAV are provided as default values but these values can be modified by the user. Along with estimates of population size, the GUI estimates SE of MAV-wide and strata-level population estimates and uses bootstrapping to estimate 95% confidence intervals around estimates. The analysis output also includes a summary of ducks observed by species and habitat type and a summary of ducks observed by species and transect.

Evaluate the Schummer et al. (2010) model. The best model for predicting mallards was the model containing the WSI for the MAV (w_i = 0.88; Table 6). Mallards occurred in higher numbers when the weather conditions within the MAV were more severe (Figure 9). All ducks combined also had a positive relationship with the WSI in the MAV but evidence for this relationship was not as strong (w_i = 0.48). For mallards, there were a predicted 0.5 (95% CI 0.0 to 1.1) million mallards present within the Arkansas MAV during the mildest WSI and a predicted 2.7 (95% CI 2.1 to 3.3) million mallards during the most severe WSI. For all ducks, there were a predicted 1.9 (95% CI 0.9 to 2.8) million ducks under the mildest observed WSI and a predicted 3.8 (95% CI 2.9 to 4.7) million ducks predicted under most severe observed WSI. For dabbling ducks other than mallards, no model performed better than the null and only models containing year had strong support for diving ducks.

Discussion

We redesigned survey strata in the Arkansas MAV based on watershed boundaries. In addition to having a lower %CV for both mallards and all ducks combined during all four surveys, 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. The estimation of strata-specific populations can also be used to evaluate the impacts of land use characteristics and hydrologic processes on waterfowl abundance at the watershed level.

Incomplete detection in aerial surveys can result from factors that obstruct the view of individuals (e.g., Smith et al. 1995) and from differences in observer's ability to detect individuals (e.g., Koneff et al. 2008). Advantages of the double observer method we used to estimate detection probabilities are that it does not require coordination with ground crews and avoids the issue of assuming that ground crews have perfect detection. Other studies have used decoys to estimate detection (e.g., Pearse et al. 2008). However, observers may develop search images for waterfowl based on cues of duck presence such as rings or ripples in water, muddy water and the motion and color contrast of flapping wings (L. Naylor, AGFC, personal communication); these cues would be absent in the case of decoys. In addition, implementation of this method is fairly straight-forward and lower cost than alternatives such as ground counts or flushing with helicopters (Koneff et al. 2008).

One drawback of this method is that it does not account for ducks that are not available for detection, that is, ducks that are present in the surveyed region but not visible from the plane, perhaps because of obstruction by vegetation or land features. Knoeff et al. (2008) suggested that availability bias was a larger contributor to overall detection bias than the visibility bias corrected for using the double-observer survey approach in their surveys of waterfowl in southwest Ontario and the Ottawa and St. Lawrence River valleys. One approach that has potential for estimating true detection is the combined distance and double-observer method (Buckland et al. 2010). Discussion with observers however raised concerns over the ability to estimate distance precisely because of slight variations in flight altitude, the lack of clear distinctness between duck groups, and the logistical challenges of estimating an additional parameter to an already demanding survey protocol. Replicate sampling such as ground counts and helicopter flushing are alternative methods of estimating true detection but these methods may be prohibitively expensive and have their own limitations in terms of bird movement on and off the survey transect between aerial and replicate surveys (Knoeff et al. 2008). These methods also assume 1) perfect detection of waterfowl by ground crews or helicopter surveys, 2) that replicate surveys cover the same waterfowl populations as aerial surveys (e.g. zero flight path error and no movement of waterfowl off or on survey transects between surveys), and 3) that the replicate surveys adequately represent the entire surveyed region (Prenzlow and Lovvorn 1996).

Further application of the double-observer method would allow for more precise estimates of detection and may allow for changes in observer-specific detection over time. In addition, we estimated detection for all forested wetland habitat combined, which includes cypress-tupelo, shrub-scrub wetlands, and bottomland hardwood forests. Smith et al. (1995) estimated detection separately for these three different types of forested wetland. More habitat-specific estimates of detection may improve the precision of estimates.

The use of the detection-adjustment increased estimates of mallard abundance by a mean of 27% (SE = 7%), other dabbling ducks by 23% (SE = 7%), diving ducks by 12% (SE = 1%), and total ducks by 24% (SE = 7%). The large variability among years appeared to have been due to the variation in the percentage of ducks observed in closed canopy habitat, which ranged from a low of 3% in November of 2009 to a high of 32% in December of 2010. Because detection was lower in closed canopy habitat, counts in closed canopy habitat had more impact on the population estimate than the same size count in open canopy habitat. The high number of ducks observed in closed canopy habitat during the December 2010 and Mid-winter 2011 surveys were in predominantly cypress-tupelo habitat. The detection probability was developed using predominantly bottomland hardwood forest and thus may not accurately estimate detection in this habitat type.

The development of the GUI tool in R reduces the time that staff spends on survey selection and analysis of waterfowl surveys. The inclusion of a kernel density estimator in the GUI also avoids the need for access to expensive licenses such as the "spatial analysis extension" for ArcGIS (ESRI 2006). The increased speed of analysis also allows for faster dissemination of survey data, which may allow managers to adjust habitat manipulations in response to the most recent information on duck distributions. In addition, the GUI allows for easier expansion of surveys into new regions by the inclusion of an option for the user to upload new transect files from which to select random transects. Expansion of the surveys will allow for better ability to distinguish distribution shifts from population changes (e.g. Brook et al. 2009). There are currently plans by the AGFC to use the GUI tool to expand waterfowl surveys west to cover the Arkansas River Valley.

Waterfowl distribution in winter is believed to be influenced by multiple factors including flooding extent, food availability, disturbance and hunter harvest pressure, and weather. Winter site fidelity may also influence waterfowl distribution although Roberston and Cooke (1999) described most North American dabbling ducks as having low levels of winter site fidelity and Krementz et al. (2012) observed few mallards (19% of females and 0% of males) marked in Arkansas retuning there the following winter. In particular there is a need for greater understanding of the influence of climate on duck distribution; as climate change may result in shifts in winter ranges. There have been relatively few studies on the influence of weather variables such as ambient temperature and snow cover on waterfowl abundances during the non-breeding season (Schummer et al. 2010). Those studies examining the relationship between climate and waterfowl abundance reported mixed results. Nichols et al. (1983) found that mallards tended to winter farther south during colder winters and that there were more band recoveries in the MAV during years with higher precipitation within the MAV. Green and Krementz (2008) investigated whether band recovery and harvest distributions of mallards had changed between 1980 and 2003 and concluded that there was no evidence for changes, counter to the idea that distributions have shifted farther north in response to milder winters. Dalby et al. (2013) found little evidence of influence of temperature on wintering duck distributions in Spain. Schummer at al. (2010) detected a quadratic relationship between WSI and rates of change of numbers of mallards and other dabbling ducks, with mallards increasing with winter severity up to a threshold after which abundance decreased. Pearse (2007) found that colder temperatures and snow cover at latitudes around 38ºN (locations between Kansas City and St Louis, MO) were positively related to duck abundance in western Mississippi. Colder temperatures decrease energy conservation of waterfowl and increasing ice coverage can lower energy acquisition through lower food availability (Jorde et al. 1983).

This study found that mallards increased in abundance during periods of increased winter severity within the MAV. This same increase in abundance with increased winter severity was observed for all ducks combined but this was driven by the inclusion of mallards in this category; other dabbling ducks did not increase in abundance with increased winter severity. Severe weather conditions within the MAV may indicate harsher conditions to the north as well; the WSI within the MAV and the WSI at latitudes between ~38 to 39ºN were highly correlated. Nichols et al. (1983) observed mallards wintering farther south during years with colder temperatures.

This research will complement ongoing work to develop models of future duck distributions using regional downscaled probabilistic climate change projections using weather severity thresholds and long-term changes in weather severity (Schummer et al. 2010). Over time, the data collected under the coordinated MAV waterfowl monitoring framework will be valuable for cross-validation of these model predictions. These data also will be useful in combination with ongoing efforts to model the impacts of precipitation, climate, and land use on the surface-water system within select MAV watersheds by providing an index of waterfowl population response to hydrologic variables presumed to be key drivers of waterfowl distribution and abundance.

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This project would not have been possible without the hard work of individuals at the Arkansas Game and Fish Commission (AGFC), the Louisiana Department of Wildlife and Fisheries (LDWF), and the Mississippi Department of Wildlife, Fisheries and Parks (MDWFP). In particular, we thank L. Naylor at AGFC, L. Reynolds at LDWF, and H. Havens at MDWFP. J. Carbaugh and J. Jackson conducted all of the Arkansas surveys. Funding for survey design and analysis was provided by the U.S. Fish and Wildlife Service. Flight costs and observer salaries were supported by AGFC.

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Table 1. Descriptions of models used in double observer analysis.

Model	Description
null	Detection is constant
canopy	Detection varies only with canopy cover (open or closed)
observer	Observer effect. Detection varies only by observer.
observer + canopy	Detection varies with observer and canopy cover (open or closed).
observer * canopy	Detection varies with observer and canopy cover (open or closed) with an interaction term between observer and canopy cover
observer + canopy + count	Detection varies with observer, canopy cover (open or closed), and group size.
observer + canopy + species	Detection varies with observer, canopy cover (open or closed), and with duck species group (mallard, teal, other dabbler, or diver).
observer * canopy + species + count	Detection varies with observer and canopy cover (open or closed) with an interaction term between observer and canopy cover, and with duck species group (mallard, teal, other dabbler, or diver) and group size.

Table 2. Estimated %CV for mallards and all ducks combined under three different sampling scenarios for four surveys conducted between November 2011 and January 2012 in the Arkansas portion of the Mississippi Alluvial Valley. SR is simple random sampling, EX is expert-opinion based stratified random sampling (five strata); WS is watershed-based stratified random sampling (eleven strata).

		%CV	
Survey	Design	Mallards	All ducks
Nov.	SR	27.9	19.9
	EX	30.1	18.3
	WS	24.1	13.7
Dec.	SR	17.1	13.6
	EX	17.5	13.3
	WS	14.8	12.0
MWS	SR	12.8	11.6
	EX	13.4	11.8
	WS	11.0	9.9
Jan.	SR	15.2	12.1
	EX	15.3	12.3
	WS	12.3	10.4
Ave	SR	18.3	14.3
	EX	19.1	13.9
	WS	15.5	11.5

Table 3. Frequency of encounter histories for non-mallard dabblers, mallards, divers, and teal by group size for double-observer aerial surveys flown during February 2012 in the Arkansas portion of the Mississippi Alluvial Valley. The first number in the encounter history indicates whether a group was recorded (1) or missed (0) by primary observer A; the second number indicates the same information for the observer B when observer B switched to the primary observer.

			Group size			
Group	Canopy	Encounter history	1-5	6-10	11-20	21+
Dabblers	Open	01	0	1	0	0
		10	1	2	4	4
		11	4	17	10	38
	Closed	01	0	0	0	0
		10	0	0	0	0
		11	0	0	0	0
Mallard	Open	01	0	0	0	1
		10	1	1	1	0
		11	6	12	9	16
	Closed	01	0	0	0	1
		10	10	4	0	1
		11	5	2	1	0
Teal	Open	01	0	0	0	0
		10	0	0	0	2
		11	0	0	4	6
	Closed	01	0	0	0	0
		10	0	0	0	0
		11	0	0	0	0
Divers	Open	01	0	0	0	0
		10	0	0	0	0
		11	0	0	1	1

Closed	01	0	0	0	0
	10	0	0	0	0
	11	0	0	0	0

Table 4. Model ranking results of double observer detection probabilities. Model results are ranked by Akaike's Information Criterion adjusted for small sample size (AIC_c) value, delta AIC_c (ΔAIC_c), and AIC_c weight (w_i)

Model	K	AIC_c	ΔAIC_c	w_i
observer + canopy	4	499.3	0.00	0.52
observer * canopy	5	501.0	1.79	0.21
observer + canopy + count	7	501.1	1.83	0.21
observer + canopy + species	7	503.9	4.62	0.05
observer * canopy + species + count	9	507.4	8.10	0.01
canopy	3	525.0	25.73	0.00
observer	3	526.8	27.52	0.00
null	2	551.5	52.28	0.00

Table 5. Detection estimates with SE and 95% confidence intervals for double-observer aerial surveys of dabblers (non-mallard), mallards, divers, and teal during February 2012 in the Arkansas portion of the Mississippi Alluvial Valley.

Parameter	*n*	Estimate	SE	95% CI
Observer 1 - open canopy	142	0.88	0.02	0.82-0.93
Observer 1 - closed canopy	24	0.36	0.10	0.12-0.71
Observer 2 - open canopy	142	0.99	0.01	0.94-1.00
Observer 2 - closed canopy	24	0.86	0.08	0.31-0.99

Table 6. Population estimates using uncorrected and detection probability-corrected values in the Arkansas portion of the Mississippi Alluvial Valley for surveys conducted during winter 2009 to 2011. n = number of transects, km = total length of transects sampled, N = estimated population.

