WINTER ABUNDANCE OF WATERFOWL, WATERBIRDS, AND WASTE RICE IN MANAGED ARKANSAS RICE FIELDS

By

James Houston Havens

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Wildlife and Fisheries Science
in the Department of Wildlife and Fisheries

Mississippi State, Mississippi

May 2007

WINTER ABUNDANCE OF WATERFOWL, WATERBIRDS, AND WASTE RICE IN MANAGED ARKANSAS RICE FIELDS

By

James Houston Havens

Approved:

Richard M. Kaminski
Richard M. Kaminski
Professor
Wildlife and Fisheries
(Director of Thesis)

Samuel K. Riffell
Assistant Professor
Wildlife and Fisheries
(Committee Member)

Brian Davis
J. Brian Davis
Regional Biologist
Ducks Unlimited, Inc.
(Committee Member)

Bruce D. Leopold
Professor and Department Head
Wildlife and Fisheries
(Graduate Coordinator)

George M. Hopper
Dean
College of Forest Resources

Name: James Houston Havens

Date of Degree: May 4, 2007

Institution: Mississippi State University

Major Field: Wildlife and Fisheries Science

Major Professor: Dr. Richard M. Kaminski

Title of Study: WINTER ABUNDANCE OF WATERFOWL, WATERBIRDS, AND WASTE RICE IN MANAGED ARKANSAS RICE FIELDS

Pages in Study: 65

Candidate for Degree of Master of Science

Winter flooding harvested rice fields benefits waterfowl, other waterbirds, subsequent agriculture, and soil-water conservation. I conducted experiments in 6 Arkansas rice fields during winters 2004-2005 and 2005-2006 to evaluate effects of different post-harvest, stubble-management practices and flooding on densities of birds and waste rice. During both winters, rolled rice paddies contained the greatest density of mallards (*Anas platyrhynchos*; $\bar{x} = 4.18$ birds/ha/survey, SE = 0.36); burned paddies attracted the most other dabbling ducks ($\bar{x} = 2.29$ birds/ha/survey, SE = 0.46) and geese ($\bar{x} = 2.88$ birds/ha/survey, SE = 0.97). Paddies with standing stubble contained the most waste rice ($\bar{x} = 96.83$ kg/ha, SE = 17.99), but geese may have depleted fields of rice by late December. Nonetheless, waterfowl continued using rice fields during winter. I recommend managers burn and flood rice fields to provide attractive habitat for waterfowl and other waterbirds and reduce stubble economically before spring planting.

ACKNOWLEDGEMENTS

I sincerely appreciate the financial support from the following sponsors of my research: Mississippi Department of Wildlife, Fisheries and Parks; Monsanto Company and Farm and Wildlife Management Center; and the U.S. Department of Interior, Natural Resources Economic Enterprises Research Grant Program. I would like to thank Monsanto Company employees for implementing rice field manipulations for my experiment and for their willingness to cooperate and assist all during my study; specifically, these individuals are Dr. John Anderson, Ray Bohanan, Monty Bohanan, Derek Bohanan, and Shane Roethle.

I am very thankful to have had Dr. Rick Kaminski as my major professor. His patience, wisdom, and encouragement have meant a great deal to me throughout my time at Mississippi State University. Dr. Kaminski has been a great teacher, mentor, and most importantly, a great friend to whom I will be forever grateful.

I thank my graduate committee members for their direction and assistance with my research. Dr. Brian Davis (Ducks Unlimited, Inc.) provided helpful advice during study-site visits, and Dr. Samuel Riffell gave helpful guidance with my statistical analyses. Thank you both for taking time from your busy schedules to work with me. I also thank Dr. Bruce Leopold, Angela Hill, Annice Hill, Steven Tucker, and the rest of the faculty and staff of the Department of Wildlife and Fisheries at Mississippi State

University for often providing help and ensuring that the department kept running smoothly.

I greatly appreciate the technicians and volunteer workers that helped me with field and laboratory duties. Jay Hitchcock helped tremendously throughout my project by constructing observation blinds, marking treatment boundaries, and processing hundreds of core samples. Adam Butler also helped construct observation blinds. I thank Kevin Brunke, Chad Scott, and Bill Sellers for making those long core sampling trips with me and for helping me to smile through it all. Also, I thank everyone else who worked diligently in the laboratory processing a seemingly endless number of core samples. These individuals are James Callicutt, Jason Ellis, Justin Mobley, Suma Pannala, and Jenny Salas. Thank you all for your hard work!

I thank Scott Edwards, Phillip Hanberry, and Jennifer Kross for "showing me the ropes" and getting me settled into the routine of graduate school. I thank Aaron Pearse for his many statistical consultations and help with analyses. I also want to thank all of my fellow graduate students for the friendships and good times we have shared along the way. May we all be hard-working and successful in our careers that follow.

I thank Rachel Ingram for her continuous encouragement and willingness to help in every way possible. Anytime I was frustrated, you helped me through it. Finally, I thank my family for supporting and believing in me throughout my life. My parents, Mark and Anna Frances Havens, have always challenged me to do my very best. Everything I have accomplished, I owe to you. Thank you for your continuous love and support.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS ii

LIST OF TABLES vi

LIST OF FIGURES ix

CHAPTER

I. WATERFOWL AND WATERBIRD USE OF POST-HARVEST MANAGED RICE FIELDS IN ARKANSAS DURING WINTER 1

- STUDY AREA 5
- METHODS 6
  - Experimental Design and Field Methods 6
  - Statistical Analyses 9
    - Density of Waterfowl and Waterbirds 9
    - Density of Mallards Exhibiting Different Activities 10
- RESULTS 11
  - Density of Waterfowl and Other Waterbirds 11
    - Mallards 11
    - Other Dabbling Ducks 12
    - Geese 13
    - Waterbirds 14
  - Density of Mallards Exhibiting Different Activities 15
    - Feeding 15
    - Resting 16
    - Locomotion 17
- DISCUSSION 18
- MANAGEMENT AND RESEARCH IMPLICATIONS 20
- LITERATURE CITED 22

