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WATERFOWL FOODS AND USE IN MANAGED GRAIN SORGHUM AND OTHER HABITATS IN THE MISSISSIPPI ALLUVIAL VALLEY

By

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Grain sorghum provides energy-rich seeds for waterfowl. I conducted experiments in 22 sorghum fields in Arkansas, Mississippi, and Louisiana during falls 2006 – 2007 to evaluate abundance of ratoon grain (i.e., second crop after harvest), waste grain, and natural seeds. I also conducted surveys of wintering waterfowl in flooded croplands and moist-soil wetlands to evaluate if ducks and geese differentially used habitats. Fertilized plots in 2007 produced >4 times more ratoon grain ($\bar{x}$ = 219.57 ± 39.65 [SE] kg/ha) than other treatments. Fertilized plots in southern regions of my study area produced ~5 times more ratoon grain ($\bar{x}$ = 262.93 ± 50.28 kg/ha) than others. Mallards and other ducks used moist-soil wetlands ($\bar{x}$ >65 ducks/ha) more than other habitats. I did not observe geese using flooded sorghum. I recommend not manipulating sorghum stubble after harvest, fertilizing, and flooding it after ratoon grain has matured, and integrating moist-soil wetlands into agricultural lands.

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CHAPTER I

POTENTIAL FOODS FOR WINTERING WATERFOWL IN MANAGED GRAIN SORGHUM FIELDS IN THE MISSISSIPPI ALLUVIAL VALLEY

The Mississippi Alluvial Valley (MAV) is an important region for migrating and wintering waterfowl in North America (Reinecke et al. 1989). Originally, the MAV was a vast bottomland hardwood ecosystem extending over 10 million ha, predominantly in Arkansas, Mississippi, and Louisiana (Reinecke et al. 1989, Fredrickson 2005). Since the mid-1800s and especially during the 1960s and 1970s, extensive use of hardwood forests for lumber and clearing forests for agriculture in the MAV caused significant deforestation (Sternitzke 1976). Today, only 2.6 million ha of forest land remain (Twedt and Loesch 1999). Loss and fragmentation of bottomland hardwoods, flood management, agriculture, and other anthropogenic influences may have reduced the capacity of the MAV to support waterfowl populations (Reinecke et al. 1988, Reinecke et al. 1989, Fredrickson 2005, Wilson et al. 2005).

Flooded cropland and waste agricultural seeds (i.e., seeds lost before or during harvest) have partially mitigated loss of historical foraging habitat for waterfowl (Delnicki and Reinecke 1986, Reinecke et al. 1989, Smith et al. 1989, Stafford et al. 2006). However, recent studies report declining availability of waste agricultural seeds in the MAV and Tennessee (Manley et al. 2004, Stafford et al. 2006, Foster 2009). Decreased availability of waste agricultural seeds results from increased harvest efficiency and prolonged periods for seed decomposition and granivory between increasingly early fall harvest times and arrival of wintering waterfowl (Barnes 1994, Manley et al. 2004, Stafford et al. 2006, Foster 2009). Some have suggested increased development and management of alternative foraging habitats to diminish effects of decreased availability of waste grain (Fredrickson 1983, Stafford et al. 2006, Reinecke and Hartke 2005, Kross et al. 2008).

Additionally, burgeoning populations of lesser snow geese (*Chen caerulescens*) wintering in the MAV may influence availability of waste agricultural seeds. Wintering mid-continent snow goose populations have been estimated at 2.5 million birds (U. S. Fish and Wildlife Service 2008), and these populations may decrease food resources for other wintering waterfowl (Abraham and Jefferies 1997). For example, Havens (2007) reported that snow geese may have depleted available waste rice for ducks at a study site in Arkansas.

Although rice, corn, and soybean are dominant row crops producing waste seed for waterfowl in the MAV, grain sorghum (hereafter sorghum) also provides waterfowl forage in this region (Reinecke et al. 1989). Sorghum is grown typically in areas of the United States too dry for corn production. In 2008, approximately 124,000 ha of sorghum was harvested in Arkansas (46,539 ha), Louisiana (44,515 ha), and Mississippi (33,184 ha; National Agricultural Statistics Service 2009). Following harvest, sorghum can regenerate from roots or stalks and produce a second seed head (i.e., ratoon). Harvested ratoon sorghum increased total annual production of grain by 3-4 Mg/ha in some areas of Texas (Gerik et al. 2003). Ratoon sorghum production is possible in the

MAV but generally is not sufficient in quantity or quality to justify commercial harvest (E. J. Larson, Mississippi State University [MSU], personal communication).

Though commercial agricultural production of ratoon sorghum may not be economical in the MAV, ratoon grain may provide food for wintering ducks. Additionally, waste sorghum resulting from harvest and seeds from natural plants growing in sorghum fields can provide food for waterfowl. The availability of chemical herbicides and herbicide-resistant technology (e.g., glyphosate resistance) are more limited for sorghum than other crops (e.g., corn and soybean); thus, natural plants may be more prevalent in sorghum than other croplands (MSU Extension 2006). Sorghum has a metabolizable energy value (ME) of approximately 3.5 kcal/g (dry mass) for ducks, comparable to that of corn (3.6 kcal/g; Kaminski et al. 2003). Common natural seeds have an average ME of approximately 2.5 kcal/g (Kaminski et al. 2003).

Considering decreased abundance of waste agricultural seeds for wintering waterfowl and possible foraging competition for these seeds with snow geese, habitat management to provide supplemental food for wintering ducks is warranted in the MAV (Stafford et al. 2006, Kross et al. 2008). Accordingly, my objectives were to estimate and compare abundances of ratoon sorghum seed, waste sorghum grain, and natural seeds among experimental post-harvest treatments of mowing, crushing, or no manipulation of sorghum stubble, and soil fertilization or not in fields in the MAV.

Study Area

I managed and collected data from 6 sorghum fields in 2006 and 16 fields in 2007 in Arkansas (n = 8), Mississippi (n = 2), and Louisiana (n = 12). I used fields on U.S.

Fish and Wildlife Service National Wildlife Refuges (NWRs; n = 15) and private lands (n = 7), wherein I received assistance from staff and landowners with experimental treatment applications (Table 1.1). I categorized sites as located in northern or southern sub-regions of the MAV based on latitude (Table 1.1). Farmers on NWRs and private lands used standard agricultural production and harvest practices for sorghum production in the MAV. No farmer used a defoliant before harvest.

Methods

Experimental Design and Treatment Application

I used a split-plot randomized block design with one block in each of 22 sorghum fields (Gomez and Gomez 1984). Each block contained 3 0.81-ha plots separated by a 30-m buffer between adjacent plots. I randomly assigned one of 3 post-harvest treatments to each plot within a block (i.e., mow, crush, and no treatment [control] of sorghum stubble). Additionally, I assigned randomly a nitrogen fertilization treatment to half (0.41 ha) of each main plot (~168 kg/ha prilled (pelletized) ammonium nitrate [~57 kg N/ha] or none).