				Index			Detection-adjusted		
Group	Survey	n	km	N	SE	%CV	N	SE	%CV
Mallards	Nov-09	105	5,346	300,203	82,282	27.4	369,105	99,482	27.0
	Dec-09	113	5,614	648,955	116,841	18.0	696,682	124,236	17.8
	MWS-10	72	4,127	2,910,008	691,646	23.8	3,114,686	752,670	24.2
	Jan-10	105	5,533	2,020,035	366,163	18.1	2,371,523	440,770	18.6
	Nov-10	108	5,393	348,112	119,977	34.5	517,354	225,874	43.7
	Dec-10	107	5,511	1,751,379	705,130	40.3	3,153,380	1,902,844	60.3
	MWS-11	93	4,959	2,056,286	705,480	34.3	3,378,105	1,826,886	54.1
	Jan-11	102	5,362	1,307,665	187,867	14.4	1,557,018	255,609	16.4
	Nov-11	209	5,895	347,690	86,126	24.8	384,709	93,383	24.3
	Dec-11	209	5,815	1,414,398	238,165	16.8	1,651,749	276,848	16.8
	MWS-12	163	4,826	882,415	117,504	13.3	1,092,697	214,831	19.7
	Jan-12	211	5,884	711,592	103,981	14.6	781,389	116,824	15.0
Other dabbling ducks	Nov-09	105	5,346	2,550,790	431,037	16.9	2,966,082	520,326	17.5
	Dec-09	113	5,614	1,179,037	192,012	16.3	1,236,632	198,882	16.1
	MWS-10	72	4,127	705,711	305,680	43.3	783,448	347,085	44.3
	Jan-10	105	5,533	1,032,634	164,525	15.9	1,189,846	198,690	16.7
	Nov-10	108	5,393	665,756	216,355	32.5	779,712	250,241	32.1
	Dec-10	107	5,511	891,151	288,181	32.3	1,380,309	653,453	47.3

	MWS-11	93	4,959	950,256	445,348	46.9	1,788,309	1,208,537	67.6
	Jan-11	102	5,362	372,206	76,569	20.6	498,509	112,840	22.6
	Nov-11	209	5,895	748,935	140,634	18.8	797,836	149,915	18.8
	Dec-11	209	5,815	1,083,403	164,031	14.0	1,121,813	182,038	16.2
	MWS-12	163	4,826	397,745	53,635	13.5	465,666	75,578	16.2
	Jan-12	211	5,884	505,279	58,053	11.5	542,948	62,352	11.5
Diving ducks	Nov-09	105	5,346	284,387	157,898	55.5	339,680	168,474	49.6
	Dec-09	113	5,614	203,863	96,793	47.5	221,354	109,138	49.3
	MWS-10	72	4,127	123,519	54,931	44.5	136,888	62,031	45.3
	Jan-10	105	5,533	57,158	22,627	39.6	63,249	24,740	39.1
	Nov-10	108	5,393	67,489	23,302	34.5	74,477	25,999	34.9
	Dec-10	107	5,511	30,429	10,393	34.2	33,893	11,692	34.5
	MWS-11	93	4,959	80,881	20,246	25.0	90,556	22,716	25.1
	Jan-11	102	5,362	104,782	63,859	60.9	117,096	72,450	61.9
	Nov-11	209	5,895	37,767	16,256	43.1	42,078	18,375	43.7
	Dec-11	209	5,815	65,101	23,944	36.8	72,413	26,864	37.1
	MWS-12	163	4,826	66,252	30,050	45.4	74,008	34,088	46.1
	Jan-12	211	5,884	49,914	30,103	60.3	56,380	34,199	60.7
Total ducks	Nov-09	105	5,346	3,135,379	519,134	16.6	3,674,866	636,882	17.3
	Dec-09	113	5,614	2,031,855	291,185	14.3	2,154,668	316,530	14.7
	MWS-10	72	4,127	3,739,239	981,078	26.2	4,035,022	1,091,466	27.1
	Jan-10	105	5,533	3,109,826	519,822	16.7	3,624,618	630,190	17.4
	Nov-10	108	5,393	1,081,357	307,353	28.4	1,371,542	418,749	30.5
	Dec-10	107	5,511	2,667,263	955,307	35.8	4,561,110	2,535,673	55.6
	MWS-11	93	4,959	3,084,286	1,137,32	36.9	5,253,475	3,027,904	57.6

Jan-11	102	5,362	1,784,654	229,155	12.8	2,172,622	330,235	15.2
Nov-11	209	5,895	1,134,800	190,231	16.8	1,225,086	202,865	16.6
Dec-11	209	5,815	2,497,801	341,996	15.1	2,845,975	396,372	13.9
MWS-12	163	4,826	1,346,412	162,324	12.1	1,632,370	283,329	17.4
Jan-12	211	5,884	1,266,785	151,513	12.0	1,380,717	168,449	12.2

Table 7. Model selection results predicting waterfowl abundance for wintering waterfowl in the Arkansas portion of the Mississippi Alluvial Valley during surveys conducted during winters 2009 to 2011. WSI.MAV is winter severity index for the MAV, WSI.DIFF, if the difference in WSI between the MAV and mid-latitude locations to the north (latitude ~38 to 39). Model results are ranked by Akaike's Information Criterion adjusted for small sample size (AIC_c) value, delta AIC_c (Δ AIC_c), and AIC_c weight (w_i)

Taxon	Model	K	AIC_c	Δ AIC_c	w_i
Mallards	WSI.MAV	3	366.81	0.00	0.88
	NULL	2	373.13	6.32	0.04
Other dabbling ducks	NULL	2	365.59	0.39	0.60
Divers	Year	4	307.01	0.00	0.41
	WSI.MAV +WSI.DIFF+ Year + Month	8	308.12	1.11	0.24
	Year + Month	6	308.82	1.81	0.17
	NULL	2	310.33	3.32	0.08
All ducks	WSI.MAV	3	377.07	0.00	0.48
	NULL	2	377.56	0.49	0.38

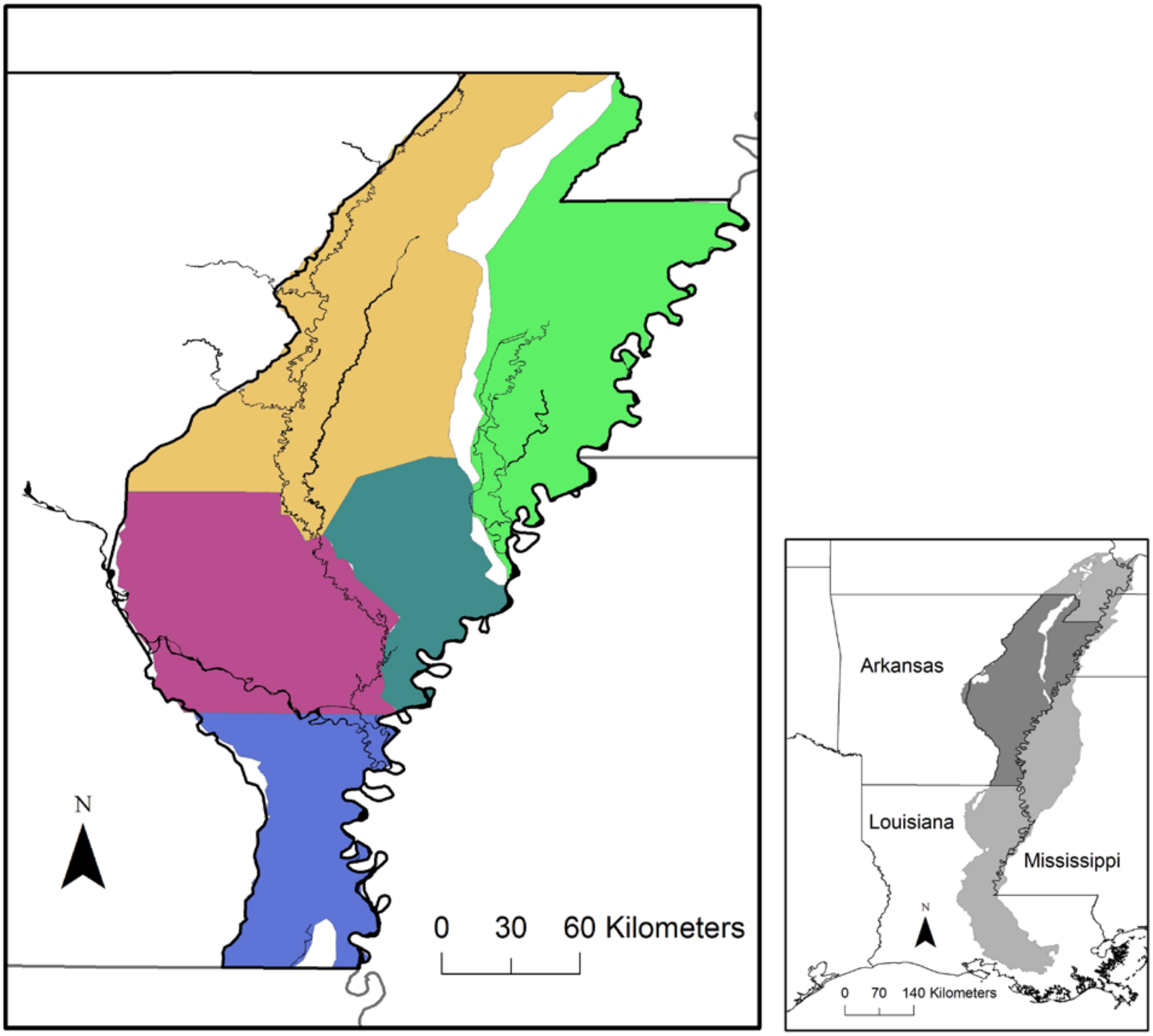


Figure 1. Expert-opinion-based stratified sampling design for aerial waterfowl surveys in the Arkansas portion of the Mississippi Alluvial Valley. Major rivers were used as guides in determining strata boundaries and are shown for reference.

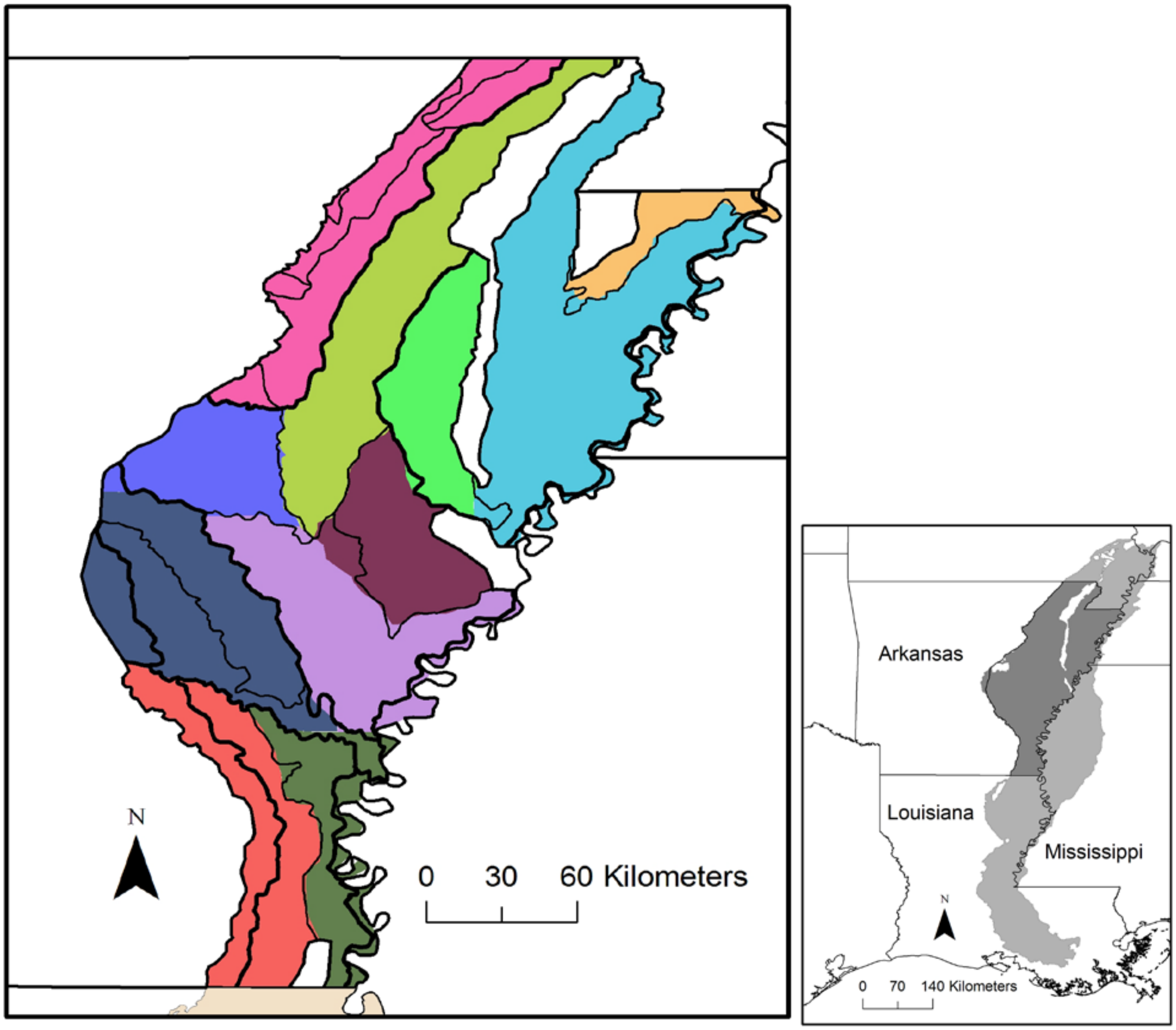


Figure 2. Watershed-based stratified sampling design for aerial waterfowl surveys in the Arkansas portion of the Mississippi Alluvial Valley. Watersheds at the accounting unit level (thick black line) and cataloguing unit level (thin black line) are shown for reference.