II. WINTER ABUNDANCE OF WASTE RICE IN POST-HARVEST MANAGED RICE FIELDS IN ARKANSAS 30

- STUDY AREA 33
- METHODS 34

CHAPTER Page

Experimental Design and Field Methods 34
Laboratory Methods 35
Statistical Methods 36
RESULTS 38
Waste-Rice Abundance 38
Percentage Change in Waste Rice 39
DISCUSSION 39
MANAGEMENT AND RESEARCH IMPLICATIONS 41
LITERATURE CITED 44

APPENDIX

A 51

LIST OF TABLES

TABLE Page

2.1 Least squares means ($\bar{x}$) and standard errors (SE) for abundance of waste rice (kg/ha, dry mass) in differently managed rice-field paddies (n) post-harvest on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, November 2004-February 2005 49

A.1 Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 52

A.2 Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 53

A.3 Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by other dabbling ducks[a] (Anatini; *n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 54

A.4 Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by other dabbling ducks[a] (Anatini; *n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 55

A.5 Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) combined (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 56

TABLE Page

A.6 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) combined (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 57

A.7 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by waterbirds[a] (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 58

A.8 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by waterbirds[a] (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 59

A.9 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by feeding mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 60

A.10 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by feeding mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 61

A.11 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by resting mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 62

A.12 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by resting mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 63

A.13 Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by mallards (*Anas platyrhynchos*) engaged in locomotion (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 ... 64

TABLE Page

A.14 Mean ($\overline{x}$) indices (and standard errors [SE, *n*]) of diurnal use by mallards (*Anas platyrhynchos*) engaged in locomotion (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006 ... 65

LIST OF FIGURES

FIGURE Page

1.1 Mean ($\bar{x}$) indices (and SE bars) of diurnal use by mallards (*Anas platyrhynchos*) of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006 25

1.2 Mean ($\bar{x}$) indices (and SE bars) of diurnal use by snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) combined of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006 26

1.3 Mean ($\bar{x}$) indices (and SE bars) of diurnal use by waterbirds of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006. Waterbirds consisted of American coot (*Fulica Americana*), common snipe (*Gallinago gallinago*), great blue heron (*Ardea herodius*), great egret (*Ardea alba*), greater yellowlegs (*Tringa melanoleuca*), killdeer (*Charadrius vociferus*), and "peeps" (family Scolopacidae)........ 27

1.4 Mean ($\bar{x}$) indices (and SE bars) of diurnal use by feeding mallards (*Anas platyrhynchos*) of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006 28

1.5 Mean ($\bar{x}$) indices (and SE bars) of diurnal use by resting mallards (*Anas platyrhynchos*) of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006 29

FIGURE Page

2.1 Mean abundance ($\bar{x}$) and standard errors (SE) of waste rice in post-harvest manipulated rice fields (A) and mean indices ($\bar{x}$) of diurnal use by waterfowl (B) and standard errors (SE) of post-harvest manipulated rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005 Horizontal line at 50 kg/ha in Figure 2.1A represents the hypothesized "giving-up" density at which waterfowl cease foraging in rice fields (Reinecke et al. 1989, Rutka 2004). 50

CHAPTER I

WATERFOWL AND WATERBIRD USE OF POST-HARVEST MANAGED RICE FIELDS IN ARKANSAS DURING WINTER

The ecology and management of wintering waterfowl have become increasingly important research and conservation issues since the 1980s (Reinecke 1981, Smith et al. 1989, Baldassarre and Bolen 2006). Previously, most research emphasis and conservation efforts were focused on the breeding grounds of waterfowl because research suggested that breeding season events influenced annual recruitment more than those occurring during other periods of the annual cycle (Heitmeyer and Fredrickson 1981, Kaminski and Gluesing 1987, Batt et al. 1992, Hoekman et al. 2002). Indeed, researchers identified gaps in our knowledge about wintering ecology of waterfowl, including the contribution of winter habitat and intrinsic resources to nutritional requirements, physiological and behavioral processes, survival, and recruitment, and if winter habitats and food resources actually limit waterfowl populations (e.g., Heitmeyer and Fredrickson 1981, Anderson and Batt 1983, Kaminski and Gluesing 1987, Hoekman et al. 2002, Heitmeyer 2006). Although our understanding of ecological relationships between waterfowl and winter seasonal phenomena are incomplete, the North American Waterfowl Management Plan (NAWMP) was established in 1986 and remains the primary ecosystem management plan to conserve critical habitats for Nearctic waterfowl and other wetland-dependent wildlife

(Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986). Under the NAWMP, there are 12 habitat-based ecoregional initiatives in the United States. The Lower Mississippi Valley Joint Venture (LMVJV) is one such initiative implemented to conserve and manage important habitats for migrating and wintering waterfowl primarily in the Lower Mississippi Alluvial Valley (MAV; LMVJV Management Board 1990).

The MAV is a continentally important region for migrating and wintering waterfowl in North America (Reinecke et al. 1989). The NAWMP and several other conservation programs, including the North American Bird Conservation Initiative and Ducks Unlimited's Conservation Plan (2001), have stressed the importance of the MAV as wintering grounds for North American waterfowl and other birds. Historically, the MAV was a vast bottomland-hardwood ecosystem (>10 million ha) that extended from southern Illinois to southern Louisiana (Fredrickson et al. 2005). Overflows of the Mississippi River and its tributaries regularly flooded the MAV during winter and spring (Reinecke et al. 1989). This bottomland ecosystem provided diverse habitat and other resources for waterfowl as well as resident and migratory wetland wildlife (LMVJV Management Board 1990). Flood-management projects dating from the late 1920s to the present have reduced the extent and changed other dynamics of seasonal flooding in the MAV. Additionally, flood management has facilitated forest clearing and conversion of the MAV from largely lowland forests to croplands (Bonney et al. 1999). Despite conversion of most of the MAV forests to agricultural land, it remains a critical ecoregion for migrating and wintering waterfowl. Indeed, waterfowl have adapted to use agricultural and natural foods in the MAV to fulfill physiological needs during winter (Delnicki and Reinecke 1986).