Landowners or NWR staff applied treatments 1-10 days after harvest (8 – 9 September 2006, 8 August – 25 September 2007). Cooperators used a tractor-drawn rotary mower ("bush-hog") to cut sorghum stubble approximately 13 cm above ground for the mowed treatment and pulled a heavy pipe or roller over stubble for the crushed treatment. Cooperators used a spin spreader to apply nitrogen fertilizer immediately after mechanical treatments were applied (hereafter fertilized plots). Ammonium nitrate is not subject to volatilization when broadcast on the soil surface like urea-based nitrogen fertilizers and remains stable until rain incorporates it into the soil.

Field Methods

I began data collection after ratoon crop maturation or first killing frost (3 – 11 November 2006, 2 November – 12 December 2007). I used a 1-m^2 sampling frame and randomly selected 10 sampling sites within each split-plot. I clipped all ratoon sorghum seed heads within the sampling frame and placed them in a labeled bag. I considered any seed head a ratoon if it was attached to a previously cut stalk or a sprout rooted within the sampling frame.

I sampled natural seed and waste grain abundances using a blower-vac and circular plastic sampling frame (12.7-cm diameter × 4 cm tall; Penny et al. 2006). I randomly located the blower-vac within the same 1-m^2 sampling area, vacuumed for 10 seconds (Penny et al. 2006), and placed collected material in a labeled bag. If any portion of a harvested sorghum head was within the circular sampling area, I collected and placed it with the vacuumed material.

Penny et al. (2006) recommended the blower-vac for use on dry soils. If I encountered wet soil conditions, I sampled natural seeds and waste grain using a core sampling technique modified from Ripley and Perkins (1965). I randomly placed the circular frame used with the blower-vac within the 1-m^2 frame and pressed it 1 cm into the soil. I assumed that sampling to this minimal depth decreased the probability of collecting residual seeds from the seed bank (Ripley and Perkins 1965). Then, I extracted wet litter, soil, and seeds from within the circular frame with a metal spatula and placed collected material in a labeled bag. I collected any portion of a sorghum head within the circular frame as described above.

To compare masses of seeds collected using the blower-vac and modified core methods, I collected 40 blower-vac and 40 modified core samples from 4 randomly selected dry-soil sampling locations within sorghum fields at 4 study sites. I randomly placed the blower-vac within the sampling frame and collected samples as described above. Then, not moving the circular frame, I collected samples as described above for the modified core technique; hence, I considered these paired samples. I stored material collected using each device in separate, labeled bags.

Laboratory Methods

I stored all samples in a freezer at -10˚ C until processed. After thawing frozen samples, I placed ratoon sorghum from samples in individual paper bags and dried for 24 hours at 80˚ C. I separated sorghum seeds from any plant material using forceps, dried seeds to a constant mass, and weighed samples (± 0.001 g; Gray et al. 1999). To process vacuumed samples, I separated natural seeds and waste sorghum grain from soil and litter using forceps and dried each separately to a constant mass (± 0.001 g; Gray et al. 1999).

I processed waste grain and natural seed samples collected from wet sites with the modified core sampler using procedures recommended for processing soil cores (Kross et al. 2008). I thawed and soaked frozen samples in a mixture of a 3% solution of hydrogen peroxide (H_2O_2), ≤ 250 cm^3 of baking soda, and ≤ 1 L of water for approximately 1 hour to oxidize clays. Kross et al. (2008) reported this mixture did not bias mass estimates of moist-soil seeds; thus, we assumed it did not bias mass estimates of similar seeds and waste sorghum grain. I rinsed thawed samples through sieves (Nos. 6 [3.35 mm], 18 [1.00 mm], and 50 [300 µm]), collected material from sieves, and allowed it to dry in open air for 48 hours. Then, I separated sorghum and natural seeds and processed components as described above. Finally, I processed components of paired blower-vac and core samples as described above.

Statistical Methods

Ratoon sorghum seeds. I deleted 3 plots (each from different blocks) from analyses because 1) weather prohibited treatment application to one plot, 2) feral hog damage prohibited random selection of sample sites within one plot, and 3) data were recorded incorrectly in the laboratory for one plot. I calculated mean kg/ha (dry mass) of ratoon sorghum grain from 5 or 10 subsamples processed from each experimental treatment-fertilizer combination in all 22 blocks and performed statistical analyses on split-plot means. I used PROC MIXED in SAS 9.2 for all analyses and designated $\alpha = 0.05$. Project financial constraints required me to process 5 instead of 10 subsamples from 36 (38%) of 96 half-plots. I used outcomes of ANOVA tests for effects of experimental treatments and interactions to evaluate effect of computing half-plot means from either 5 or 10 subsamples. F-statistics and p-values were similar and conclusions were the same using either 5 or 10 subsamples. Therefore, I calculated means using maximum number of available processed subsamples (i.e., $n = 5$ or 10) for all analyses hereafter. I designated post-harvest treatment, fertilization, sub-region (i.e., north or south), and year as fixed effects and site and block (nested within site) as random effects.

I tested all main effects and interactions but removed non-significant interactions for final inference.

Waste sorghum and natural seeds. I compared masses of waste grain and natural seeds collected by modified core sampler and blower-vac using a paired *t*-test (Freund and Wilson 2003). The modified core sampler collected more waste grain and natural seed than the blower-vac ($t_{37} > 2.0$, $P < 0.009$); thus, I plotted mass of waste grain and natural seed collected using the blower-vac against each of these collected via the core sampler, validated linearity, and used simple linear regression to estimate mass of each seed type collected by each device. I desired to estimate the seed mass collected by the blower-vac because it is designed to collect seeds on the soil surface and thus likely those produced during the current growing season (Penny et al. 2006). Mass of waste grain and natural seed collected using the blower-vac was correlated with mass collected using the modified core (i.e., waste grain: slope = 0.8426, y-intercept = -0.0011, $r^2 = 0.96$, $n = 37$; natural seeds: slope = 0.6702, y-intercept = – 0.0026, $r^2 = 0.63$, $n = 37$). I used these equations to adjust waste grain and natural seed abundance and calculated half-plot means from these data.

I calculated mean abundance (kg/ha) of waste grain sorghum and natural seeds from 10 samples collected from each treatment combination within 22 blocks and performed statistical analyses on half-plot means. I designated post-harvest treatment, sub-region, and year as fixed effects and site and block (nested in site) as random effects. I did not consider post-harvest nitrogen fertilization in analyses of waste grain because its abundance is related to combine and harvest operations and not post-harvest fertilization.

I tested main effects and interactions but removed non-significant interactions for final inference. I used a priori $\alpha = 0.05$ for all statistical tests.