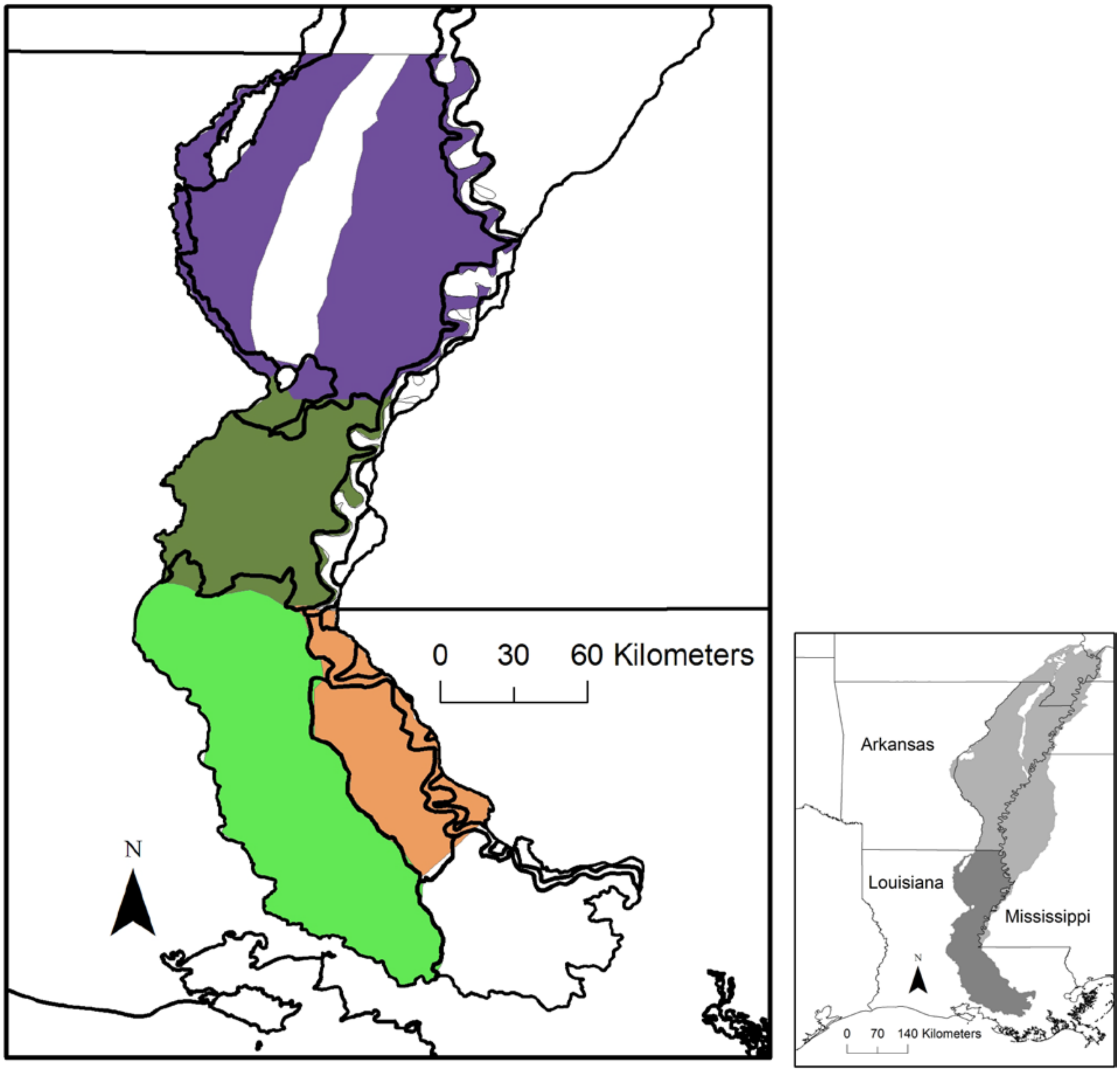


Figure 3. Watershed-based stratified sampling design for aerial waterfowl surveys in the Louisiana portion of the Mississippi Alluvial Valley. Watersheds (thick black line) and sub-watersheds (thin black line) boundaries are shown for reference.

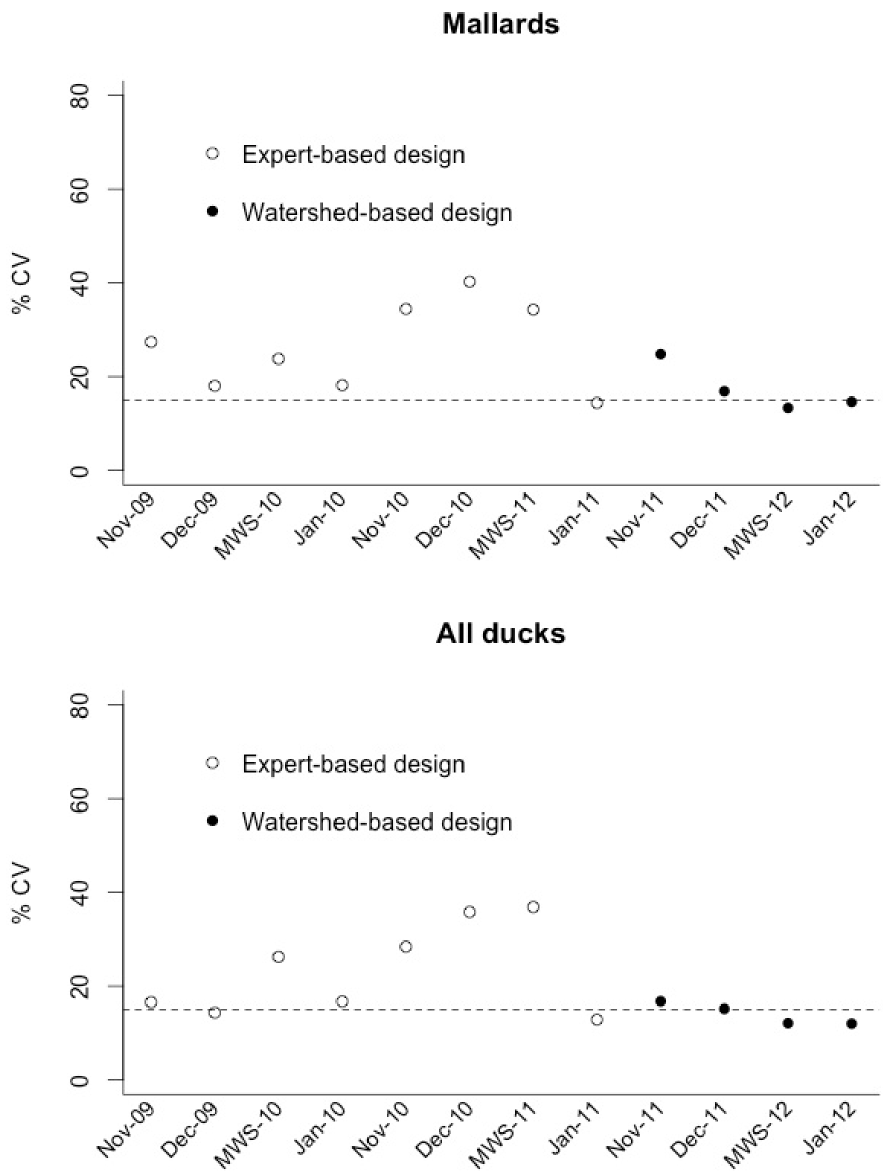


Figure 4. Estimates of %CV of mean number of mallards and all ducks per transect in the Arkansas portion of the Mississippi Alluvial Valley during surveys conducted during winters 2009-2010 to 2011-2012 winters. Dotted line shows target precision of 15% CV.

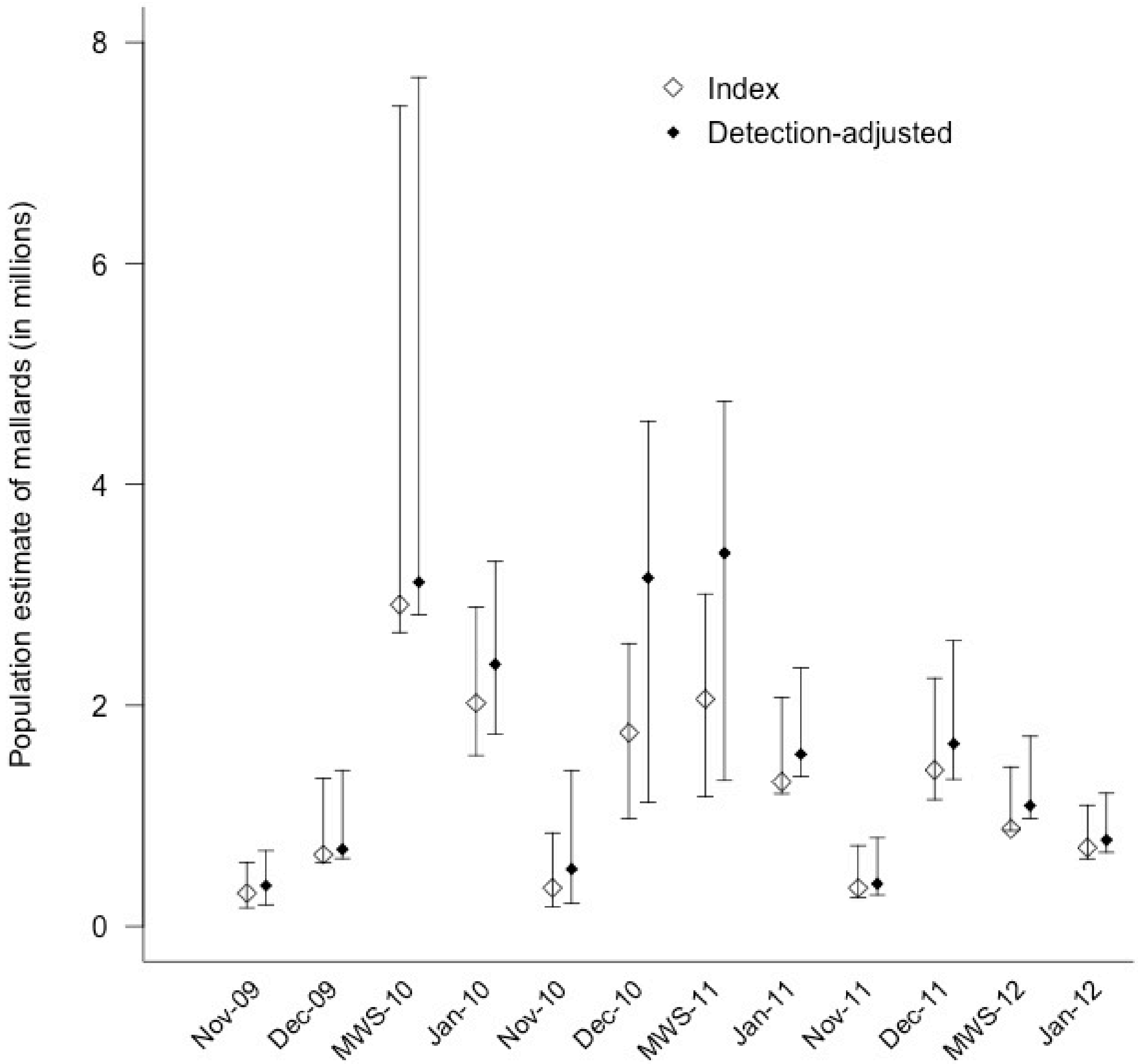


Figure 5. Population indices compared to detection-adjusted numbers of mallards in the Arkansas portion of the Lower Mississippi Alluvial Valley during winters 2009-2010 to 2011-2012 with 95% confidence intervals from bootstrapping. MWS=midwinter survey, conducted in early January of each year.

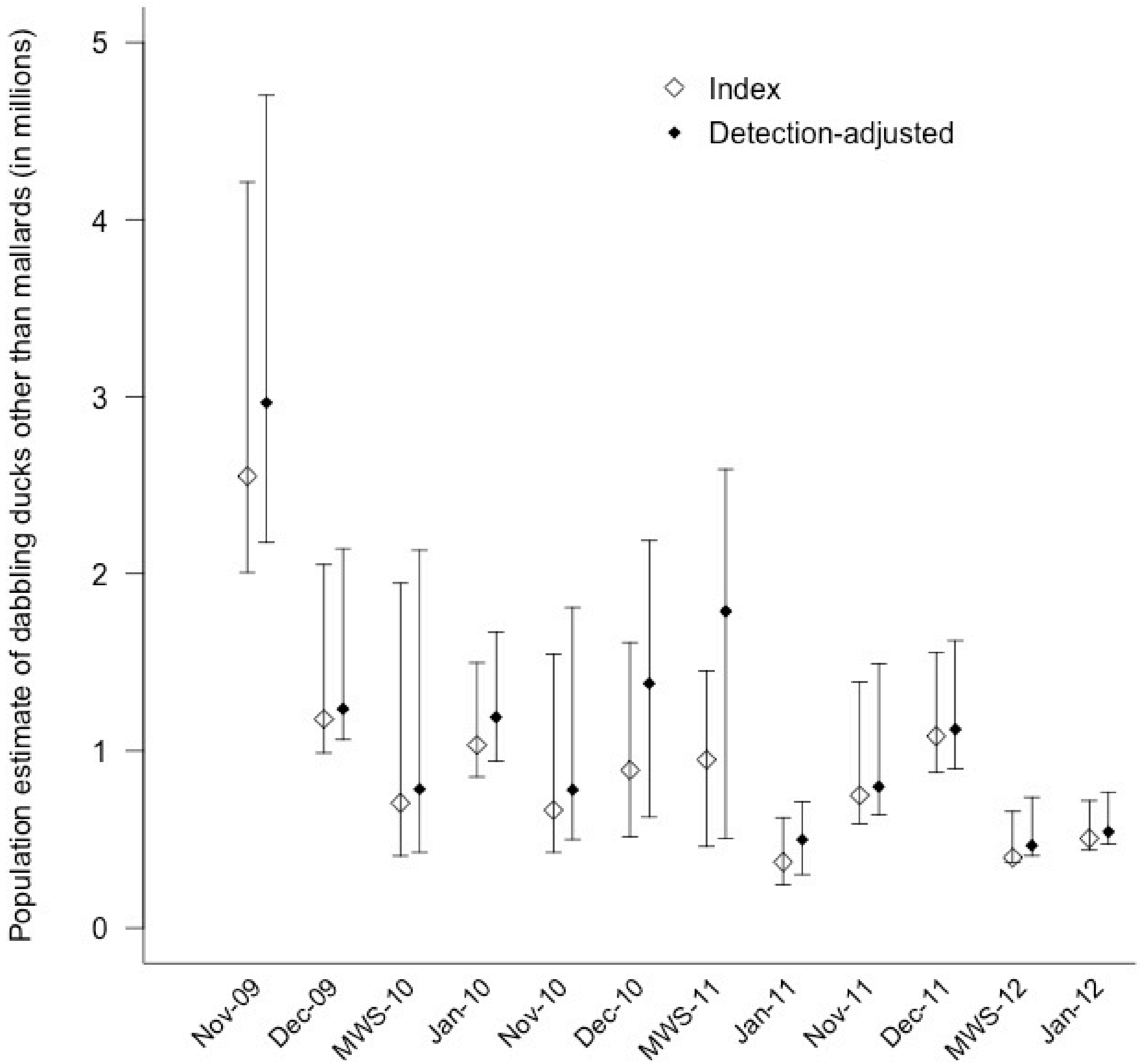


Figure 6. Population indices compared to detection-adjusted numbers of all dabbling ducks other than mallards in the Arkansas portion of the Lower Mississippi Alluvial Valley during winters 2009-2010 to 2011-2012 with 95% confidence intervals from bootstrapping. MWS=midwinter survey, conducted in early January of each year.