Availability and quality of foraging habitat are central to waterfowl research and conservation planning and implementation in the MAV because scientists and managers assume food availability influences carrying capacity and therefore waterfowl abundance in the MAV during winter (Reinecke et al. 1989, LMVJV Management Board 1990). The LMVJV recognizes the importance of flooded agricultural lands as foraging habitats for waterfowl and incorporates estimates of availability of waste agricultural seeds (i.e., seeds inadvertently not collected by combines during harvest) to determine foraging habitat needed to support winter waterfowl population goals of the LMVJV. Rice is an important crop and food for migrating and wintering waterfowl in the MAV (Delnicki and Reinecke 1986). However, Manley et al. (2004) reported significant declines (79-99%) in waste rice in Mississippi rice fields between harvest and early winter. Subsequently, Stafford et al. (2006) reported that waste rice declined, on average, 71% in the MAV from 271 kg/ha at harvest to 78 kg/ha in late autumn mostly from decomposition. This significant reduction in availability of waste rice potentially has decreased waterfowl carrying capacity of harvested rice fields nearly six-fold in the MAV (Stafford et al. 2006).

The LMVJV recommended integrated habitat conservation, management, and research on public and private lands in the MAV to accomplish the following objectives: 1) conserve and increase area of forested wetlands, 2) create or restore wetlands on former agricultural lands, 3) provide adequate wetland habitat on public and private lands to support waterfowl and other wetland-dependent wildlife, and 4) establish and maintain partnerships between public and private conservation groups to achieve habitat goals (LMVJV Management Board 1990). Indeed, opportunities exist within integrated agriculture and wildlife conservation programs to create complexes of cropland and natural wetlands in the MAV (e.g., Wetlands and Conservation Reserve Programs; LMVJV Management Board 1990). Loesch et al. (1994) concluded that integrating waterfowl habitat management with traditional farming practices was necessary to meet foraging requirements of wintering waterfowl.

The LMVJV objectives that embrace the most acreage are wetland restoration and enhancement on private lands. These objectives capitalize on opportunities to integrate agriculture and waterfowl management on private lands to sustain or improve farm profits, water quality, soil conservation, and availability of winter food for waterfowl (Loesch et al. 1994). Because of the importance of waste rice as food for waterfowl and scientific evidence of its current decreased availability in the MAV, Stafford et al. (2005) and Kross (2006:1) evaluated the potential of common post-harvest practices used in the MAV (i.e., burning, disking, mowing, rolling, or no treatment [control] of rice stubble) to conserve waste rice during fall for wintering waterfowl. They reported leaving rice stubble standing or burning it resulted in the greatest mean abundance of waste rice in late fall. Additionally, leaving standing stubble also derived agronomic, economic, and environmental benefits (Manley 1999:36, Manley et al. 2005). However, to my knowledge, no investigators have evaluated waterfowl and other waterbird use of rice fields during winter after rice fields were managed in these ways after harvest.

Therefore, my objectives were to estimate and compare densities of waterfowl and other waterbirds in general and, specifically, densities of mallards (*Anas platyrhynchos*) engaged in different behavioral activities among experimental post-harvest treatments of burning, disking, mowing, rolling, or no manipulation of rice stubble on a private rice production farm in Arkansas. I conducted my study to determine if waterfowl and waterbird responses to post-harvest management strategies were consistent with strategies to conserve waste rice and generate information beneficial to rice producers and wildlife managers whose goal is to manage harvested fields for wintering waterfowl and other waterbirds.

STUDY AREA

I conducted my experiment in 6 different harvested rice fields on the Monsanto Farm and Wildlife Management Center. I used 3 independent fields in each of winters 2004-2005 and 2005-2006. The Monsanto property is a 1,214-ha farm in the Arkansas Grand Prairie, approximately 8 km south of Stuttgart, Arkansas (Arkansas County; 34° 30' N, 91° 33' 4" W). I selected this site because of the area's importance for rice production, winter waterfowl abundance, and Monsanto's interest and willingness to cooperate in the study. The primary purpose of the farm and center is to demonstrate profitable coexistence of agriculture, forestry, and wildlife management. The farm annually produces corn, rice, soybean, and wheat. With about 364 ha of winter flooded hardwood bottomland and 200 ha of winter flooded croplands, the farm attracts a diversity of waterfowl and other wetland wildlife. The remaining 650 ha is not flooded during winter. Waterfowl hunting was allowed in the bottomland-hardwood forest during morning hours only and in a few selected croplands during mornings or afternoons but never in my experimental rice fields.

METHODS

Experimental Design and Field Methods

I used a randomized complete block design for my experiment and designated individual rice fields as blocks. In falls 2004 and 2005, the manager at the Monsanto farm provided 3 separate rice fields for my study. Each of the 6 fields was typical of production agriculture rice fields with contour levees in the Arkansas Grand Prairie. I used levees between adjacent paddies within fields to separate randomly assigned post-harvest treatments (Kross 2006:5). Because treatments were applied to paddies, I designated paddies as experimental units for data analysis. Monsanto farm staff harvested rice fields with a conventional combine and applied treatments to the entire area of experimental paddies (0.4-4.2 ha) ≤ 2 weeks after harvest in September 2004 and 2005. I measured the area of each treatment or control paddy using a Garmin™ GPS 12 Personal Navigator and marked edges of experimental paddies with stems of giant cane (*Arundinaria gigantean*) to designate boundaries of paddies. Farm staff applied 5 post-harvest treatments (i.e., burning, disking, mowing, rolling, and no treatment of rice stubble [control]) to each of 3 fields in 2004 (Kross 2006:5) and 3 treatments (i.e., burning, rolling, no treatment [control]) to each of 3 fields in 2005. I did not apply disking and mowing in 2005 because waterfowl and waterbird responses to these treatments were low or intermediate in 2004 (see results), and Monsanto farm managers did not routinely use these practices because they either damaged equipment (i.e., mowers) or were costly (i.e., mowing and disking). Farm staff used a levee disk to construct a firebreak around paddies receiving the burned treatment to contain fire in designated treatment areas. Farm staff ignited fires with drip torches and monitored fires until they burned across paddies. Farm staff was unable to burn one paddy in a field in 2004 due to a fire ban (Kross 2006:6). For disked paddies, farm staff tilled paddies twice with a disk to ensure rice stubble was flattened and partially incorporated into the soil. For mowed paddies, farm staff cut rice stubble about 15 cm above ground with a rotary mower. For rolled paddies, farm staff pulled a smooth roller over paddies until rice stubble was flattened on the ground. Farm staff flooded paddies in mid-November 2004-2005 to provide habitat for wintering waterfowl and other waterbirds.