Duck energy days. I calculated DEDs (Reinecke et al. 1989) as:

$$DED = \sum_{i=1}^{n}\left(\frac{(mass_i - [FT \times pM_i]) \times 1000g/kg \times TME_i}{DER}\right)$$

where:

DED	=	carrying capacity (DED/ha),
n	=	total number of food sources,
$mass_i$	=	mean mass (kg/ha) of food source *i*,
FT	=	assumed foraging threshold (Greer et al. 2009; 50 kg/ha),
pM_i	=	proportion of $mass_i$ to total seed mass,
TME_i	=	true metabolizable energy of food source *i* (kcal/g; Kaminski et al. 2003), and
DER	=	average daily energy requirement of dabbling ducks (294.35 kcal/g; cf., Miller and Eadie 2006, K. J. Reinecke, U.S. Geological Survey, personal communication).

Results

Ratoon Sorghum Seeds

I detected a fertilization by year interaction on mean abundance of ratoon grain ($F_{1,\,108} = 11.30$, $P = 0.011$). Fertilized plots in 2007 produced over 4 times more ratoon grain ($\bar{x} = 219.57$ kg/ha ± 39.65 [SE] kg/ha) than non-fertilized plots in 2007 ($\bar{x} = 53.23$ kg/ha ± 11.43; $t_{108} = 5.76$, $P < 0.001$) and fertilized ($\bar{x} = 15.27$ kg/ha ± 6.20; $t_{108} = -3.69$,

P = 0.004) and non-fertilized plots in 2006 ($\bar{x}$ = 29.06 kg/ha ± 12.71; t_{108} = 3.34, P = 0.001). I also detected an interaction between fertilizer and sub-region ($F_{1, 108}$ = 18.12, P < 0.001). Fertilized plots at southern sites produced nearly 5 times more ratoon grain than non-fertilized plots at these sites ($\bar{x}$ = 262.93 kg/ha ± 50.28 vs. 55.07 kg/ha ± 14.63; t_{108} = 5.07, P < 0.001) and fertilized plots and non-fertilized plots at northern sites ($\bar{x}$ = 41.87 kg/ha ± 8.50, t_{108} = -2.81, P = 0.006; $\bar{x}$ = 36.07 kg/ha ± 9.2; t_{108} = 2.50, P = 0.014). I did not detect a difference in mean ratoon grain abundance among post-harvest treatments ($F_{2, 108}$ = 0.38, P = 0.687; Table 1.2).

Waste Sorghum and Natural Seeds

Mean abundance of waste grain was 109.84 ± 36.50 kg/ha. I did not detect any effects of mechanical treatment ($F_{2, 47}$ = 0.05, P = 0.950), year, or sub-region on abundance of waste grain ($F_{1, 47} \leq$ 2.04, P > 0.160).

Southern sites ($\bar{x}$ = 16.36 kg/ha ± 2.70; $F_{1, 109}$ = 4.07, P = 0.046) produced more natural seed than northern sites ($\bar{x}$ = 15.05 kg/ha ± 3.53;). I did not detect effects of mechanical treatment ($F_{2, 109}$ = 0.04, P = 0.954) or fertilizer ($F_{1, 109}$ = 2.18, P = 0.143) on abundance of natural seeds.

Duck Energy Days

I calculated DEDs using mean ratoon abundance from fertilized fields at southern sites in 2007, overall mean waste grain abundance, and mean natural seed abundance at southern sites. This combination represents the statistically greatest food resources available as determined by this study. Such a field has potential to produce 5,035 DEDs/ha.

Discussion

Differences in rainfall amounts between years of my study may have affected production of ratoon grain and explain the observed fertilizer by year interaction. My study sites were in counties classified as severely dry to normal during May – August 2006 (National Climatic Data Center [NCDC] 2007). During August – November 2006, these counties were normal. Specifically, these counties were severely to moderately dry in July 2006 which is an important month in grain development (Vanderlip 1993, NCDC 2007). In 2007, northern counties were classified normal to moderately dry and southern counties were normal during the initial growing season (NCDC 2008). During the 2007 ratoon growing season, all counties were normal to wet (NCDC 2008).

Though grain sorghum is drought resistant, moisture stress during certain growing stages can negatively impact initial grain production (Vanderlip 1993), and a large ratoon crop rarely follows a poor initial crop (Livingston and Coffman 1997). Water stress and rainfall timing also can negatively affect ratoon grain production and delay maturation (Touchton and Martin 1981). Additionally, rainfall timing can influence effectiveness of supplemental nitrogen fertilization (MSU Extension 2009). Ammonium nitrate fertilizer is advantageous because it does not volatize; however, it must be incorporated into the soil by rain or it will not be available to the plant (MSU Extension 2009).

I did not quantitatively examine potential effects of dates of harvest and application of treatments because these varied and could not be controlled among sites.

However, dates of harvest and subsequent treatment application may have influenced ratoon production and partially explain sub-region by year interaction. In 2006, I applied treatments at all sites in 2 days (8 – 9 September). In 2007, I applied treatments over 42 days because crops were harvested between 15 August and 25 September. In 2007, I applied treatments at all southern sites within 3 days (15-17 August) but over 34 days at northern sites (22 August – 25 September). Ratoon grain yield may have been negatively impacted at sites that did not produce mature ratoon crops before frost occurred (Touchton and Martin 1981).

Growing degree days (GDDs) also varied between years and sub-regions of my study and could explain interactions involving both sub-regions and year. GDDs are a measure of reference and are calculated using maximum and minimum degree of day and (for sorghum) a base temperature of 60˚F (GDD60; Reddy et. al 1996). To produce a mature crop, from plant emergence to grain maturity, sorghum requires approximately 2000 GDD60, approximately 800 – 850 after bloom (E. J. Larson, MSU, personal communication). To produce a mature ratoon crop, sorghum requires approximately 800 GDD60 after harvest (E. J. Larson, MSU, personal communication).

In 2006, northern sub-region sites accumulated approximately 86 GDD60 between harvest and data collection (MSU Extension 2009). In 2007, these sites accumulated ~407 GDD60 in the same time frame (MSU Extension 2009). Sites did not accumulate enough GDD60 either year to produce a mature crop; however, in 2007 the additional GDD60 were enough to produce food resources even without reaching maturity. Sites in the southern sub-region accumulated ~634 GDD60 in 2006 between harvest and data collection and ~1210 GDD60 in 2007 during the same time frame (MSU Extension 2009). In both years, abundant crops were produced though it is likely that grain did not reach maturity in 2006. The ability of southern sub-region sites to accumulate more GDDs after harvest may make southern sub-region sites more likely to produce substantial ratoon crop.