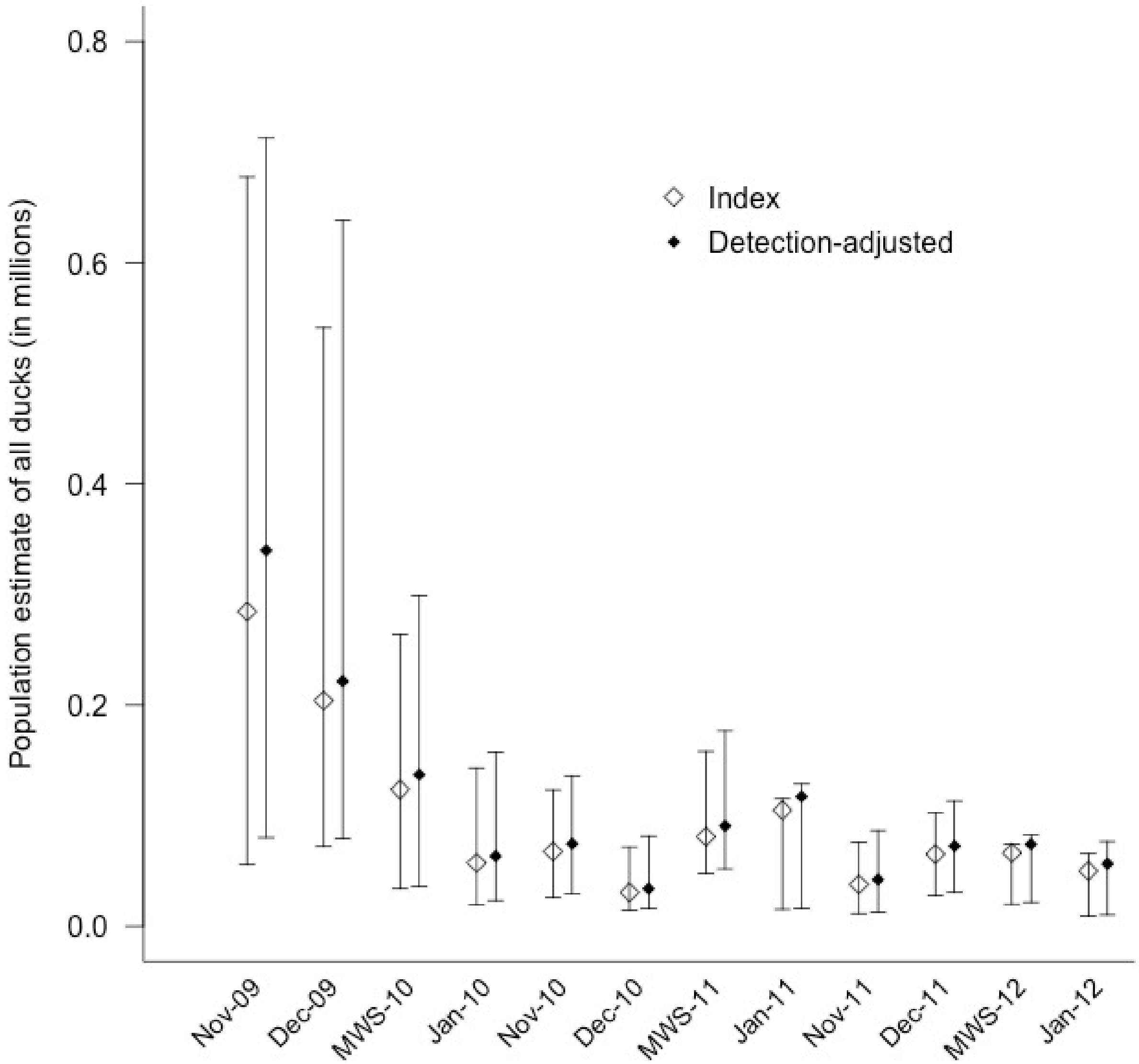


Figure 7. Population indices compared to detection-adjusted numbers of diving ducks in the Arkansas portion of the Lower Mississippi Alluvial Valley during winters 2009-2010 to 2011-2012 with 95% confidence intervals from bootstrapping. MWS=midwinter survey, conducted in early January of each year.

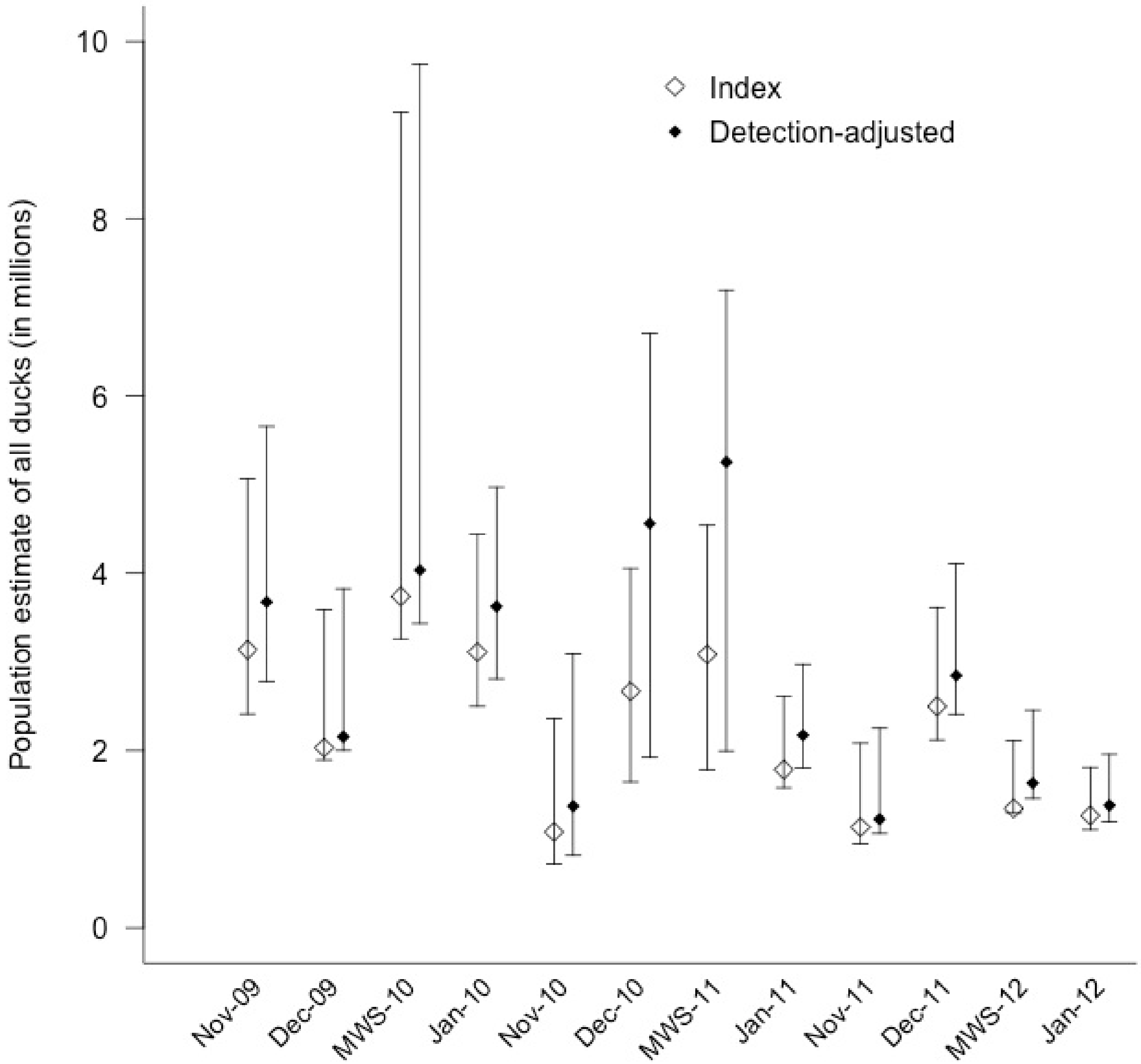


Figure 8. Population indices compared to detection-adjusted numbers of all ducks in the Arkansas portion of the Lower Mississippi Alluvial Valley during winters 2009-2010 to 2011-2012 with 95% confidence intervals from bootstrapping. MWS=midwinter survey, conducted in early January of each year.

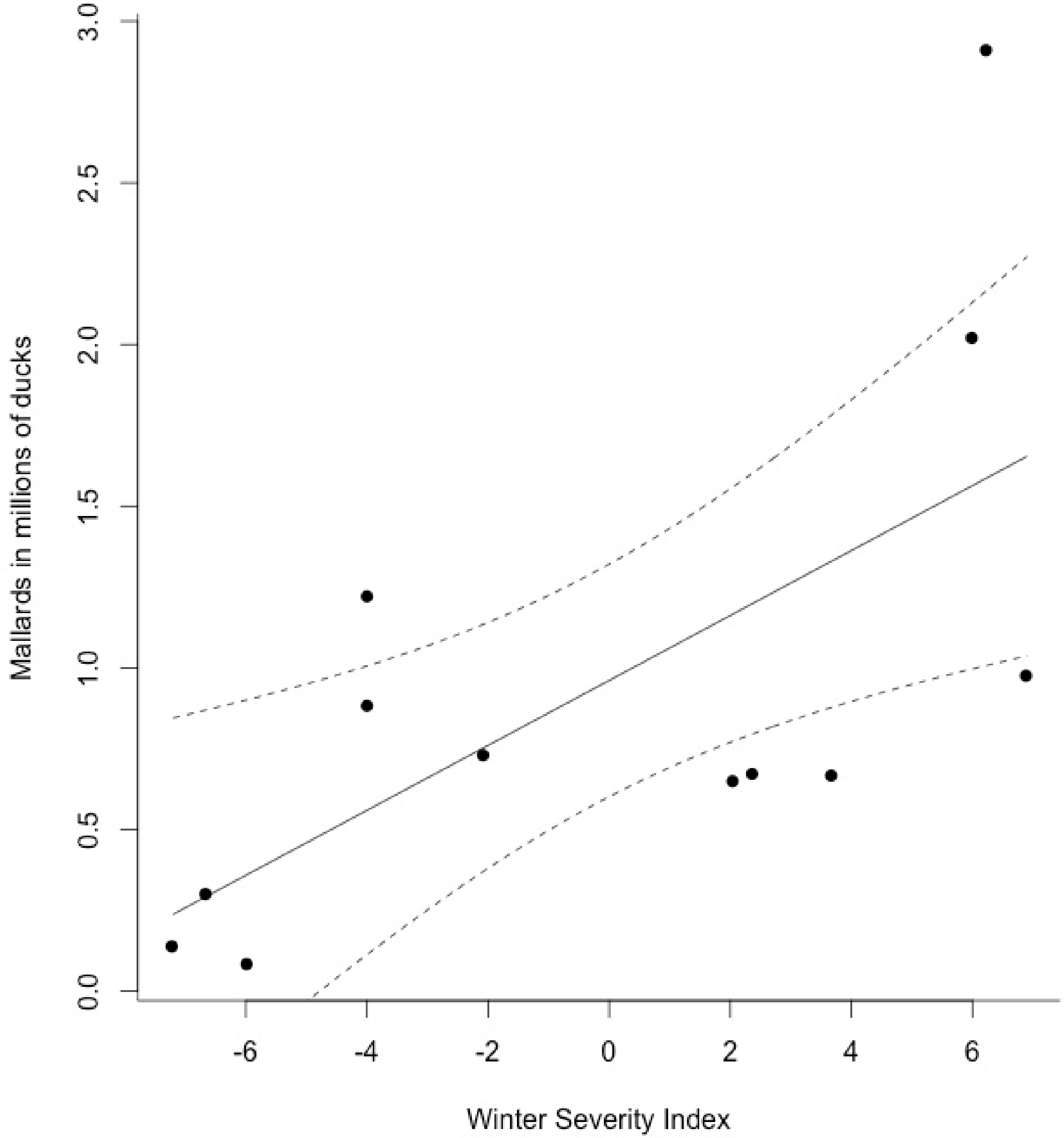


Figure 9. Number of mallards in the Arkansas portion of the Mississippi Alluvial Valley as predicted by the Winter Severity Index (see methods) in the region during winters 2009-2011. Dotted lines indicate 95% confidence intervals. Higher values indicate more severe weather conditions, points indicate observed values.

Appendix A. Use of public lands by waterfowl according to habitat type.

Appendix A1. Detection-bias corrected mallard use by land ownership and habitat. Use relative to availability is % Use divided by % available by survey. Habitat codes: Ag=non-rice agriculture, bay=bayou, blh=bottomland hardwood, cyp-tup= cypress-tupelo, fish-res= aquaculture impoundments and reservoirs, msu=moist-soil, ox=oxbow lakes, ss=shrub-scrub.