Using a modified scan sampling technique (Altmann 1974) and a spotting scope, I conducted diurnal observations of waterfowl and other waterbirds to quantify their densities while using experimental paddies during winters 2004-2006. I completed 4 observational sampling days in December 2004 and 2005, 3 days in January 2005 and 4 days in January 2006, and one day each in February 2005 and 2006. The interval between successive sampling days ranged from 6-14 days depending on weather and averaged 8.5 days (SE = 0.61, n = 15 intervals). I completed only one observational day in February 2005 and 2006, because farm staff drained rice fields for spring planting immediately after these sampling days. I observed birds from Pot-Belly Blinds^{TM} resting atop 3.05-m towers positioned at the edge of each rice field. I made observations through windows elevated 1-m above the towers, providing an above-ground vantage of 4.05 m.

Along field edges, I positioned blinds to avoid looking directly into the sun in early morning and late afternoon.

To generate estimates of diurnal use, I observed waterfowl and waterbirds using treated and control paddies in each of 3 fields each year for one hour in the morning (0700-1200) and one hour in the afternoon (1200-1700) of each sampling day (i.e., 3 fields x 2 hr/day = 6 hr/sampling day). I scanned each paddy 3 times during each morning and afternoon sampling period. I calculated the mean density of waterfowl and waterbirds by species (or other taxa; e.g., shorebirds, wading birds, etc.) as the *n* birds/ha per sampling day. As I scanned birds, I used a tape recorder to record species (or other taxa) and current activity of each bird observed using treatment or control paddies. I categorized activities as feeding (e.g., tipping-up, surface feeding), locomotion (e.g., alighting on or flushing from a paddy, swimming, walking), resting (e.g., sleeping, loafing), maintenance (e.g., preening, scratching), alert (e.g., raised head), courtship (e.g., head pumping, copulation), and agonistic behavior (e.g., chasing, bill threats; Paulus 1984). To ensure my observations were distributed equally across diurnal time periods and experimental paddies, I randomly ordered fields for observation on the first sampling day of each winter and rotated the starting field in the sequence for each consecutive sampling day during the remainder of winter sampling. I allowed a minimum "settling time" of 15 minutes from my arrival time inside a blind to my first scan, so I could assume birds present were not disturbed by my presence.

Statistical Analyses

Density of Waterfowl and Waterbirds

I analyzed data on density (i.e., birds/ha/survey) of mallards, other dabbling ducks, geese, and other waterbirds combined regardless of activity, using a factorial repeated-measures analysis of variance (ANOVA). I tested the null hypothesis that variation in density was not influenced by field treatment, survey number during winter (hereafter, survey), or the interaction of treatment and survey (PROC MIXED; SAS Institute 1999). I used multiple surveys throughout winters 2004-2005 and 2005-2006 to conduct the repeated-measures ANOVA and the small-sample version of Akaike's Information Criterion (AIC_c) to select the compound symmetry temporal covariance structure (Burnham and Anderson 2002).

Because only 3 fields were available in each year of my experiment, I expected statistical power would be low to detect differences among treatments. Therefore, I chose (a priori) a Type I error rate of $\alpha = 0.10$ similar to other management-oriented experiments with small sample size (Tacha et al. 1982). To test homogeneity of variances, I performed a Levene's test on each response variable (PROC GLM; SAS Institute 1999). This test indicated variances were equal for geese and other waterbirds in winters 2004-2006, but unequal for mallards and other dabbling ducks in winter 2005-2006 and mallards in winters 2004-2005 and 2005-2006. Neither $\log_e$ nor square-root transformations yielded equal variances, so I conducted ANOVAs on non-transformed data. Although my data sets did not meet the assumptions of normality and equal variances, I assumed ANOVA was robust to these violations of assumption (Freund and

Wilson 2003:237). When I detected a treatment effect ($P \leq 0.10$), I performed all pair-wise comparisons of means using a Tukey's test (Freund and Wilson 2003:256).

Density of Mallards Exhibiting Different Activities

I analyzed data on density of mallards observed feeding, in locomotion, or resting using a factorial, repeated-measures ANOVA. I restricted analyses to mallards, because they were the most abundant species, comprising nearly 50% of all waterfowl and waterbirds observed in winters 2004-2005 and 2005-2006. Additionally, I restricted analyses to feeding, locomotion, and resting because these activities comprised 87-97% of all mallard activities. I tested the null hypothesis that variation in activity-specific densities of mallards (e.g., feeding mallards/ha/survey) was not influenced by treatment, survey, or their interaction (PROC MIXED; SAS Institute 1999). I used multiple sampling days throughout winters 2004-2005 and 2005-2006 to conduct the repeated-measures ANOVA. Because mallard activity-specific density data were a subset of the mallard density data, I also conducted analyses on non-transformed data. When I detected a treatment effect ($P \leq 0.10$), I performed all pair-wise comparisons of means using a Tukey's test (Freund and Wilson 2003:256).

RESULTS

Density of Waterfowl and Other Waterbirds

Mallards

I found that density of mallards varied among surveys in winter 2004-2005 ($F_{7,70} = 3.60$, $P = 0.002$), but I did not detect an effect of post-harvest field treatments ($F_{4,70} = 1.68$, $P = 0.165$) or an interaction between treatment and survey effects ($F_{28,70} = 0.60$, $P = 0.932$). Mallard density was relatively low (i.e., < 0.50 birds/ha/survey) until early January 2005, then increased to a maximum in late January ($\bar{x} = 6.13$ birds/ha/survey), and subsequently declined on the last survey ($\bar{x} = 4.06$ birds/ha/survey; Table A.1). In winter 2005-2006, density of mallards again varied among surveys ($F_{8,46} = 1.96$, $P = 0.074$), but was influenced by post-harvest treatment ($F_{2,46} = 4.35$, $P = 0.019$). I did not detect an interaction of treatment and survey effects ($F_{16,46} = 0.62$, $P = 0.851$). In Mallard density was relatively high from mid-December 2005 to early January 2006 ($\bar{x} = 5.06$-8.07 birds/ha/survey), then declined in mid-January ($\bar{x} < 0.95$ birds/ha/survey) and remained low subsequently (Table A.2). Mallard use of rolled paddies ($\bar{x} = 6.07$ birds/ha/survey, SE = 1.27) was 4.6 times greater ($t_{46} = 2.83$, $P = 0.019$) than that of untreated paddies with standing stubble ($\bar{x} = 1.32$ birds/ha/survey, SE = 1.27) and 2.5 times greater than that of burned paddies ($\bar{x} = 2.46$ birds/ha/survey, SE = 1.27; $t_{46} = -2.14$, $P = 0.092$), but I did not detect a difference in mallard density between burned and standing stubble paddies ($t_{46} = 0.68$, $P = 0.775$). When I combined all data for experimental treatments applied in both winters (i.e., burned, rolled, or no treatment), I detected an interaction of treatment and year effects ($F_{2,131} = 3.52$, $P = 0.033$). In both winters, use by mallards of burned or rolled paddies was 3.9-4.2 times greater than that of paddies with standing stubble (Figure 1.1).