Waste grain and natural seeds provided little potential food for waterfowl (i.e., < 130 kg/ha). Grain sorghum producers that manage fields for production agriculture strive to decrease abundance of these resources (MSU Extension 2006). Abundance of waste grain was more than two times the current estimate of “giving up density” (Greer et al. 2009); however, much of this grain may have decomposed before waterfowl arrived on wintering grounds (Foster 2009). Abundance of natural seeds in sub-regions were well below giving up density and likely made no biological contribution to available food for wintering waterfowl.

Management and Research Implications

If managers attempt a ratoon sorghum crop for harvest, the decision must be carefully considered (Livingston and Coffman 1997). However, when attempting to ratoon sorghum for wildlife, any production is critical because few food resources (i.e., waste grain and natural seeds) are present otherwise. Nitrogen fertilization increases ratoon yield and should be applied under the best moisture conditions possible. I did not detect a treatment effect of stubble manipulation and manipulation would incur unnecessary labor and expense, therefore I recommend leaving stubble standing after harvest.

Leaving a portion of the initial grain crop unharvested would be desirable (Foster 2009) because ratoon yield can vary depending upon environmental conditions, and fields with little sorghum ratoon produce low DEDs. Though decomposition depletes waste sorghum by January, unharvested sorghum left standing decomposes at a much lesser rate (Foster 2009). Decreased rates of decomposition likely apply to standing ratoon grain as well. Managers also may consider seeding harvested sorghum fields with commercially available millets (e.g., *Panicum ramosum*; Atkeson and Givens 1952). Many millets mature in approximately 60 days and thus would produce a fall crop before frost and provide additional food sources to waterfowl.

Farmers and wildlife managers should consider hybrid of sorghum planted to optimize ratoon production (Touchton and Martin 1981). Hybrids that mature early, require fewer GDDs, or can tolerate early planting could increase the time between harvest and frost. Increased time could allow ratoon grain to reach maturity before frost and thereby increase ratoon yields. Farmers and managers should consult local crop agronomists to determine proper variety selection.

LITERATURE CITED

Abraham, K. F., and R. L. Jefferies. 1997. High goose populations: causes, impacts and implications. Pages 7-22 *in* B. J. D. Batt, editor. Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture special publication, U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ontario.

Atkeson, T. Z., and L. S. Givens. 1952. Upland farming as a method of supplementing the natural waterfowl food supply in the Southeast. Journal of Wildlife Management 16:442-446.

Barnes, H. 1994. California strips rice and sets new record. Rice Journal 97:13.

Delnicki, D., and K. J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. Journal of Wildlife Management 50:43-51.

Foster, M. A. 2009. Abundances and losses of agricultural seeds for waterfowl in Tennessee. Thesis, University of Tennessee – Knoxville, Knoxville, Tennessee, USA.

Fredrickson, L. H. 2005. Contemporary bottomland hardwood systems: structure, function and hydrologic condition resulting from two centuries of anthropogenic activities. Pages 19-35 *in* L. H. Fredrickson, S. L. King, and R. M. Kaminski, editors. Ecology and management of bottomland hardwood systems: the state of our understanding. University of Missouri-Columbia, Gaylord Memorial Laboratory Special Publication No. 10, Puxico, Missouri, USA.

Fredrickson, L. H. 1983. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service, Resource Publication 148.

Freund, R. J., and W. J. Wilson. 2003. Statistical methods. Second edition. Academic Press. Boston, Massachusetts, USA.

Gerik, T., B. Bean, and R. Vanderlip. 2003. Sorghum growth and development. Texas Cooperative Extension and The Texas A&M University System, Temple, USA.

Greer, D. M., B. D. Dugger, K. J. Reinecke, and M. J. Petrie. 2009. Depletion of rice as food of waterfowl wintering in the Mississippi Alluvial Valley. The Journal of Wildlife Management 73:in press.

Gomez, K. A., and A. A. Gomez. 1984. Statistical procedures for agriculture research. Second edition. John Wiley & Sons, Inc., Hoboken, New Jersey, USA.

Gray, M. J., R. M. Kaminski, and G. Weerakkody. 1999. Predicting seed yield of moist-soil plants. Journal of Wildlife Management 63:1261-1268.

Havens. J. H. 2007. Winter abundance of waterfowl, waterbirds, and waste rice in managed Arkansas rice fields. Thesis, Mississippi State University, Starkville, USA.

Kaminski, R. M., J. B. Davis, H. W. Essig, P. D. Gerard, and K. J. Reinecke. 2003. True metabolizable energy for wood ducks from acorns compared to other waterfowl foods. Journal of Wildlife Management 67:542-550.

Kross, J., R. M. Kaminski, K. J. Reinecke, E. J. Penny, and A. T. Pearse. 2008. Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley. Journal of Wildlife Management 23:707-714.

Livingston, S. D., and C. G. Coffman. 1997. Ratooning grain sorghum on the Texas gulf coast. Texas Agricultural Extension Service, College Station, Texas, USA.

Manley, S. W., R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. 2004. Waterbird foods in winter managed rice fields in Mississippi. Journal of Wildlife Management 68:74-83.

Miller, M. R., and J. McA. Eadie. 2006. The allometric relationship between resting metabolic rate and body mass in wild waterfowl (Anatidae) and an application to estimation of winter habitat requirements. The Condor 108:166-177.

MSU Extension. 2006. Crops: sorghum. <http://msucares.com/cropssorghum/index.html>. Accessed 15 March 2007.

MSU Extension. 2009. Weather reports. <http://ext.msstate.edu/anr/drec/stations.cgi>. Accessed 15 September 2009.

MSU Extension. 2009. Fertilizer management. <http://msucares.com/crops/fertilizer/index.html>. Accessed 2 May 2009.

National Agricultural Statistics Service [NASS]. 2009. Quick Stats.

<http://www.nass.usda.gov/QuickStats/Create_Federal_All.jsp>. Accessed 5 May 2009.

National Climatic Data Center [NCDC]. 2007. Climate of 2006 annual review U.S. drought. <http://www.ncds.noaa.gov/oa/climate/research/2006/ann/drought-summary.html>. Accessed 27 March 2009.

National Climatic Data Center [NCDC]. 2008. Climate of 2007 annual review U.S. drought. <http://www.ncds.noaa.gov/oa/climate/research/2007/ann/drought-summary.html>. Accessed 20 May 2009.

Penny, E. J., R. M. Kaminski, and K. J. Reinecke. 2006. A new device to estimate abundance of moist-soil plant seeds. Wildlife Society Bulletin 34:186-190.

Reddy, K. R., H. F. Hodges, W. H. McCarty, and J. M. McKinion. 1996. Weather and cotton growth: present and future. Bulletin 1061. Divistion of Agriculture, Forestry, and Veterinary Medicine, Mississippi State University.

Reinecke, K. J., and K. M. Hartke. 2005. Estimating moist-soil seeds available to waterfowl with double sampling for stratification. Journal of Wildlife Management 69:794-799.