Survey	Land	% Use	Use rel. to avail.	Pop. Est. for AR MAV	ag	bay	blh	cyp-tup	ditch	fish res	lake	msu	ox	rice	river	ss
Nov 2009	Federal	15%	3.51	35,112	0	0	0	49	0	0	0	0	0	51	0	0
Nov 2009	Private	85%	0.91	317,135	64	0	0	0	0	1	0	10	6	20	0	0
Nov 2009	State	0%	0.00	-	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2009	All	100%	1.00	369,105	54	0	0	8	0	1	0	9	5	24	0	0
Dec 2009	Federal	7%	1.98	37,418	5	1	10	0	0	0	0	78	0	0	0	6
Dec 2009	Private	89%	0.95	620,310	40	0	7	0	0	20	0	14	0	16	0	3
Dec 2009	State	4%	1.57	27,132	72	0	0	2	0	0	0	11	0	15	0	0
Dec 2009	All	100%	1.00	696,682	39	0	7	0	0	18	0	18	0	15	0	3
MWS 2010	Federal	4%	0.76	63,971	42	0	23	0	0	0	12	0	1	22	0	1
MWS 2010	Private	92%	1.02	2,979,624	25	0	3	0	0	38	0	25	1	5	0	4
MWS 2010	State	4%	0.96	73,972	14	0	13	0	0	51	0	23	0	0	0	0
MWS 2010	All	100%	1.00	3,114,686	25	0	4	0	0	37	1	24	1	5	0	3
Jan 2010	Federal	4%	0.93	59,942	20	19	14	0	0	0	37	8	0	1	1	1
Jan 2010	Private	91%	0.99	2,202,011	61	0	0	0	0	2	0	11	1	25	0	1
Jan 2010	State	5%	1.46	85,921	3	0	1	88	0	0	0	4	4	0	0	0
Jan 2010	All	100%	1.00	2,371,523	56	1	1	4	0	1	1	10	1	23	0	1
Nov 2010	Federal	17%	4.88	68,456	0	0	0	96	0	0	0	0	3	0	0	1
Nov 2010	Private	83%	0.88	429,058	10	0	0	30	0	18	0	2	0	37	1	2
Nov 2010	State	0%	0.11	1,387	0	0	0	0	0	0	0	0	29	0	71	0
Nov 2010	All	100%	1.00	517,354	8	0	0	41	0	15	0	2	1	30	1	2
Dec 2010	Federal	47%	10.37	886,370	0	0	0	83	0	2	0	0	0	12	2	0
Dec 2010	Private	49%	0.54	1,596,415	11	1	3	6	0	35	12	3	0	13	4	13
Dec 2010	State	4%	1.01	79,141	1	1	2	0	0	0	85	2	0	0	8	0
Dec 2010	All	100%	1.00	3,153,380	5	0	2	42	0	18	9	1	0	12	4	6
Mid 2011	Federal	5%	1.31	119,477	3	0	1	0	0	1	0	1	91	0	2	2

Mid 2011	Private	66%	0.72	2,273,051	25	0	1	2	0	23	0	7	1	40	1	1
Mid 2011	State	29%	7.62	638,159	0	0	0	100	0	0	0	0	0	0	0	0
Mid 2011	All	100%	1.00	3,378,105	17	0	1	30	0	15	0	4	5	27	0	1
Jan 2011	Federal	6%	1.61	67,906	7	0	1	65	0	0	0	0	19	5	1	3
Jan 2011	Private	94%	1.00	1,464,765	18	1	0	1	2	4	0	12	0	51	0	11
Jan 2011	State	1%	0.01	454	3	7	10	47	0	0	0	1	12	0	0	20
Jan 2011	All	100%	1.00	1,557,018	17	1	1	5	1	4	0	12	1	48	0	11
Nov 2011	Federal	12%	3.45	35,977	0	0	0	0	4	0	89	0	0	7	0	0
Nov 2011	Private	88%	0.94	341,421	28	0	1	1	1	0	2	0	19	48	0	0
Nov 2011	State	0%	0.00	-	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2011	All	100%	1.00	384,709	25	0	1	1	0	17	0	13	0	43	0	0
Dec 2011	Federal	13%	3.25	145,483	20	0	1	40	40	0	0	39	0	0	0	0
Dec 2011	Private	84%	0.90	1,403,570	27	0	1	3	3	23	0	17	1	25	0	0
Dec 2011	State	3%	0.98	40,080	1	0	29	0	0	70	0	0	0	0	0	0
Dec 2011	All	100%	1.00	1,651,749	25	0	2	8	0	21	0	20	0	21	0	0
MWS 2012	Federal	17%	3.49	103,404	2	0	5	43	0	0	0	49	0	0	0	0
MWS 2012	Private	83%	0.90	920,997	35	0	1	0	0	8	0	10	1	39	0	6
MWS 2012	State	0%	0.07	2,014	10	0	80	0	0	0	0	6	0	0	0	5
MWS 2012	All	100%	1.00	1,092,697	30	0	2	7	0	7	0	16	1	32	0	5
Jan 2012	Federal	11%	3.14	66,595	19	1	22	0	0	0	0	25	0	0	12	0
Jan 2012	Private	86%	0.92	675,428	30	0	2	0	1	5	0	30	1	29	0	1
Jan 2012	State	3%	0.96	18,625	1	0	4	0	0	0	0	51	0	38	2	2
Jan 2012	All	100%	1.00	781,389	28	0	4	0	0	4	0	30	0	26	1	1
Ave	Federal	13%	3.22	140,843	10	2	6	31	4	0	11	17	9	8	1	1
Ave	Private	82%	0.89	1,268,649	31	0	2	4	1	15	1	12	2	29	1	4
Ave	State	4%	1.23	80,574	10	1	14	24	0	12	9	10	4	5	8	3
Ave	All	100%	1.00	1,589,033	27	0	2	12	0	13	1	13	1	26	1	3

Appendix A2. Detection-bias corrected mallard use by land ownership and habitat. Use relative to availability is % Use divided by % available by survey. Habitat codes: Ag=non-rice agriculture, bay=bayou, blh=bottomland hardwood, cyp-tup= cypress-tupelo, fish-res= aquaculture impoundments and reservoirs, msu=moist-soil, ox=oxbow lakes, ss=shrub-scrub.

Survey	Land	% Use	Use rel. to avail.	Pop. Est. for AR MAV	ag	bay	blh	cyp-tup	ditch	fish res	lake	msu	ox	rice	river	ss
Nov 2009	Federal	20.5%	4.7	380,540	48	0	0	30	0	0	0	4	0	18	0	0
Nov 2009	Private	75.3%	0.8	2,262,963	64	0	0	0	0	2	0	16	2	15	0	0
Nov 2009	State	4.3%	1.5	113,101	8	0	5	2	0	2	0	84	0	0	0	0
Nov 2009	All			2,966,082	58	0	0	7	0	2	0	17	2	15	0	0
Dec 2009	Federal	0.5%	0.0	168	65	0	9	0	0	0	0	26	0	0	0	0
Dec 2009	Private	97.4%	1.0	1,133,415	73	0	0	0	0	9	0	6	2	10	0	1
Dec 2009	State	2.1%	0.0	644	35	0	0	0	0	2	0	44	2	18	0	0
Dec 2009	All			1,236,632	72	0	0	0	0	8	0	7	2	10	0	1
MWS 2010	Federal	2.9%	0.5	11,110	22	0	8	0	2	0	4	0	0	65	0	0
MWS 2010	Private	95.8%	1.1	779,584	26	0	0	0	0	10	0	56	0	8	0	0
MWS 2010	State	1.2%	0.3	6,034	89	0	2	0	0	9	0	0	0	0	0	0
MWS 2010	All			783,448	27	0	0	0	0	9	0	54	0	9	0	0
Jan 2010	Federal	2.1%	0.5	15,789	51	0	0	0	0	0	2	47	0	0	0	0
Jan 2010	Private	93.4%	1.0	1,131,448	67	0	1	0	0	1	0	7	0	23	0	1
Jan 2010	State	4.5%	1.4	40,414	15	0	0	81	0	0	0	3	1	0	0	0
Jan 2010	All			1,189,846	64	0	1	4	0	1	0	7	0	22	0	1
Nov 2010	Federal	0.5%	0.1	3,017	0	2	0	15	0	0	0	0	66	0	0	18
Nov 2010	Private	99.1%	1.1	775,812	12	0	0	11	0	57	1	4	3	12	0	1
Nov 2010	State	0.4%	0.1	2,786	0	0	0	0	0	96	0	0	4	0	0	0
Nov 2010	All			779,712	12	0	0	11	0	57	1	3	4	11	0	1
Dec 2010	Federal	32%	7.1	263,896	0	0	0	76	0	0	0	0	0	24	0	0

Dec 2010	Private	66%	0.7	935,019	12	1	0	5	1	26	34	1	0	14	1	5
Dec 2010	State	2%	0.5	18,725	6	0	0	0	0	0	63	0	0	0	31	0
Dec 2010	All			1,380,309	8	0	0	28	0	17	24	1	0	17	1	4
Mid 2011	Federal	0.6%	0.2	8,433	0	1	0	2	0	95	0	0	0	0	0	2
Mid 2011	Private	51.0%	0.6	925,625	17	0	0	1	0	36	4	4	1	40	0	1
Mid 2011	State	48.5%	12.7	561,122	0	0	0	83	0	16	0	0	1	0	0	0
Mid 2011	All			1,788,309	9	0	0	40	0	27	0	2	1	20	0	1
Jan 2011	Federal	7.3%	2.1	28,857	2	0	0	97	1	0	0	0	0	0	0	0
Jan 2011	Private	89.4%	1.0	448,408	12	0	0	5	0	18	0	7	0	55	0	3
Jan 2011	State	3.3%	0.0	436	0	0	0	45	0	0	0	4	0	0	0	51
Jan 2011	All			498508.82	11	0	0	13	0	16	0	6	0	49	0	4
Nov 2011	Federal	8.5%	2.4	78,333	96	0	0	0	0	0	1	0	0	2	0	0
Nov 2011	Private	91.4%	1.0	1,090,031	27	0	0	1	3	0	2	2	18	44	0	2
													10			
Nov 2011	State	0.1%	0.0	912	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2011	All			1,182,545	33	0	0	2	0	17	0	2	2	41	0	2
Dec 2011	Federal	10.9%	2.7	200,208	35	0	0	20	0	0	0	40	6	0	0	0
Dec 2011	Private	87.1%	0.9	2,435,109	37	0	0	1	0	14	0	7	0	40	0	0
Dec 2011	State	2.0%	0.8	53,841	11	0	0	0	0	88	0	1	0	0	0	0
Dec 2011	All			2,773,562	36	0	0	3	0	14	0	10	1	35	0	0
MWS 2012	Federal	13.6%	2.8	35,254	14	1	0	52	0	0	0	48	0	0	0	0
MWS 2012	Private	86.3%	0.9	409,085	86	0	0	0	0	18	0	13	3	25	0	0
													10			
MWS 2012	State	0.0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
MWS 2012	All			465,666	34	0	0	7	0	15	0	17	3	22	0	0
Jan 2012	Federal	7.6%	2.1	31,122	41	0	0	1	1	0	0	49	0	0	4	0
Jan 2012	Private	91.0%	1.0	499,511	38	0	0	0	0	17	0	21	0	24	0	0

Jan 2012	State	1.4%	0.4	5,662	0	0	0	0	0	2	0	65	0	33	0	0
Jan 2012	All			542,948	37	0	0	0	0	15	0	23	0	23	0	0
Ave	Federal	8.9%	2.1	88,060	31	0	2	24	0	8	1	18	6	9	0	2
Ave	Private	85.3%	0.9	1,068,834	39	0	0	2	0	17	3	12	3	26	0	1
Ave	State	5.8%	1.5	66,973	14	0	1	18	0	18	5	17	17	4	3	4
Ave	All			1,298,964	33	0	0	10	0	16	2	12	1	23	0	1

Appendix A3. Detection-bias corrected mallard use by land ownership and habitat. Use relative to availability is % Use divided by % available by survey. Habitat codes: Ag=non-rice agriculture, bay=bayou, blh=bottomland hardwood, cyp-tup= cypress-tupelo, fish-res= aquaculture impoundments and reservoirs, msu=moist-soil, ox=oxbow lakes, ss=shrub-scrub.

Survey	Land	% Use	Use rel. to avail.	Pop. Est. for AR MAV	ag	bay	blh	cyp-tup	ditch	fish res	lake	msu	ox	rice	river	ss
Nov 2009	Federal	57%	13.2	121,173	73	0	0	26	0	0	0	0	0	0	0	0
Nov 2009	Private	41%	0.4	140,764	77	0	0	0	0	3	0	20	0	0	0	0
Nov 2009	State	2%	0.8	6,326	0	0	0	0	0	0	0	100	0	0	0	0
Nov 2009	All	100%	1.0	339,680	73	0	0	15	0	1	0	10	0	0	0	0
Dec 2009	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Dec 2009	Private	100%	1.1	222,197	3	0	0	3	0	90	0	0	4	0	0	0
Dec 2009	State	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Dec 2009	All	100%	1.0	221,354	3	0	0	3	0	90	0	0	4	0	0	0
MWS 2010	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
MWS 2010	Private	100%	1.1	142,185	3	0	0	0	3	33	0	27	34	0	0	0
MWS 2010	State	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
MWS 2010	All	100%	1.0	136,888	3	0	0	0	3	33	0	27	33	0	0	0
Jan 2010	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Jan 2010	Private	98%	1.1	63,364	14	0	0	0	0	65	0	15	0	0	4	2
Jan 2010	State	2%	0.5	764	0	0	0	0	0	0	0	100	0	0	0	0
Jan 2010	All	100%	1.0	63,249	14	0	0	0	0	64	0	16	0	0	4	1
Nov 2010	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2010	Private	100%	1.1	74,777	0	0	0	0	0	100	0	0	0	0	0	0
Nov 2010	State	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2010	All	100%	1.0	74,477	0	0	0	0	0	100	0	0	0	0	0	0
Dec 2010	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0