Other Dabbling Ducks

In both winters, I observed the following dabbling ducks exclusive of mallards: American wigeon (*Anas americana*), gadwall (*A. strepera*), American green-winged teal (*A. carolinensis*), northern pintail (*A. acuta*), and northern shoveler (*A. clypeata*). For winter 2004-2005, I did not detect effects of surveys ($F_{7,70} = 1.37$, $P = 0.230$; Table A.3), post-harvest treatments ($F_{4,70} = 1.18$, $P = 0.325$), or an interaction of these effects ($F_{28,70} = 0.92$, $P = 0.585$) on variation in density of these other dabbling ducks as a group. In winter 2005-2006, density of other dabbling ducks varied among post-harvest treatments ($F_{2,46} = 11.06$, $P \leq 0.001$), but I neither detected an effect of surveys ($F_{8,46} = 1.59$, $P = 0.153$; Table A.4) nor an interaction of treatment and survey ($F_{16,46} = 1.12$, $P = 0.365$). Use of rolled paddies in winter 2005-2006 by other dabbling ducks ($\bar{x} = 0.89$ birds/ha/survey, SE = 0.20) was 6.8 times greater ($t_{46} = 4.27$, $P \leq 0.001$) than that of untreated paddies containing standing stubble ($\bar{x} = 0.13$ birds/ha/survey, SE = 0.20) and 4.2 times greater than that of burned paddies ($\bar{x} = 0.21$, SE = 0.20; $t_{46} = -3.84$, $P = 0.001$), but I did not detect a difference between burned and standing stubble paddies ($t_{46} = 0.44$, $P = 0.901$). When I combined data on other dabbling duck density for both winters, I detected an interaction of treatment and year effects ($F_{2,131} = 5.86$, $P = 0.004$). In both winters, I found that use by other dabbling ducks in rolled or burned paddies was 2.9-6.7 times greater than that of paddies with standing stubble.

Geese

In both winters, I observed snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) using my experimental paddies. Goose use was sporadic; therefore, I combined data for these species for analysis. I found that density of geese varied among surveys in winter 2004-2005 ($F_{7,70} = 2.78$, $P = 0.013$; Table A.5), but I did not detect an effect of post-harvest treatments ($F_{4,70} = 1.06$, $P = 0.384$) or an interaction of treatment and survey effects ($F_{28,70} = 0.53$, $P = 0.970$). I did not observe use of experimental rice paddies by geese in winter 2004-2005 until late December 2004 ($\bar{x}$ = 16.94 birds/ha/survey). Goose density was relatively low from early to mid-January 2005 (i.e., < 0.03 birds/ha/survey) but increased in late January 2005 ($\bar{x}$ = 4.44 birds/ha/survey). Density of geese in winter 2005-2006 also varied among surveys ($F_{8,46} = 2.38$, $P = 0.031$; Table A.6), but I did not detect an effect of post-harvest treatments ($F_{2,46} = 0.16$, $P = 0.854$) or an interaction of treatment and survey effects ($F_{16,46} = 0.20$, $P = 1.000$). I observed geese using experimental paddies from early December 2005 to early January 2006. I found that maximum density of geese occurred in early December 2005 ($\bar{x}$ = 12.58 birds/ha/survey) but then decreased to <1 bird/ha/survey by mid-December 2005 and did not increase subsequently. When I combined data for both winters, I found that density of geese varied among post-harvest treatments ($F_{2,131} = 2.56$, $P = 0.081$), but I did not detect an interaction of treatment and year effects ($F_{2,131} = 1.35$, $P = 0.264$). Goose use of burned paddies ($\bar{x}$ = 2.88 birds/ha/survey, SE = 0.97) in winters 2004-2006 was 2.9 times greater ($t_{131} = 2.05$, $P = 0.105$) than that of rolled paddies ($\bar{x}$ = 0.98 birds/ha/survey, SE = 0.88), but I did not detect a difference in goose use between burned and standing stubble paddies ($\bar{x}$ = 1.03 birds/ha/survey, SE = 0.88; t_{131} = 1.99, P = 0.119) or between rolled and standing stubble paddies (t_{131} = -0.06, P = 0.998; Figure 1.2).

Waterbirds

I categorized all rails, shorebirds, and wading birds collectively as waterbirds. Waterbirds were composed of American coot (*Fulica americana*), common snipe (*Gallinago gallinago*), great blue heron (*Ardea herodius*), great egret (*Ardea alba*), greater yellowlegs (*Tringa melanoleuca*), killdeer (*Charadrius vociferus*), and "peeps" (Family: Scolopacidae). Density of waterbirds varied among surveys ($F_{7,70}$ = 2.18, P = 0.046) in winter 2004-2005, but I did not detect an effect of post-harvest treatments ($F_{4,70}$ = 0.98, P = 0.423) or an interaction of treatment and survey effects ($F_{28,70}$ = 0.96, P = 0.537). Density of waterbirds in winter 2004-2005 was relatively low (i.e., < 0.04 birds/ha/survey) until it maximized in mid-December 2004 ($\bar{x}$ = 3.09 birds/ha/survey) and remained low (i.e., ≤ 0.24 birds/ha/survey) subsequently (Table A.7). In winter 2005-2006, density of waterbirds varied among post-harvest treatments ($F_{2,46}$ = 4.52, P = 0.016), but I did not detect an effect of surveys ($F_{8,46}$ = 0.76, P = 0.643; Table A.8) or an interaction of treatment and survey on variation in density of waterbirds ($F_{16,46}$ = 0.86, P = 0.618). Waterbird use of rolled paddies ($\bar{x}$ = 0.67 birds/ha/survey, SE = 0.19) was 33.5 times greater (t_{46} = 2.83, P = 0.018) than that of untreated paddies with standing stubble ($\bar{x}$ < 0.02 birds/ha/survey, SE = 0.19) and was 5.6 times greater (t_{46} = -2.29, P = 0.068) than that of burned paddies ($\bar{x}$ = 0.12 birds/ha/survey, SE = 0.19). When I combined data for winters 2004-2006, I found that density of waterbirds varied among post-harvest treatments ($F_{2,131} = 3.49$, $P = 0.033$), but I did not detect an interaction of treatment and year effects ($F_{2,131} = 0.21$, $P = 0.815$). Waterbird use of rolled paddies ($\bar{x}$ = 0.99 birds/ha/survey, SE = 0.29) in winters 2004-2006 was 33.0 times greater (t_{131} = 2.60, $P = 0.028$) than that of untreated paddies with standing stubble ($\bar{x}$ = 0.03 birds/ha/survey, SE = 0.29), but I did not detect a difference in waterbird use between rolled and burned paddies ($\bar{x}$ = 0.34 birds/ha/survey, SE = 0.33; $t_{131} = -1.63$, $P = 0.235$) or between burned and standing stubble paddies ($t_{131} = 0.75$, $P = 0.732$; Figure 1.3).