Reinecke, K. J., R. C., Barkley, and C. K. Baxter. 1988. Potential effects of changing water conditions on mallards wintering in the Mississippi Alluvial Valley. Pages 325-337 *in* M. W. Weller, editor. Waterfowl in winter. University of Minnesota Press, Minneapolis, Minnesota, USA.

Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pages 203-247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Ripley, T. H., and C. J. Perkins. 1965. Estimating ground supplies of seed available to bobwhites. Journal of Wildlife Management 29:117-121.

Smith, L. M., R. L. Pederson, and R. M. Kaminksi, editors. 1989. Habitat management for migrating and wintering waterfowl in North America. Texas Tech Universtiy Press, Lubbock, Texas, USA.

Stafford, J. D., R. M. Kaminski, K. J. Reinecke, and S. W. Manley. 2006. Waste rice for waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 70:61-69.

Sternitzke, H.S. 1976. Impact of changing land use on Delta hardwoods. Journal of Forestry 74:25-27.

Touchton, J. T., and P. B. Martin. 1981. Response of ratooning grain sorghum to nitrogen fertilizer and insecticides. Agronomy Journal 73:298-300.

Twedt, D. J., and C. R. Loesch. 1999. Forest area and distribution in the Mississippi Alluvial Valley: implications for breeding bird conservation. Journal of Biogeography 26:1215-1224.

U. S. Fish and Wildlife Service. 2008. Waterfowl population status. Division of Migratory Bird Management, Laurel, Maryland, USA.

Vanderlip, R. L. 1993. How a sorghum plant develops. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, USA.

Weisz, P. R., R. F. Denison, and T. R. Sinclair. 1985. Response to drought stress of nitrogen fixation (acetylene reduction) rates by field-grown soybeans. Plant Physiology 78:525-530.

Wilson, R. R., J. M. Oliver, D. J. Twedt, and W. B. Uihlein. 2005. Bottomland hardwood restoration in the Mississippi Alluvial Valley: looking past the trees to see the forest. Pages 519-526 *in* L. H. Fredrickson, S. L. King, and R. M. Kaminski, editors. Ecology and management of bottomland hardwood systems: the state of our understanding. University of Missouri-Columbia, Gaylord Memorial Laboratory Special Publication No. 10, Puxico, Missouri, USA.

Table 1.1 Study sites on National Wildlife Refuges (NWRs) and private lands in 2006 and 2007 in northern (>34° N) and southern sub-regions of the Mississippi Alluvial Valley.

Site	Latitude/longitude	Nearest city
Cache River NWR[a,b]	35˚ 04' 45" N, 91˚ 21' 45" W	Augusta, Arkansas
Shadwick Farm[b]	34˚ 23' 31" N, 91˚ 21' 45" W	Ethel, Arkansas
York Woods[b]	34˚ 2' 8" N, 90˚ 10' 17" W	Greenville, Mississippi
Duck Creek[b]	31˚ 45' 32" N, 91˚ 37' 59" W	Clayton, Louisiana
Grand Cote NWR[a,b]	31˚ 6' 34" N, 91˚ 8' 16" W	Marksville, Louisiana
Lake Ophelia NWR[b]	31˚ 31' N, 91˚ 54' 49" W	Marksville, Louisiana

[a]Study site in 2006.

[b]Study site in 2007.

Table 1.2. Ratoon grain sorghum abundance (kg/ha) by all combinations of experimental factors evaluated in southern (<34° N latitude) and northern (>34° N latitude) sub-regions of the Mississippi Alluvial Valley.

			Treatments								
			Control			Mow			Crush		
Sub-region	Fertilization (F) or none (N)	Year	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*
South	F	2006	4.9	0.8	3	0.0	0.0	3	0.0	0.0	3
		2007	202.2	40.9	8	397.9	96.7	8	458.2	122.8	9
	N	2006	7.3	7.6	3	0.0	0.0	3	0.0	0.0	3
		2007	84.0	30.0	8	70.8	46.2	8	68.0	22.1	9
North	F	2006	57.4	22.5	3	8.4	6.0	3	20.9	14.1	3
		2007	100.2	15.5	7	22.0	14.8	6	17.3	6.5	6
	N	2006	121.5	45.9	3	5.1	5.1	3	40.4	19.9	3
		2007	63.3	16.1	7	0.9	0.5	6	13.8	8.4	7

CHAPTER II

WATERFOWL USE OF FLOODED CROPLANDS AND WETLANDS IN THE MISSISSIPPI ALLUVIAL VALLEY

The Mississippi Alluvial Valley (MAV) is an important region for migrating and wintering waterfowl in the southern Mississippi Flyway (Reinecke et al. 1989). Originally, the MAV was extensively covered by bottomland hardwood forests that flooded naturally, but today <25% of the MAV is forested and most has been converted to agricultural land (Reinecke et al. 1989, Fredrickson 2005). Waterfowl have adapted to landscape and hydrological changes, and agricultural seeds are a large component of wintering waterfowl diets (Delnicki and Reinecke 1986, Smith et al. 1989, Combs and Fredrickson 1996).

The North American Waterfowl Management Plan (NAWMP) and the Lower Mississippi Valley Joint Venture (LMVJV) have developed conservation plans and wetland management strategies based on use of flooded croplands by waterfowl and estimates of available agricultural seeds (LMVJV Management Board 1990). However, recent research suggests abundance of waste rice and other agricultural seeds (i.e., seeds lost before or during harvest) has declined since the 1980s (Manley et al. 2004, Stafford et al. 2006, Foster 2009). Decreased availability of waste agricultural seeds may be related to increasingly efficient and early fall harvests, decomposition of seeds post-harvest, and granivory by birds and mammals (Barnes 1994, Manley et al. 2004, Stafford et al. 2006, Foster 2009). Additionally, burgeoning populations of lesser snow geese (*Chen caerulescens*) wintering in the MAV may decrease availability of waste seeds. Wintering mid-continent snow goose populations have been estimated at nearly 2.5 million birds (U. S. Fish and Wildlife Service 2008), and these populations may decrease food resources for other wintering waterfowl (Abraham and Jefferies 1997, Abraham et al. 2005, Sherfy and Kirkpatrick 2003). For example, Havens (2007) reported that snow geese may have depleted available waste rice at a study site in Arkansas.

Several managers of National Wildlife Refuges (NWRs) and private waterfowl hunting areas in Louisiana and Mississippi have observed limited use by snow geese of flooded grain sorghum (hereafter sorghum) fields relative to other croplands (e.g., M. Chouinard, Hatchie NWR, personal communication). Researchers have observed snow geese in dry sorghum fields in Texas (e.g., Ballard and Tacha 1995, Dennis 1996), but Glazener (1946) reported few or no snow geese in sorghum fields if rice or corn fields were present nearby. Many waterfowl managers in the MAV desire information on croplands and other wetlands that may be avoided or little used by snow geese yet readily used by ducks. Therefore, I conducted surveys of flooded sorghum, rice, soybean, and moist-soil wetlands on NWRs in Arkansas and Louisiana to evaluate whether ducks and geese differentially used these managed lands.