Dec 2010	Private	100%	1.1	34,734	0	0	0	0	0	98	0	0	0	0	2	0
Dec 2010	State	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Dec 2010	All	100%	1.0	33,893	0	0	0	0	0	98	0	0	0	0	2	0
Mid 2011	Federal	16%	4.7	11,601	0	0	0	0	0	96	0	4	4	0	0	0
Mid 2011	Private	75%	0.8	69,205	2	0	0	0	0	89	1	2	2	1	1	4
Mid 2011	State	8%	2.2	4,921	0	0	0	0	0	100	0	0	0	0	0	0
Mid 2011	All	100%	1.0	90,556	2	0	0	0	0	91	0	1	2	0	1	3
Jan 2011	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Jan 2011	Private	100%	1.1	117,698	0	0	0	0	0	76	0	0	19	5	0	0
Jan 2011	State	0%	0.0	3	0	0	0	0	0	0	0	0	100	0	0	0
Jan 2011	All	100%	1.0	117,096	0	0	0	0	0	76	0	0	19	5	0	0
Nov 2011	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2011	Private	100%	1.1	42,436	0	3	0	0	0	89	1	0	0	0	1	6
Nov 2011	State	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Nov 2011	All	100%	1.0	42,078	0	3	0	0	0	89	1	0	0	0	1	6
Dec 2011	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Dec 2011	Private	92%	1.0	67,080	20	0	0	0	0	4	0	0	74	1	0	0
Dec 2011	State	8%	3.2	5,693	0	0	0	0	0	0	0	0	100	0	0	0
Dec 2011	All	100%	1.0	72,413	18	0	0	0	4	76	0	4	0	1	0	0
MWS 2012	Federal	1%	0.1	288	0	0	0	0	0	0	0	0	100	0	0	0
MWS 2012	Private	92%	1.0	69,535	8	0	0	0	0	71	1	12	0	0	0	0
MWS 2012	State	7%	2.6	4,774	0	0	0	0	0	100	0	0	0	0	0	0
MWS 2012	All	100%	1.0	74,008	8	0	0	0	0	72	0	11	1	0	0	0
Jan 2012	Federal	0%	0.0	-	0	0	0	0	0	0	0	0	0	0	0	0
Jan 2012	Private	99%	1.1	56,600	6	0	0	0	0	93	0	0	1	0	0	0
Jan 2012	State	1%	0.2	294	0	0	0	0	0	100	0	0	0	0	0	0
Jan 2012	All	100%	1.0	56,380	6	0	0	0	0	93	0	0	1	0	0	0

Ave	Federal	6%	1.5	4,487	24	0	0	9	0	32	0	1	35	0	0	0
Ave	Private	92%	1.0	102,233	11	0	0	0	0	68	0	6	11	1	1	1
Ave	State	2%	0.8	2,143	0	0	0	0	0	43	0	29	29	0	0	0
Ave	All	100%	1.0	110,173	11	0	0	2	1	74	0	6	5	1	0	1

Appendix A4. Detection-bias corrected mallard use by land ownership and habitat. Use relative to availability is % Use divided by % available by survey. Habitat codes: Ag=non-rice agriculture, bay=bayou, blh=bottomland hardwood, cyp-tup= cypress-tupelo, fish-res= aquaculture impoundments and reservoirs, msu=moist-soil, ox=oxbow lakes, ss=shrub-scrub.

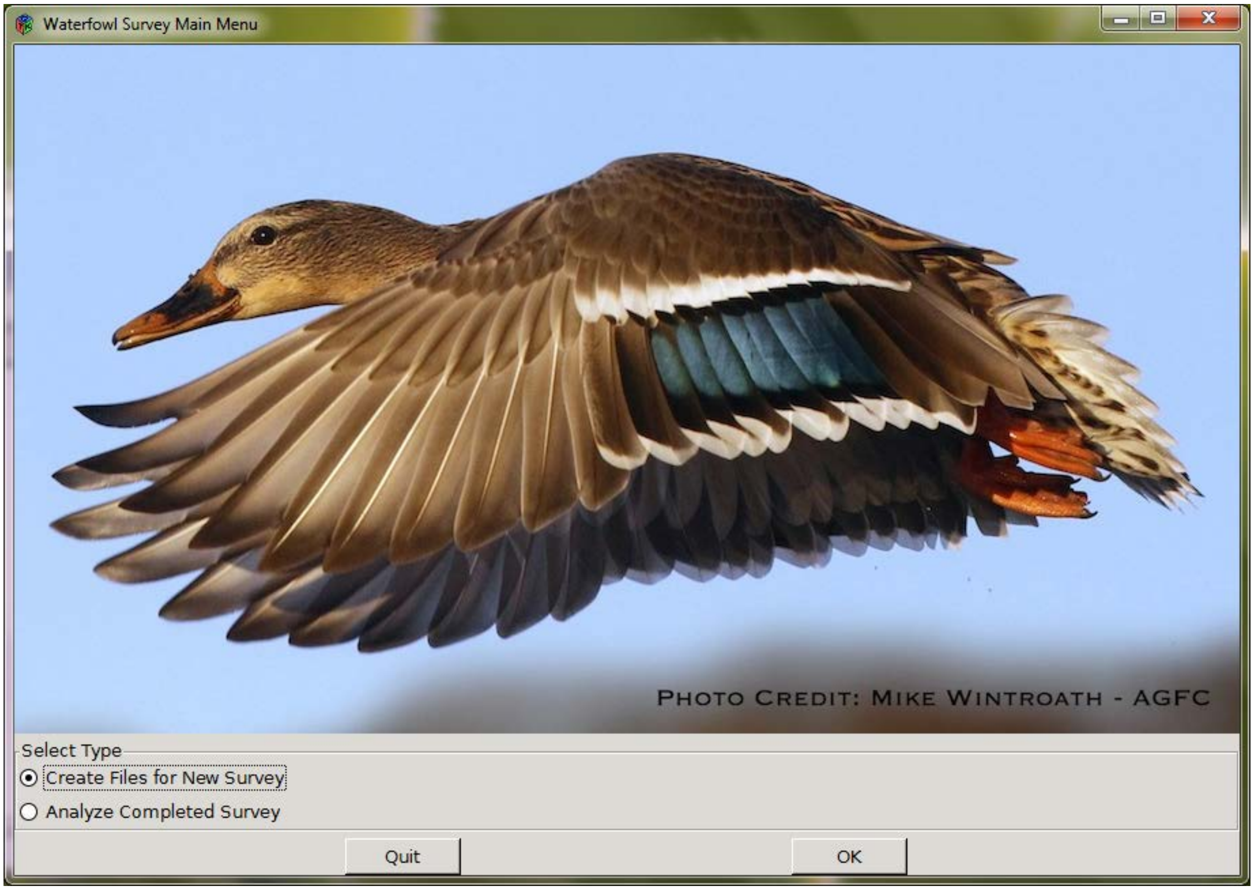
Survey	Land	% Use	Use rel. to avail.	Pop. Est. for AR MAV	ag	bay	blh	cyp-tup	ditch	fish res	lake	msu	ox	rice	river	ss
Nov 2009	Federal	23%	5.3	526,672	50	0	0	31	0	0	0	3	0	17	0	0
Nov 2009	Private	73%	0.8	2,732,983	65	0	0	0	0	2	0	16	2	15	0	0
Nov 2009	State	4%	1.3	120,575	7	0	4	2	0	1	0	85	0	0	0	0
Nov 2009	All	100%	1.0	3,674,866	59	0	0	7	2	2	0	16	2	15	0	0
Dec 2009	Federal	3%	0.8	45,638	11	1	10	0	0	0	0	72	0	0	0	6
Dec 2009	Private	95%	1.0	2,046,078	55	0	2	1	0	21	0	8	2	11	0	2
Dec 2009	State	3%	1.0	51,947	55	0	0	1	0	1	0	26	1	16	0	0
Dec 2009	All	100%	1.0	2,154,668	54	0	2	1	0	20	0	10	1	10	0	2
MWS 2010	Federal	4%	0.7	76,954	40	0	21	0	0	0	11	0	1	27	0	1
MWS 2010	Private	93%	1.0	3,893,580	24	0	2	0	0	33	0	30	2	5	0	3
MWS 2010	State	3%	0.8	82,879	18	0	12	0	0	48	0	21	0	0	0	0
MWS 2010	All	100%	1.0	4,035,022	25	0	3	0	0	32	1	29	1	6	0	3
Jan 2010	Federal	3%	0.8	75,582	27	15	11	0	0	0	29	17	0	1	1	1
Jan 2010	Private	92%	1.0	3,398,749	62	0	0	0	0	3	0	10	1	24	0	1
Jan 2010	State	5%	1.4	125,849	7	0	1	85	0	0	0	4	3	0	0	0
Jan 2010	All	100%	1.0	3,624,618	58	1	1	4	0	3	1	9	1	22	0	1
Nov 2010	Federal	7%	2.0	73,230	0	0	0	93	0	0	0	0	6	0	0	1
Nov 2010	Private	93%	1.0	1,277,927	10	0	0	17	0	46	0	3	2	20	0	1
Nov 2010	State	0%	0.1	3,676	0	0	0	0	0	60	0	0	13	0	27	0
Nov 2010	All	100%	1.0	1,371,542	10	0	0	22	0	43	0	0	3	18	0	1
Dec 2010	Federal	41%	9.1	1,128,981	0	0	0	81	0	2	0	0	0	15	2	0

Dec 2010	Private	56%	0.6	2,603,563	11	1	2	5	0	33	20	2	0	13	3	10
Dec 2010	State	3%	0.8	95,908	2	1	2	0	0	0	81	1	0	0	13	0
Dec 2010	All	100%	1.0	4,561,110	6	0	1	36	0	19	14	1	0	14	3	5
Mid 2011	Federal	4%	1.0	148,645	3	0	1	0	0	18	0	1	75	0	1	1
Mid 2011	Private	62%	0.7	3,289,686	22	0	1	1	0	28	0	6	1	39	1	2
Mid 2011	State	35%	9.1	1,182,767	0	0	0	92	0	8	0	0	14	4	1	2
Mid 2011	All	100%	1.0	5,253,475	14	0	0	33	0	21	0	3	4	24	0	1
Jan 2011	Federal	6%	1.7	98,199	5	0	1	73	0	0	0	11	1	51	0	9
Jan 2011	Private	93%	1.0	2,028,593	16	1	0	1	1	9	0	2	7	0	0	34
Jan 2011	State	2%	0.0	864	2	4	6	46	0	0	0	4	14	0	0	25
Jan 2011	All	100%	1.0	2,172,622	15	1	0	6	1	8	0	10	1	47	0	9
Nov 2011	Federal	9%	2.7	89,743	56	0	0	0	2	0	38	0	0	4	0	0
Nov 2011	Private	91%	1.0	1,118,124	27	0	0	1	2	0	2	2	21	44	0	1
Nov 2011	State	0%	0.0	-	0	0	0	0	0	0	0	0	100	0	0	0
Nov 2011	All	100%	1.0	1,225,086	29	0	0	2	0	19	0	5	1	40	0	1
Dec 2011	Federal	12%	3.0	228,052	25	0	1	33	0	0	0	40	2	0	0	0
Dec 2011	Private	86%	0.9	2,452,786	31	0	1	2	0	21	0	13	0	30	0	0
Dec 2011	State	2%	0.9	66,296	4	0	18	0	0	78	0	0	0	0	0	0
Dec 2011	All	100%	1.0	2,845,975	29	0	1	6	0	19	0	16	1	26	0	0
MWS 2012	Federal	16%	3.2	143,570	2	0	4	45	0	0	0	49	0	0	0	0
MWS 2012	Private	84%	0.9	1,392,487	36	0	1	0	0	12	0	10	1	35	0	5
MWS 2012	State	0%	0.1	6,017	5	0	39	0	0	48	0	3	4	0	0	2
MWS 2012	All	100%	1.0	1,632,370	30	0	1	7	0	10	0	16	1	29	0	4
Jan 2012	Federal	10%	2.7	99,971	26	1	15	0	0	0	0	32	0	0	9	0
Jan 2012	Private	88%	0.9	1,228,381	33	0	1	0	0	12	0	25	0	27	0	1
Jan 2012	State	2%	0.7	24,682	1	0	3	0	0	1	0	54	0	37	1	2
Jan 2012	All	100%	1.0	1,380,717	31	0	2	0	0	11	0	27	0	24	1	1

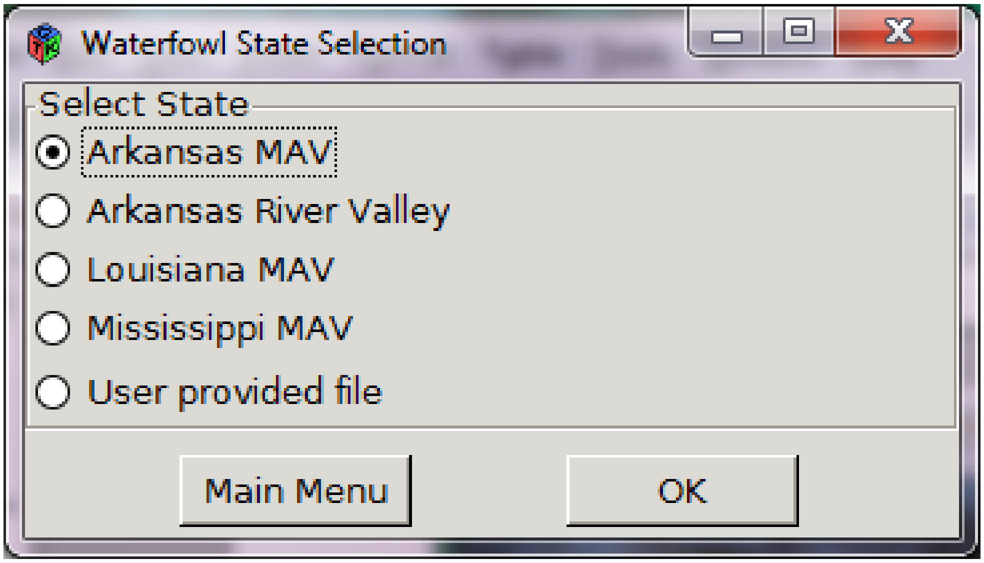
Ave	Federal	11%	2.7	227,936	20	1	5	30	0	2	6	19	7	9	1	2
Ave	Private	84%	0.9	2,288,578	33	0	1	2	0	18	2	11	3	22	0	5
Ave	State	5%	1.4	146,788	8	0	7	19	0	20	7	16	12	5	3	3
Ave	All	100%	1.0	2,827,673	30	0	1	10	0	17	1	12	1	23	0	2

Appendix B. Screen shots of GUI.