Density of Mallards Exhibiting Different Activities

Feeding

Density of feeding mallards varied among surveys ($F_{7,70} = 3.37$, $P = 0.004$) in winter 2004-2005, but I did not detect an effect of post-harvest treatments ($F_{4,70} = 0.57$, $P = 0.682$) or an interaction of treatment and survey effects ($F_{28,70} = 0.62$, $P = 0.916$). In winter 2004-2005, density of feeding mallards was relatively low (i.e., < 0.43 birds/ha/survey) until early January 2005, peaked in late January ($\bar{x}$ = 4.07 birds/ha/survey), and then declined on the last survey ($\bar{x}$ = 1.76 birds/ha/survey; Table A.9). In winter 2005-2006, density of feeding mallards varied among post-harvest treatments ($F_{2,46} = 5.78$, $P = 0.006$), but I did not detect an effect of surveys ($F_{8,46} = 1.43$, $P = 0.210$; Table A.10), or an interaction of treatment and survey effects ($F_{16,46} = 0.65$, $P = 0.827$). Feeding in rolled paddies by mallards ($\bar{x}$ = 4.04 birds/ha/survey, SE = 0.86) was 10.4 times greater ($t_{46} = 3.30$, $P = 0.005$) than that in untreated paddies with standing stubble ($\bar{x}$ = 0.39 birds/ha/survey, SE = 0.86) and was 2.8 times greater than that of burned paddies ($\bar{x}$ = 1.42, SE = 0.86; t_{46} = -2.37, P = 0.057), but I did not detect a difference between burned and standing stubble paddies (t_{46} = 0.93, P = 0.625). When I combined data on density of feeding mallards for winters 2004-2006, I detected an interaction of treatment and year effects ($F_{2,131}$ = 2.45, P = 0.090). Across winters, I observed 4.2-6.6 times more feeding mallards using burned or rolled paddies than untreated paddies with standing stubble (Fig 1.4).

Resting

Density of resting mallards varied among surveys ($F_{7,70}$ = 2.96, P = 0.009) in winter 2004-2005, but I did not detect an effect of post-harvest treatments ($F_{4,70}$ = 1.74, P = 0.151) or an interaction of treatment and survey effects ($F_{28,70}$ = 1.11, P = 0.357). In winter 2004-2005, density of resting mallards was relatively low (i.e., < 0.20 birds/ha/survey) until late January 2005, then increased to a maximum ($\bar{x}$ = 1.63 birds/ha/survey; Table A.11) on the last survey. In winter 2005-2006, I did not detect an effect of surveys ($F_{8,46}$ = 0.94, P = 0.493; Table A.12), post-harvest treatments ($F_{2,46}$ = 0.98, P = 0.382), or an interaction of these effects on variation in density of resting mallards ($F_{16,46}$ = 0.74, P = 0.740). When I combined data for winters 2004-2006, density of resting mallards varied among post-harvest treatments ($F_{2,131}$ = 2.58, P = 0.080), but I did not detect an interaction of treatment and year effects ($F_{2,131}$ = 1.25, P = 0.291). Density of resting mallards in rolled paddies ($\bar{x}$ = 0.57 birds/ha/survey, SE = 0.18) was 8.1 times greater (t_{131} = 2.10, P = 0.094) than that in untreated paddies with standing stubble ($\bar{x}$ = 0.07 birds/ha/survey, SE = 0.18), but I did not detect a difference in resting mallards between rolled and burned paddies ($\bar{x}$ = 0.52 birds/ha/survey, SE =

0.20; $t_{131} = -0.20$, $P = 0.978$) or between burned and standing stubble paddies ($t_{131} = 1.74$, $P = 0.195$; Figure 1.5).

Locomotion

In winter 2004-2005, I detected an interaction of treatment and survey effects ($F_{28,70} = 1.55$, $P = 0.073$; Table A.13) for mallards engaged in locomotion. Use of rolled or burned paddies by mallards engaged in locomotion was 4.4-24.0 times greater than paddies containing standing stubble. In winter 2005-2006, density of mallards engaged in locomotion varied among surveys ($F_{8,46} = 2.53$, $P = 0.023$), but I did not detect an effect of post-harvest treatments ($F_{2,46} = 0.05$, $P = 0.947$), or an interaction of treatment and survey effects ($F_{16,46} = 0.58$, $P = 0.881$). In winter 2005-2006, density of mallards engaged in locomotion was relatively high in mid-December 2005 ($\bar{x} = 2.25$ birds/ha/survey), late December 2005 ($\bar{x} = 2.29$ birds/ha/survey), and early January 2006 ($\bar{x} = 2.13$ birds/ha/survey), but then declined subsequently (Table A.14). When I combined data for winters 2004-2006, density of mallards engaged in locomotion varied among post-harvest treatments ($F_{2,131} = 2.35$, $P = 0.099$), but I did not detect an interaction of treatment and year effects ($F_{2,131} = 1.17$, $P = 0.315$). Density of mallards engaged in locomotion in burned paddies ($\bar{x} = 1.11$ birds/ha/survey, SE = 0.33) was 2.8 times greater ($t_{131} = 2.17$, $P = 0.081$) than that in untreated paddies with standing stubble ($\bar{x} = 0.40$ birds/ha/survey, SE = 0.30), but I did not detect a difference in mallards engaged in locomotion between burned and rolled paddies ($\bar{x} = 0.66$ birds/ha/survey, SE = 0.30; $t_{131} = 1.35$, $P = 0.371$) or between rolled and standing stubble paddies ($t_{131} = 0.89$, $P = 0.649$).