Study Area

I conducted surveys of waterfowl using flooded croplands and moist-soil wetlands (i.e., natural emergent managed wetlands [Reinecke et al. 1989]) at Cache River and Grand Cote NWRs. Cache River NWR (35˚ 04' 45.88"N, 91˚ 21' 45.11"W) is located

25.7 km south of Augusta, Arkansas. It is 25,091 ha and has 1,740 ha of cropland. In winter 2006-2007, I surveyed 5 flooded sorghum fields, 4 flooded rice fields, 2 flooded soybean fields, and 2 moist-soil units at Cache River NWR. In winter 2007-2008, I surveyed 1 flooded sorghum field, 5 flooded rice fields, 4 flooded soybean fields, and 3 moist-soil units at Cache River NWR. Grand Cote NWR (31˚ 6' 34.59"N, 91˚ 8' 16.20"W) is located 9.2 km south of Marksville, Louisiana. It is 2,459 ha with 825 ha of croplands and 336 ha of managed moist-soil wetlands. In winter 2006-2007, I surveyed one flooded sorghum field, 4 flooded rice fields, one flooded soybean field, and one moist-soil unit. In winter 2007-2008, I surveyed one flooded sorghum field, 3 flooded rice fields, 2 flooded soybean fields, and 2 moist-soil units.

Methods

Survey Methods

At Cache River and Grand Cote NWRs, I surveyed waterfowl in flooded croplands and moist-soil wetlands every 7-10 days during December – February in 2006 – 2007 and 2007 – 2008. I surveyed primarily sanctuary areas within NWRs so human disturbance would be minimal, and so it did not confound comparisons of habitat use by waterfowl. At Grand Cote, waterfowl hunting occurred on 2 fields each winter (i.e., winter 2006-2007, 2 sorghum fields; winter 2007-2008, one sorghum field and 1 soybean field). I conducted surveys of these fields 4-6 days after a hunting event; hence, I assumed previous hunting had negligible influence on waterfowl use. Grand Cote and

Cache River NWRs prohibited morning access to sanctuaries; therefore, I conducted all surveys between 1200 and 1400 h.

I conducted flush surveys as used routinely by NWR biologists (Richard Crossett, Cache River NWR, personal communication). I drove a truck or all-terrain vehicle along roads or levees bordering surveyed fields, never following the same directional route between consecutive surveys. I recorded number and species of all waterfowl that flushed by my presence. While in the field, I also recorded the approximate boundary of flooded, surveyed areas on aerial maps and subsequently used ArcGIS 9.0 to determine area (ha) of flooded and surveyed fields to calculate waterfowl densities.

Statistical Analyses

Mallards (*Anas platyrhynchos*) comprised 51% of all ducks observed (n = 298,730). Second in abundance was American green-winged teal (*A. crecca carolinensis*, 25%). Therefore, I calculated mean density of mallards and combined all other dabbling and diving ducks. I used repeated measures analysis of variance to test the null hypothesis of no difference in mean density of mallards and other ducks among flooded croplands and moist-soil wetlands. I used PROC MIXED in SAS 9.2 for all analyses and designated $\alpha = 0.10$ because of small sample size ($8 \leq n \leq 16$; Tacha et al. 1982). I designated habitat type as a fixed effect, year as a repeated measure, and site as a random effect. If I detected a significant effect, I conducted all pair-wise comparisons of means using differences of least squared means. I did not conduct analysis of snow goose data because their occurrence was low (see results).

Results

I detected a difference in mean density of ducks other than mallards among habitat types ($F_{3, 35} = 3.04$, $P = 0.042$). Mean density of these ducks in moist-soil units ($\bar{x} = 72.37$ ducks/ha ± 14.25 [SE]) was 2 – 3 times greater than in sorghum ($\bar{x} = 33.11$ ducks/ha ± 14.25; $t_{35} = -1.88$, $P = 0.068$), rice ($\bar{x} = 22.48$ ducks/ha ± 10.07; $t_{35} = 2.81$, $P = 0.008$), and soybean ($\bar{x} = 21.99$ ducks/ha ± 13.43; $t_{35} = 2.54$, $P = 0.016$; Figure 1). I did not detect a difference in mean density of mallards among habitat types ($F_{3, 35} = 0.85$, $P = 0.476$; Figure 1). I did not detect a year effect in either group of waterfowl ($F_{1, 35} \leq 0.11$, $P \geq 0.748$). I observed snow geese in 5 different fields; i.e., twice in one flooded rice field ($\bar{x} = 143.05$ geese/ha) and once each in 2 flooded rice fields ($\bar{x} = 738.09$ and 9.57 geese/ha) and 2 moist-soil units ($\bar{x} = 340.06$ and 30.16 geese/ha).

Discussion

Ducks other than mallards used moist-soil units significantly greater than flooded croplands. Mallards also occurred in greatest densities in moist-soil wetlands, but within-habitat variability was large and these differences were not statistically significant (Figure 1). I cannot explain greater use by ducks of moist-soils units than flooded croplands; however, moist-soil wetlands provide diverse plant and animal food resources and microhabitats for roost, courtship, and cover (Paulus 1984, Gray et al. 1999, Kross et al. 2008).

Lack of observations of snow geese in flooded sorghum is consistent with other reports of few or no snow geese in sorghum fields if rice or corn was present nearby (Glazener 1946, Alisauskas et al. 1988, Sedinger 1997). Use of unflooded sorghum by snow geese in Texas was attributed to amount of new vegetation present (i.e., tender sprouts of sorghum); waste grain was unavailable due to disking (Iverson et al. 1985, Ballard and Tacha 1995). Sorghum fields where stubble has been left standing have limited new shoot growth and minimal stalk re-growth compared to fields in which stubble has been manipulated (e.g., disked, mowed) post-harvest (Livingston and Coffman 1997, Ballard and Tacha 1995; cf. Chapter 1, this study). Fall flooding sorghum fields may limit availability of new growth, possibly making these fields less attractive to snow geese than other habitats where waste grain and natural seeds are more abundant (this study, Kross et al. 2008, Foster 2009).

Research and Management Implications

I could not determine cause of increased use of moist-soil units by ducks other than mallards from this study; however, based on my observations and other studies of habitat use by wintering waterfowl (Havens 2007, Pearse 2007, Heath Hagy, Mississippi State University, unpublished data), I recommend managers provide flooded habitats diverse in foraging types (agricultural vs. natural seeds) and vegetation structure (harvested vs. unharvested, open emergent vs. dense emergent). I recommend further study of waterfowl use of post-harvest managed sorghum and other croplands similar to studies conducted in managed rice fields and moist-soil units in the MAV (Havens 2007, Heath Hagy, unpublished data).