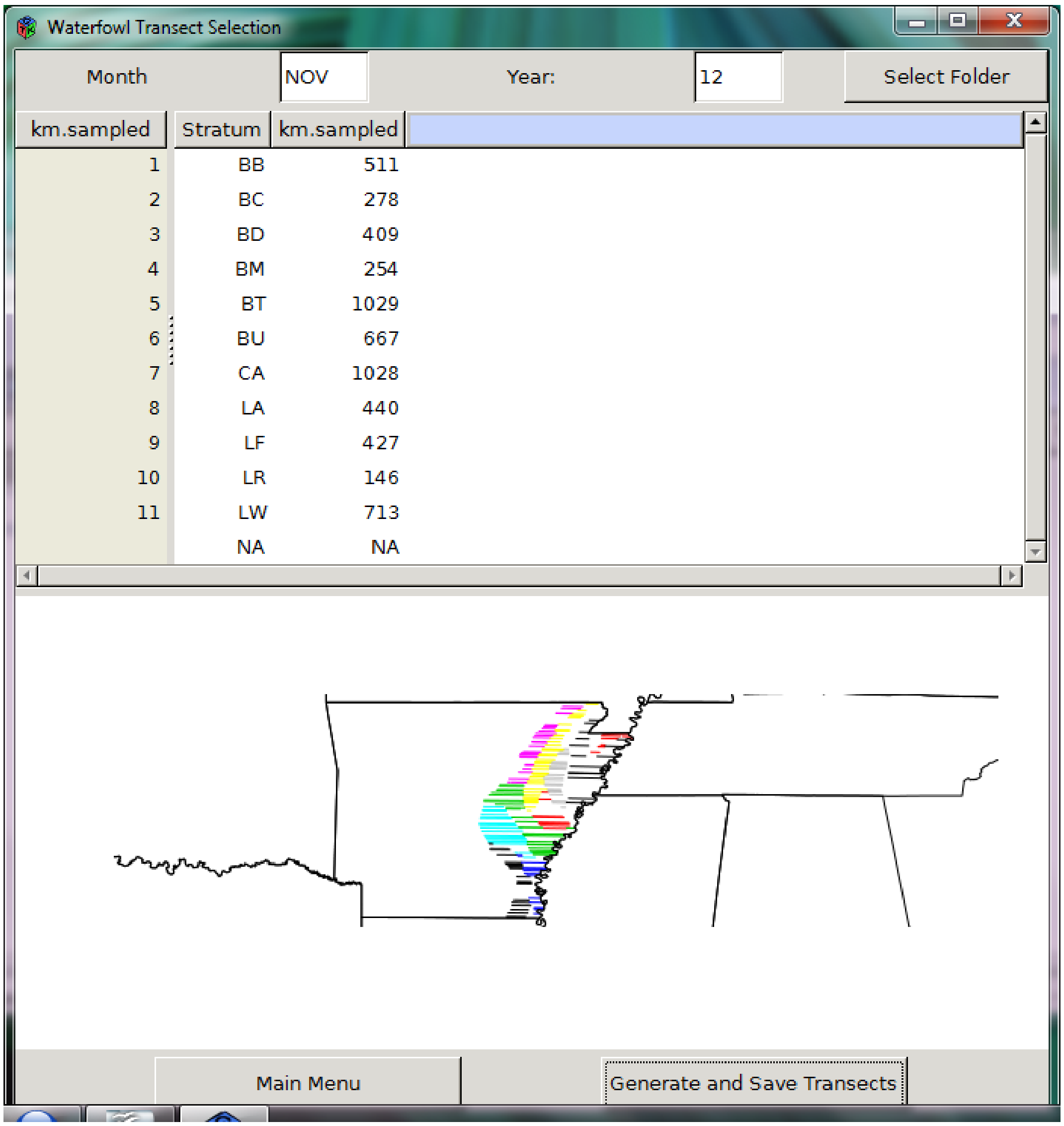
Appendix B1. Screen shot of Main Menu of waterfowl GUI.



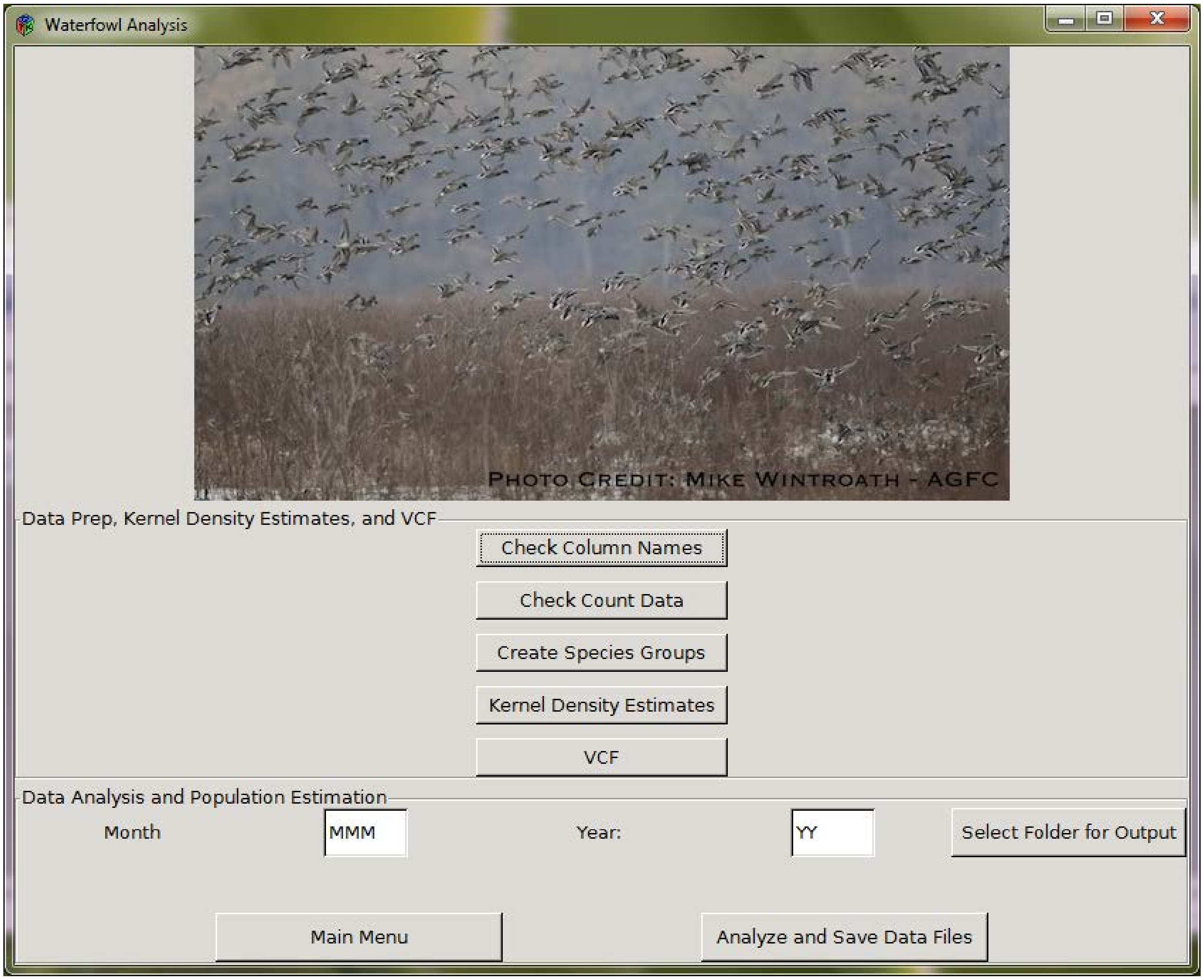
Appendix B2. Screen shot of “Create files for New Survey” in waterfowl GUI. Window asks the location of the transects to be selected.



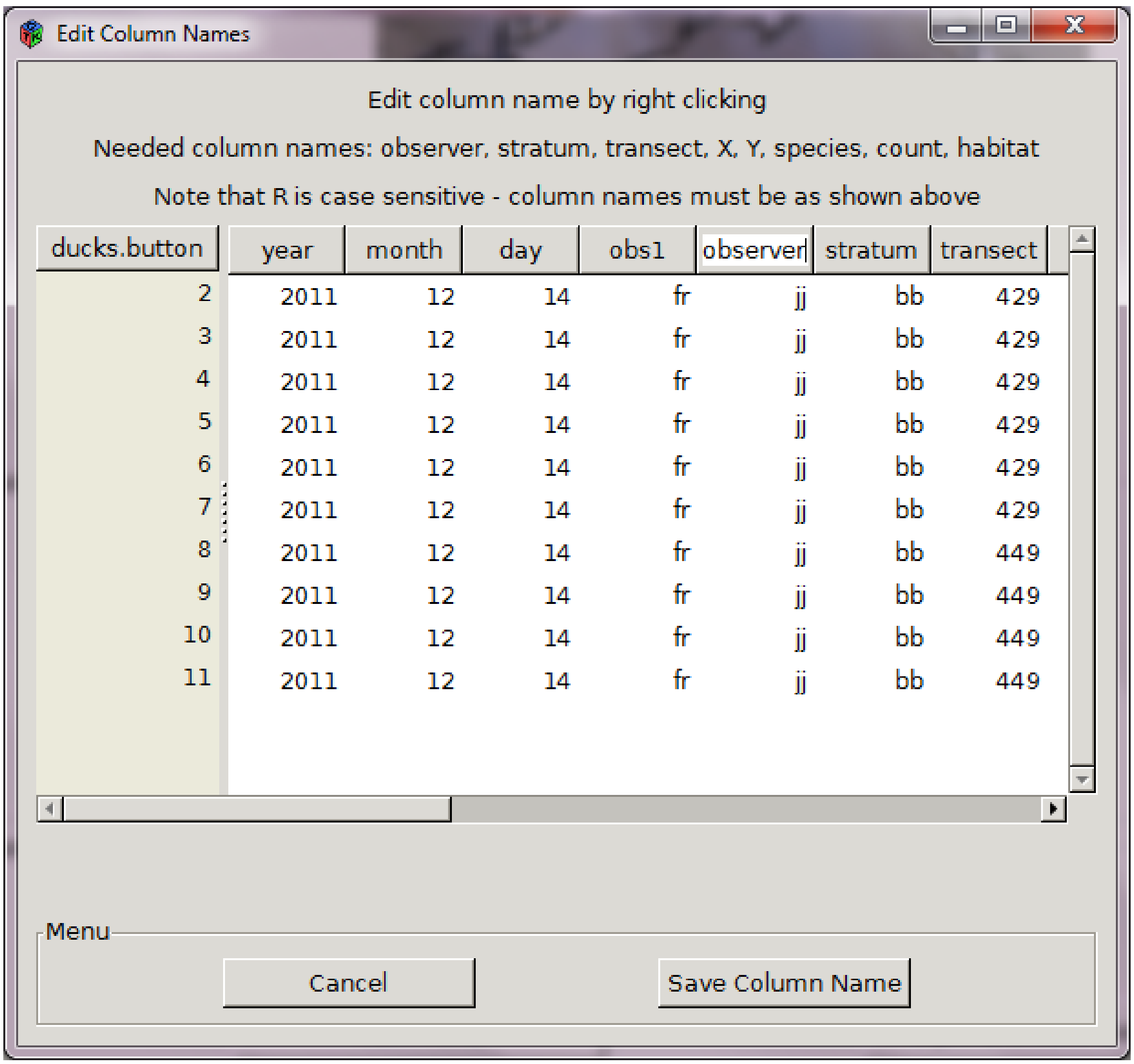
Appendix B3. Screen shot of “Create files for New Survey” in waterfowl GUI. User inputs month and year and selects folder where files should be saved. If desired, user edits total desired km in each strata. After “Generate and Save Transects” button is pressed, GUI outputs five text files: four of these are for input into the “Record” program (or files to be read into GPS unit in the case of Mississippi). A fifth file lists the target and actual total transect lengths in each strata. A shapefile of the randomly selected transects is also saved.



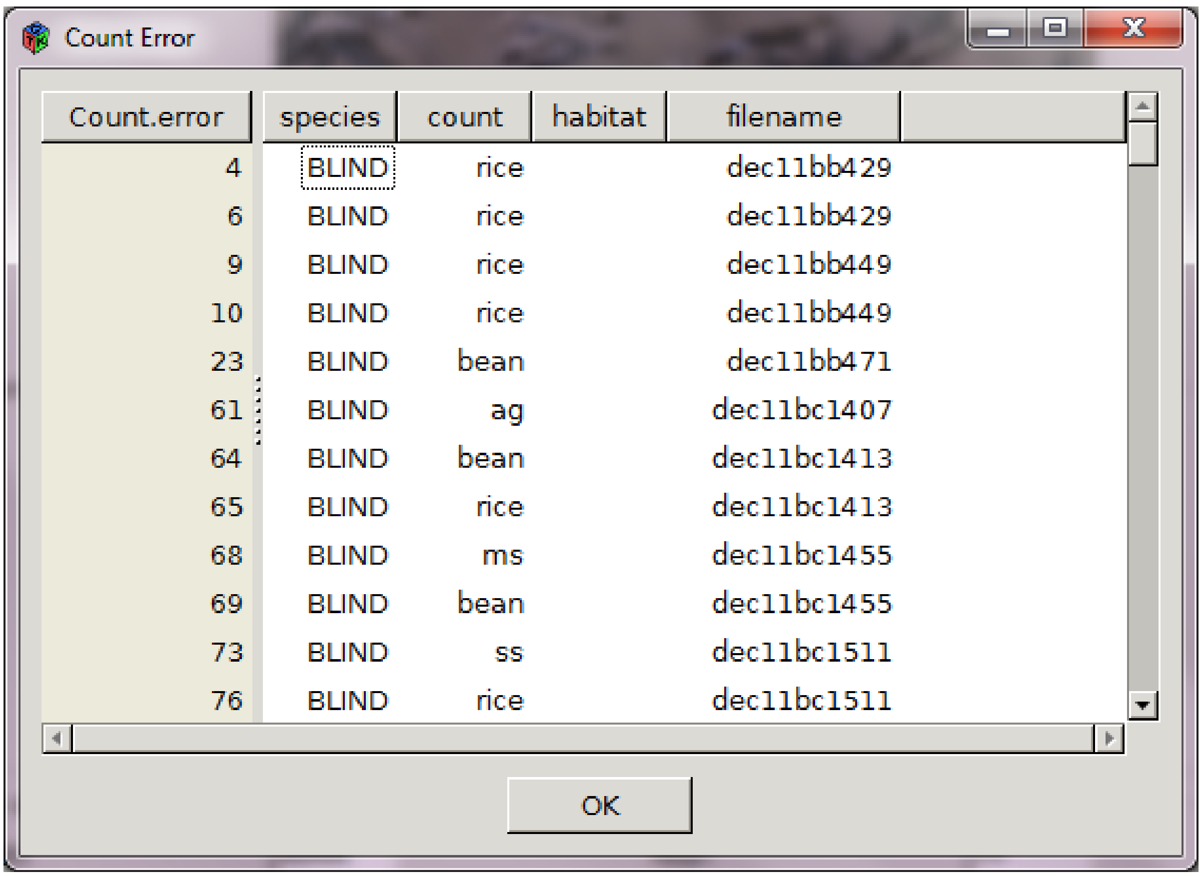
Appendix B4. Screen shot of main analysis window in waterfowl GUI.