DISCUSSION

The Monsanto Farm and Wildlife Management Center is a production farm; thus, standard agricultural practices were used on all experimental rice fields before winters 2004-2006. Regionally common rice varieties were planted, and entire fields were harvested using conventional combines. Post-harvest field manipulations were applied to experimental paddies in the same manner that rice farmers apply these to entire fields. Therefore, my experimental fields and avian responses within them were representative of rice fields on the Monsanto farm and perhaps the surrounding locale of the Grand Prairie of Arkansas. However, my results may not broadly apply to the scale of the MAV.

Although harvested rice fields left in standing stubble during fall in the MAV conserved the greatest abundance of waste rice (Kross 2006:10), I observed the greatest densities of waterfowl and waterbirds in paddies that were burned or rolled after harvest and flooded in late fall. I also observed the greatest densities of feeding and resting mallards in burned and rolled paddies, suggesting these paddies may be more attractive to mallards than flooded paddies with standing stubble. Waterfowl and waterbirds may have been attracted to burned and rolled paddies in part by the structural interspersion of rice stubble and open water following flooding.

Interspersion of rice stubble and open water may be a proximate cue attracting waterfowl and waterbirds to burned or rolled and flooded rice fields analogous to waterfowl and other waterbirds being attracted to natural wetlands with interspersion of emergent vegetation and open water (Weller and Fredrickson 1973). Proximate cues are stimuli from the environment that attract birds or other animals to habitat and may reflect aspects of habitat quality (e.g., availability or accessibility of food resources), but need not be essential elements for individual survival and reproduction unlike ultimate factors (Hilden 1965). Experiments in natural wetlands on waterfowl breeding (Kaminski and Prince 1981) and wintering grounds (Smith et al. 2004) demonstrated that waterfowl were most attracted to manipulated sites that had relatively equal coverage ratios of emergent vegetation and open water (i.e., "hemi-marshes"; Weller and Fredrickson 1973). I did not measure the ratios of rice stubble and open water in my experimental paddies; therefore, I cannot infer any causal relationship between waterfowl and waterbird use of paddies and interspersion of rice stubble and open water. Nonetheless, my results suggest that the patchy distribution of burned, rolled, or otherwise manipulated and flooded stubble in rice fields may have attracted waterfowl and waterbirds, and the open water areas may have facilitated birds alighting and moving through paddies in search or acquisition of food or engaging in other activities (e.g., rest, courtship, etc.). In contrast, dense standing stubble may have impeded bird access and movement within flooded rice paddies, but the stubble nonetheless may have provided cover for the birds.

In both winters, I observed little or no use by mallards and other dabbling ducks in all experimental paddies until after geese (mostly snow geese) used paddies. Prior to goose use, I observed regenerated green shoots of rice protruding through the water surface, reducing the surface area of open water in the paddies. When geese began using paddies, they toppled both dead and green rice shoots and created open water areas. Use of rice fields by geese may provide open water and facilitate use by mallards and other dabbling ducks. Furthermore, the presence of geese and their physical effect on rice paddies enhancing rice-stubble and open-water interspersion may have been proximate cues for ducks. However, geese also apparently had a negative effect on abundance of waste rice in my experimental paddies in winter 2004-2005, depleting waste rice in late December 2004 before most ducks began using the paddies in early January 2005 (Chapter 2). In contrast, waterbird density in winter 2004-2005 appeared to be unaffected by disturbance of rice paddies from geese, perhaps because waterbirds forage on invertebrates rather than waste rice (Elphick and Oring 1998).

MANAGEMENT AND RESEARCH IMPLICATIONS

I recommend burning rice fields in the MAV because this practice conserved more waste rice than rolling or disking stubble (Kross 2006:10), was more economical than mechanical treatments (Kross 2006:16), attracted waterfowl and other waterbirds (this study), and remains a legal practice in the MAV. When burning rice stubble is not an option (e.g., burn bans due to drought or proximity of smoke-sensitive areas), I recommend rolling rice paddies. Managers may desire to roll entire fields or paddies or merely roll strips of stubble and then compare waterfowl use among these strategies. I base this suggestion on knowledge that waterfowl and waterbirds in this study were attracted to rice paddies having an interspersion of stubble and open water and that standing stubble contained the greatest abundance of waste rice (Kross 2006:10). I do not recommend mowing or disking rice stubble because of the expense of implementing these treatments (Kross 2006:16) and the decreased bird responses I observed in mowed and disked paddies. Also, Manley (1999:37) demonstrated that disked rice fields promote suspension and exportation of soil particles and nutrients from fields through runoff, and Manley et al. (2005) reported that disking can bury "red rice" (i.e., a noxious plant for rice producers) in the soil and cause risk of germination in subsequent growing seasons. I also recommend investigation of waterfowl and waterbird use of post-harvest managed rice fields at a large spatial scale to develop general prescriptions for post-harvest rice field management in the MAV. Other related variables for possible research include optimal interspersion ratios and configurations of open water and rice stubble, waterfowl food/energy intake rates in differently managed rice paddies and those exploited by geese, nocturnal use of flooded rice fields by waterfowl, exploitation of waste rice by geese in harvested and flooded fields, management strategies to deter goose use, and waterfowl use of rice fields after "giving-up" densities of food have been exceeded.

LITERATURE CITED

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour 49:227-267.

Anderson, M. G., and B. D. J. Batt. 1983. Workshop on the ecology of wintering waterfowl. Wildlife Society Bulletin 11:22-24.

Baldassarre, G. A., and E. G. Bolen. 2006. Waterfowl ecology and management. Second Edition. Krieger, Malabar, Florida, USA.