Snow geese are able to denude croplands and wetlands of vegetation ("eat-outs"; Atkeson and Givens 1952, Havens 2007). Snow geese move, sometimes long distances, to other feeding sites after eat-outs (Ballard and Tacha 1995). Ballard and Tacha (1995) surveyed over 17,000 ha to evaluate habitat use by snow geese. My survey areas encompassed nearly 3,000 ha. To increase likelihood of observing snow goose use of croplands and other habitats, future researchers may be required to increase survey area and frequency. Additionally, I recommend development of coordinated air and ground surveys to generate reliable estimates of snow goose abundance and habitat use.

Based on herbivorous habits of snow geese (Glazener 1946, Frederick and Klaas 1982, Alisauskas et al. 1988) and the ability of non-manipulated sorghum stubble to produce ratoon grain (Chapter 1), flooded sorghum may be an effective strategy for providing food to wintering ducks rather than snow geese in the MAV. I recommend not manipulating sorghum stubble after harvest (Chapter 1) and flooding sorghum after ratoon seed maturation to a depth beneficial for dabbling and diving ducks (i.e., 20 – 30 cm; Reinecke et al. 1989, Fredrickson 1983).

LITERATURE CITED

Abraham, K. F., and R. L. Jefferies. 1997. High goose populations: causes, impacts and implications. Pages 7-22 *in* B. J. D. Batt, editor. Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture special publication, U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ontario.

Abraham, K. F., R. L. Jefferies, and R. T. Alisauskas. 2005. The dynamics of landscape change and snow geese in mid-continent North America. Global Change Biology 11:841-855.

Alisauskas, R. T., C. D. Ankney, and E. E. Klaas. 1988. Winter diets and nutrition of midcontinental lesser snow geese. Journal of Wildlife Management 52:403-414.

Atkeson, T. Z., and L. S. Givens. 1952. Upland farming as a method of supplementing the natural waterfowl food supply in the Southeast. Journal of Wildlife Management 16:442-446.

Ballard, B. M. and T. C. Tacha. 1995. Habitat use by geese wintering in southern Texas. The Southwestern Naturalist 40:68-75.

Barnes, H. 1994. California strips rice and sets new record. Rice Journal 97:13.

Combs, D. L., and L. H. Fredrickson. 1996. Foods used by male mallards wintering in southeastern Missouri. Journal of Wildlife Management 60:603-610.

Delnicki, D., and K. J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. Journal of Wildlife Management 50:43-51.

Dennis, M. H. 1996. Evaluation of sorghum stubble management alternatives in southern Texas. Thesis, Texas A & M University – Kingsville, Kingsville, Texas, USA.

Foster, M. A. 2009. Abundances and losses of agricultural seeds for waterfowl in Tennessee. Thesis, University of Tennessee – Knoxville, Knoxville, Tennessee, USA.

Frederick, R. B., and E. E. Klaas. 1982. Resource use and behavior of migrating snow geese. Journal of Wildlife Management 46:601-614.

Fredrickson, L. H. 1983. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildlife Service, Resource Publication 148.

Fredrickson, L. H. 2005. Contemporary bottomland hardwood systems: structure, function and hydrologic condition resulting from two centuries of anthropogenic activities. Pages 19-35 *in* L. H. Fredrickson, S. L. King, and R. M. Kaminski, editors. Ecology and management of bottomland hardwood systems: the state of our understanding. University of Missouri-Columbia, Gaylord Memorial Laboratory Special Publication No. 10, Puxico, Missouri, USA.

Glazener, W. C. 1946. Food habits of wild geese on the gulf coast of Texas. Journal of Wildlife Management 10:322-329.

Gray, M. J., R. M. Kaminski, and G. Weerakkody. 1999. Predicting seed yield of moist-soil plants. Journal of Wildlife Management 63:1261-1268.

Havens. J. H. 2007. Winter abundance of waterfowl, waterbirds, and waste rice in managed Arkansas rice fields. Thesis, Mississippi State University, Starkville, USA.

Iverson, G. C., P. A. Vohs, and T. C. Tacha. 1985. Habitat use by sandhill cranes wintering in western Texas. Journal of Wildlife Management 49:1074-1083.

Kross, J., R. M. Kaminski, K. J. Reinecke, E. J. Penny, and A. T. Pearse. 2008. Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley. Journal of Wildlife Management 23:707-714.

Livingston, S. D., and C. G. Coffman. 1997. Ratooning grain sorghum on the Texas gulf coast. Texas Agricultural Extension Service, College Station, Texas, USA.

Lower Mississippi Valley Joint Venture Management Board. 1990. Conserving waterfowl and wetlands: the Lower Mississippi Valley Joint Venture. North American Waterfowl Management Plan, Vicksburg, Mississippi, USA.

Manley, S. W., R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. 2004. Waterbird foods in winter managed rice fields in Mississippi. Journal of Wildlife Management 68:74-83.

Paulus, S. L. 1984. Activity budgets of nonbreeding gadwalls in Louisiana. Journal of Wildlife Management 48:371-380.

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

Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989. Mississippi Alluvial Valley. Pages 203-247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Sedinger, J. S. 1997. Adaptations to and consequences of an herbivorous diet in grouse and waterfowl. The Condor 99:314-326.

Sherfy, M. H., and R. L. Kirkpatrick. 2003. Invertebrate response to snow goose herbivory on moist-soil vegetation. Wetlands 23:236-249.

Smith, L. M., R. L. Pederson, and R. M. Kaminski, editors. 1989. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Stafford, J. D., R. M. Kaminski, K. J. Reinecke, and S. W. Manley. 2006. Waste rice for waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 70:61-69.

Tacha, T. C., W. D. Warde, and E. P. Burnham. 1982. Use and interpretation of statistics in wildlife journals. Wildlife Society Bulletin 10:355-362.

U. S. Fish and Wildlife Service. 2008. Waterfowl population status. Division of Migratory Bird Management, Laurel, Maryland, USA.