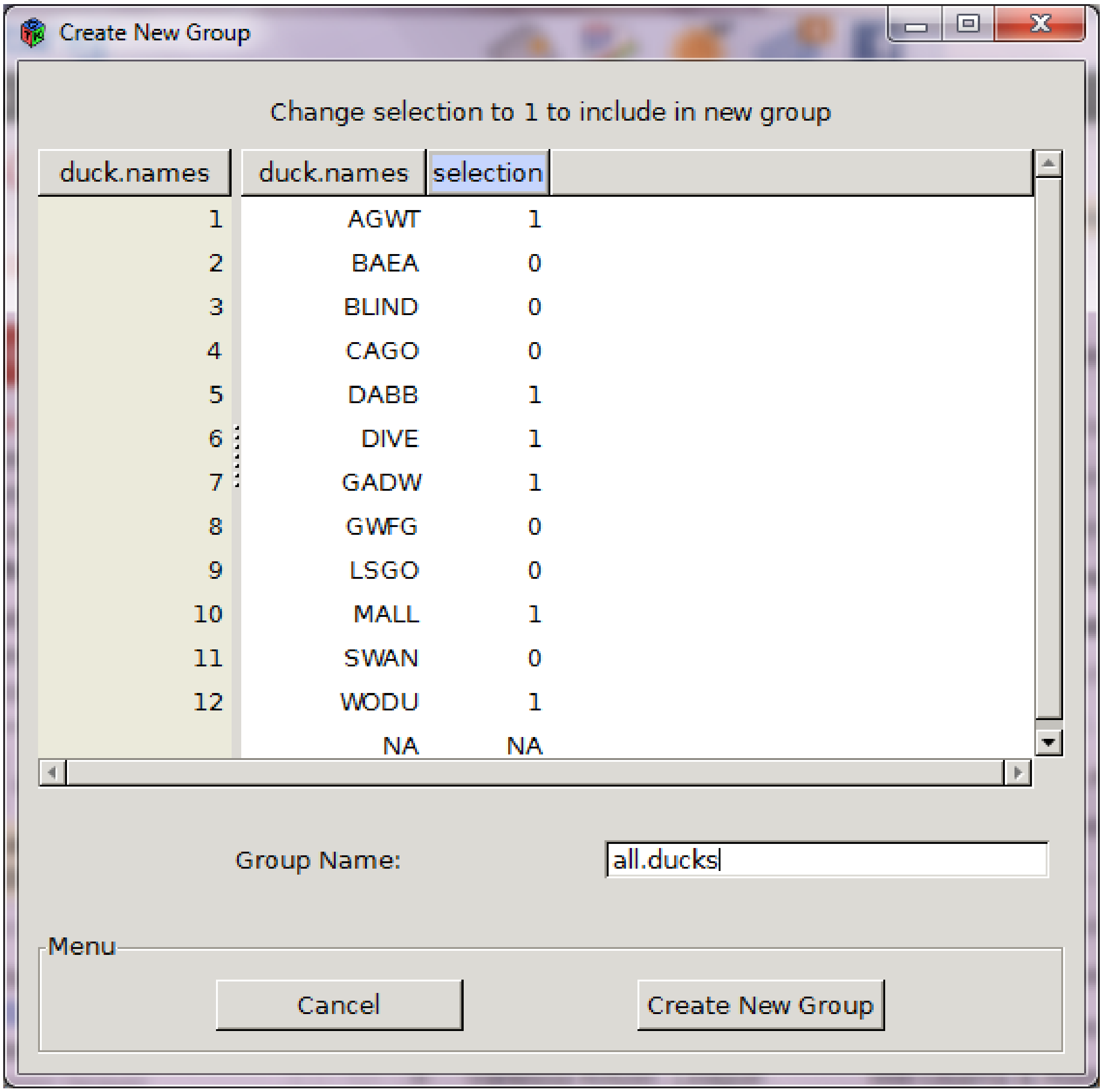
Appendix B5. Screen shot of "Check Column Names" window under the analysis option in the waterfowl GUI. For analysis, the GUI requires eight (8) columns: observer, stratum, transect, X, Y, species, count, and habitat. Because these columns must be named exactly as shown, this window allows the user to edit the column names.



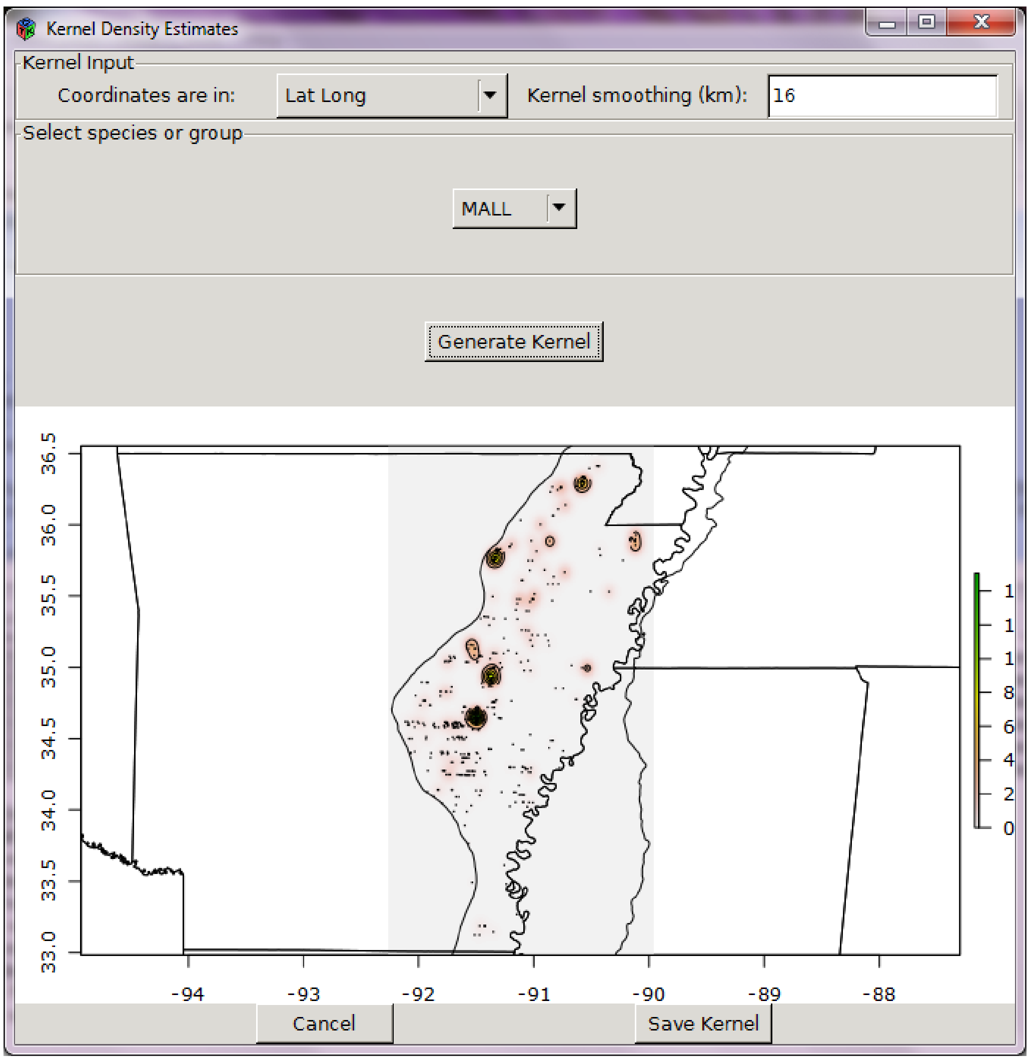
Appendix B6. Screen shot of “Check Count Error” window under the analysis option in the waterfowl GUI. This window displays any non-numeric text that has been entered in the “count” column along with the species, habitat, and file in which the text was located. This allows the user to correct any typos that were inadvertently entered into the data.



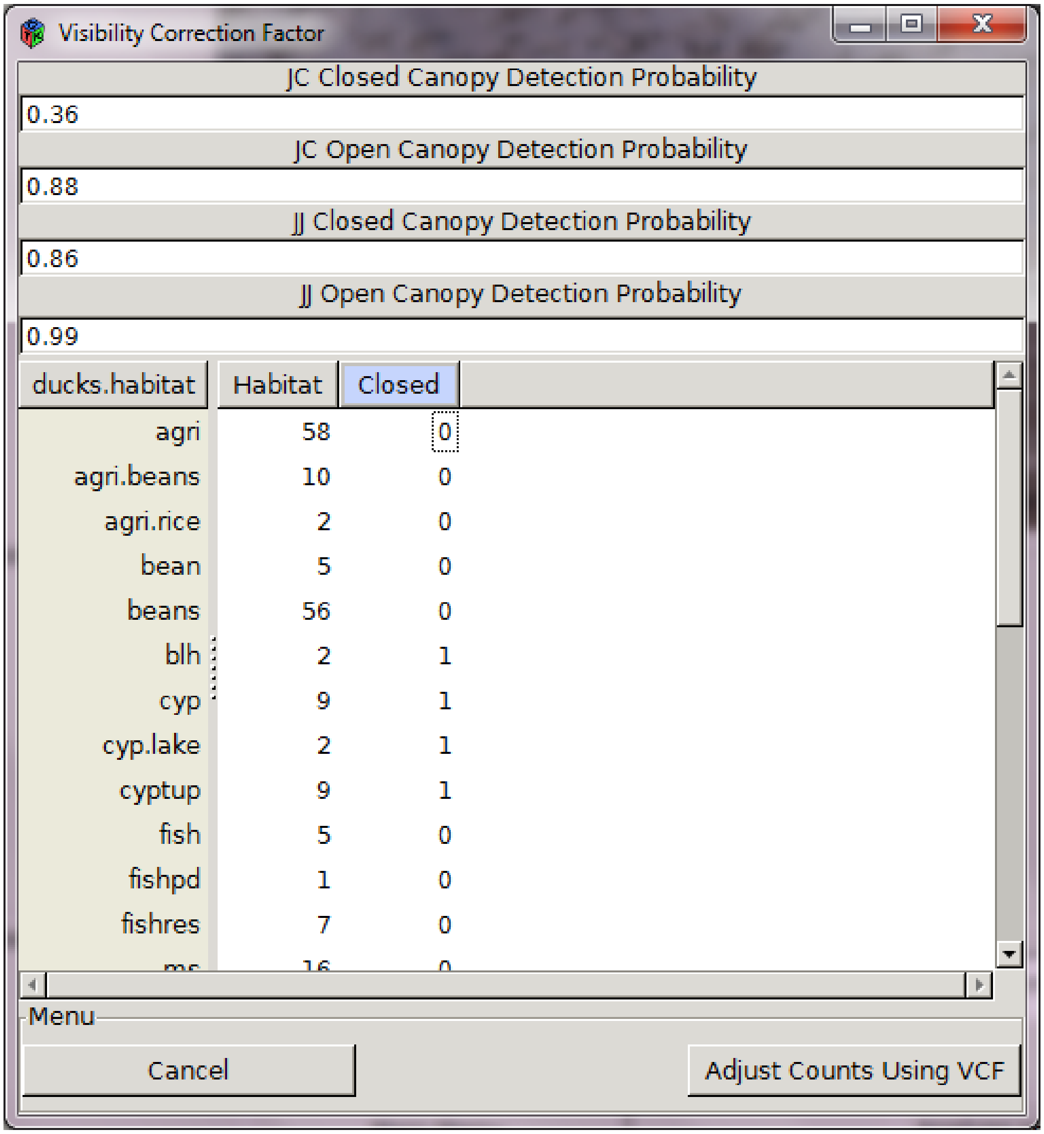
Appendix B7. Screen shot of "Create New Group" window under the analysis option in the waterfowl GUI. This window allows the user to create new groups (e.g. all ducks combined) to be used in the analysis. The user inputs a "1" next to the species to be included in the group and then enters a name for the group.



Appendix B8. Screen shot of “Kernel Density Estimates” window under the analysis option in the waterfowl GUI. This window allows the user to create kernel density estimates for any species or previously created group. The user inputs coordinate type (lat-long or UTM) and smoothing factor (default is 16 km) and selects species or group from pull-down list. Pressing “Generate Kernel” creates the kernel and displays it overlaid a map of the United States. Individual locations are displayed as points. Selecting “Save Kernel” saves a tiff file that can then be imported into a GIS (e.g. ArcGIS).



Appendix B9. Screen shot of "Detection Correction Factor" window under the analysis option in the waterfowl GUI. This window allows the user to adjust for detection bias by observer and canopy cover. The default values were calculated using data collected in the Arkansas MAV during February of 2012. Because these values are observer specific, they should not be used outside of surveys flown by these same observers. The user specifies which habitat types quality as closed canopy by entering a "1" in the "Closed" column.



Appendix B10. Screen shot of main analysis window in the waterfowl GUI. After the user has inspected and cleaned the data, the user can generate estimates of species and total duck numbers. After inputting the month and year (used in naming the output files) and selecting a folder for the generated files, the user selects “Analyze and Save Data Files”. The GUI then generates estimates of species and total duck numbers by strata with SEs and bootstrapped 95% confidence intervals. The GUI also summarizes habitat by % of each species observed in each habitat type and provides a summary of the species observed by transect.