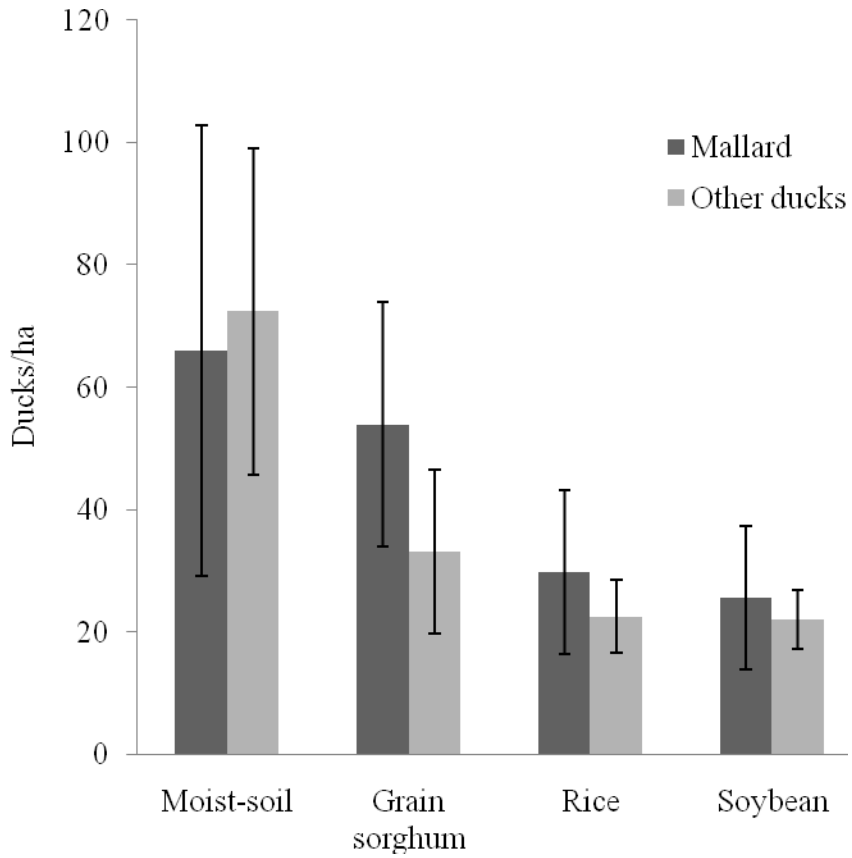

Figure 2.1. Mean density of mallard (*Anas platyrhynchos*) and other ducks per hectare (± SE) in flooded habitats at Cache River and Grand Cote National Wildlife Refuges during December – February 2006 – 2008.

CHAPTER III

EXECUTIVE SUMMARY AND SYNTHESIS

Harvested croplands provide food resources for wintering waterfowl through waste agricultural and naturally occurring seeds (Delnicki and Reinecke 1986, Reinecke et al. 1989, Smith et al. 1989, Stafford et al. 2006). Through advancing harvest technology these food resources are decreasing in abundance (Barnes 1994, Manley et al. 2004, Stafford et al. 2006, Foster 2009). Ratoon, or second crop, grain may provide food resources not traditionally available in harvested grain sorghum (hereafter sorghum) fields. Additionally, burgeoning populations of snow geese may be using resources to the detriment of later-migrating ducks (Abraham and Jefferies 1997, Abraham et al. 2005, Sherfy and Kirkpatrick 2003). However, snow geese may not use flooded sorghum, especially if other flooded crops are available in the area (Glazener 1946, Ballard and Tacha 1995, Dennis 1996). My primary goal was to determine if harvested sorghum can provide food for ducks but not snow geese.

In Chapter 1, I estimated abundance of traditional food resources (waste grain and natural seeds) and evaluated the effectiveness of post-harvest management strategies to produce ratoon grain. I evaluated three post-harvest strategies (mowing, crushing, or not manipulating stubble [control]) based upon standard agricultural practices for producing ratoon grain in Texas and a nitrogen fertilization rate based on recommendations by grain agronomist Dr. Erick Larson, Mississippi State University. I discovered that without ratoon grain, harvested sorghum fields provided little potential food for ducks. In southern regions of my study area, leaving stubble standing after harvest and applying nitrogen fertilizer to produce a ratoon crop increased available waterfowl food resources ~5 fold.

In Chapter 2, I evaluated the use of flooded grain sorghum by ducks and geese. I determined that ducks other than mallards used grain sorghum at similar densities as other flooded croplands (i.e., rice and soybean) but at lesser densities than moist-soil wetlands. Mallards used moist-soil wetlands and flooded crop fields at similar densities. I did not observe snow geese in flooded sorghum fields. However, I observed snow geese so few times I could not make inferences about their use of flooded sorghum.

I determined ducks use flooded sorghum fields similarly to other flooded crops, so it is beneficial to manage sorghum as waterfowl habitat. However, if these fields are traditionally harvested, very little food is available. If stubble is left standing after harvest, nitrogen fertilizer is applied, appropriate growing degree days are accumulated and autumn precipitation or irrigation is possible, a ratoon crop likely will be produced and increased food resources will be available.

LITERATURE CITED

Abraham, K. F., and R. L. Jefferies. 1997. High goose populations: causes, impacts and implications. Pages 7-22 *in* B. J. D. Batt, editor. Arctic ecosystems in peril: report of the Arctic Goose Habitat Working Group. Arctic Goose Joint Venture special publication, U.S. Fish and Wildlife Service, Washington, D.C., and Canadian Wildlife Service, Ottawa, Ontario.

Abraham, K. F., R. L. Jefferies, and R. T. Alisauskas. 2005. The dynamics of landscape change and snow geese in mid-continent North America. Global Change Biology 11:841-855.

Barnes, H. 1994. California strips rice and sets new record. Rice Journal 97:13.

Ballard, B. M. and T. C. Tacha. 1995. Habitat use by geese wintering in southern Texas. The Southwestern Naturalist 40:68-75.

Delnicki, D., and K. J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. Journal of Wildlife Management 50:43-51.

Dennis, M. H. 1996. Evaluation of sorghum stubble management alternatives in southern Texas. Thesis, Texas A & M University – Kingsville, Kingsville, Texas, USA.

Foster, M. A. 2009. Abundances and losses of agricultural seeds for waterfowl in Tennessee. Thesis, University of Tennessee – Knoxville, Knoxville, Tennessee, USA.

Glazener, W. C. 1946. Food habits of wild geese on the gulf coast of Texas. Journal of Wildlife Management 10:322-329.

Manley, S. W., R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. 2004. Waterbird foods in winter managed rice fields in Mississippi. Journal of Wildlife Management 68:74-83.

Reinecke, K. J., R. M. Kaminski, D. J. Moorehead, J. D. Hodges, and J. R. Nassar. 1989.

Mississippi Alluvial Valley. Pages 203-247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, editors. Habitat management for migrating and wintering waterfowl in North America. Texas Tech University Press, Lubbock, Texas, USA.

Sherfy, M. H., and R. L. Kirkpatrick. 2003. Invertebrate response to snow goose herbivory on moist-soil vegetation. Wetlands 23:236-249.

Smith, L. M., R. L. Pederson, and R. M. Kaminksi, editors. 1989. Habitat management for migrating and wintering waterfowl in North America. Texas Tech Universtiy Press, Lubbock, Texas, USA.

Stafford, J. D., R. M. Kaminski, K. J. Reinecke, and S. W. Manley. 2006. Waste rice for waterfowl in the Mississippi Alluvial Valley. Journal of Wildlife Management 70:61-69.