Batt, B. D. J., A. D. Afton, M. G. Anderson, C. D. Ankney, D. H. Johnson, J. A. Kadlec, and G. L. Krapu, editors. 1992. Ecology and management of breeding waterfowl. University of Minnesota Press, Minneapolis, Minnesota, USA.

Bonney, R., D. N. Pashley, R. J. Cooper, and L. Niles, editors. 1999. Strategies for Bird Conservation: The Partners in Flight Planning Process. Cornell Lab of Ornithology.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Canadian Wildlife Service and U.S. Fish and Wildlife Service. 1986. North American waterfowl management plan. Canadian Wildlife Service and U.S. Fish and Wildlife Service, Washington, D.C.

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.

Ducks Unlimited Conservation Plan. 2001. Ducks Unlimited, Inc. Memphis, Tennessee, USA.

Elphick, C. S., and L. W. Oring. 1998. Winter management of Californian rice fields for waterbirds. Journal of Applied Ecology 35:95-108.

Fredrickson, L. H., S. L. King, and R. M. Kaminski, editors. 2005. Ecology and management of bottomland hardwood systems: the state of our understanding. University of Missouri-Columbia, Gaylord Memorial Laboratory Special Publication Number 10, Puxico, Missouri, USA.

Freund, R. J., and W. J. Wilson. 2003. Statistical methods. Second edition. Academic Press, San Diego, California, USA.

Heitmeyer, M. E. 2006. The importance of winter floods to mallards in the Mississippi Alluvial Valley. Journal of Wildlife Management 70:101-110.

_____, and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Transactions of the North American Wildlife and Natural Resources Conference 46:44-57.

Hilden, O. 1965. Habitat selection in birds. Annales Zoologici Fennici 2:53-75.

Hoekman, S. T., L. S. Mills, D. W. Howerter, J. H. Devries, and I. J. Ball. 2002. Sensitivity analyses of the life cycle of midcontinent mallards. Journal of Wildlife Management 66:883-900.

Kaminski, R. M., and E. A. Gluesing. 1987. Density- and habitat-related recruitment in mallards. Journal of Wildlife Management 51:141-148.

_____, and H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45:1-15.

Kross, J. K. 2006. Conservation of waste rice and estimates of moist-soil seed abundance for wintering waterfowl in the Mississippi Alluvial Valley. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Loesch, C. R., K. J. Reinecke, and C. K. Baxter. 1994. Lower Mississippi Valley Joint Venture Evaluation Plan. U.S. Fish and Wildlife Service, Lower Mississippi Valley Joint Venture, Vicksburg, Mississippi, 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. 1999. Ecological and agricultural values of winter-flooded ricefields in Mississippi. Dissertation, Mississippi State University, Mississippi State, Mississippi, USA.

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

_____, R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. 2005. Agronomic implications of waterfowl management in Mississippi ricefields. Wildlife Society Bulletin 33:981-992.

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

Reinecke, K. J. 1981. Winter waterfowl research needs and efforts in the Mississippi Delta. Proceedings of the International Waterfowl Symposium 4:231-236.

_____, 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.

SAS Institute. 1999. SAS/STAT User's Guide. SAS Institute, Cary, North Carolina, USA.

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.

_____, D. A. Haukos, and R. M. Prather. 2004. Avian response to vegetative pattern in playa wetlands during winter. Wildlife Society Bulletin 31:474-480.

Stafford, J. D., R. M. Kaminski, K. J. Reinecke, M. E. Kurtz, and S. W. Manley. 2005. Post-harvest field manipulations to conserve waste rice for waterfowl. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 59:155-163.

_____, 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.

Weller, M. W., and L. H. Fredrickson. 1973. Avian ecology of a managed glacial marsh. Living Bird 12:269-291.

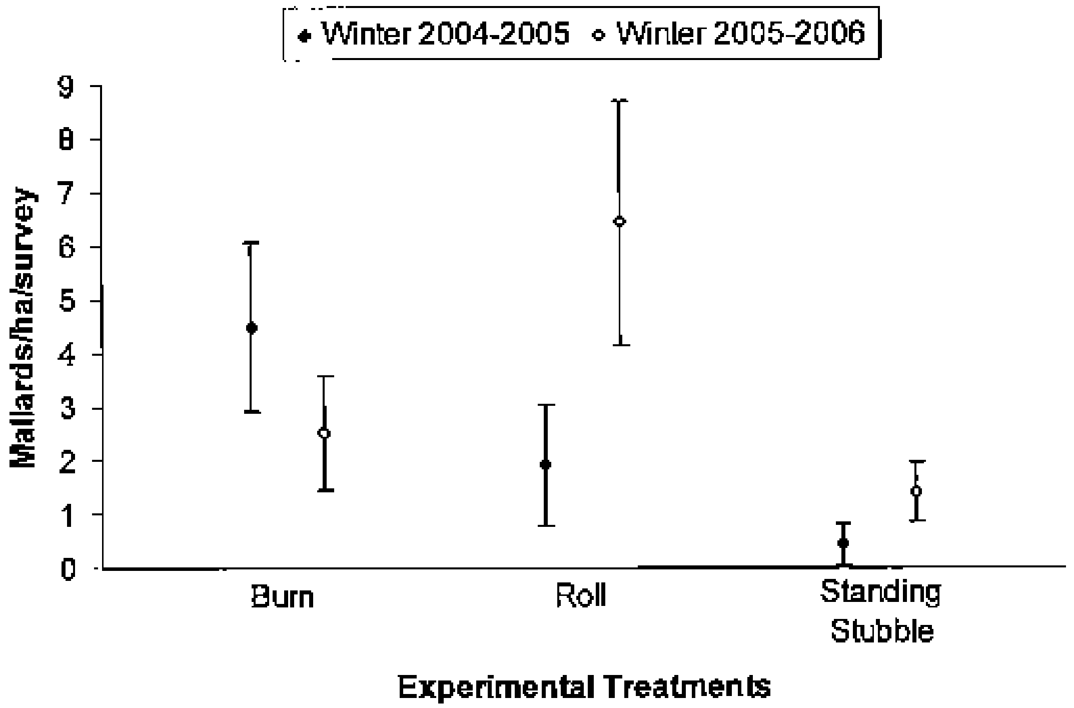

Figure 1.1. Mean ($\bar{x}$) indices (and SE bars) of diurnal use by mallards (*Anas platyrhynchos*) of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006.

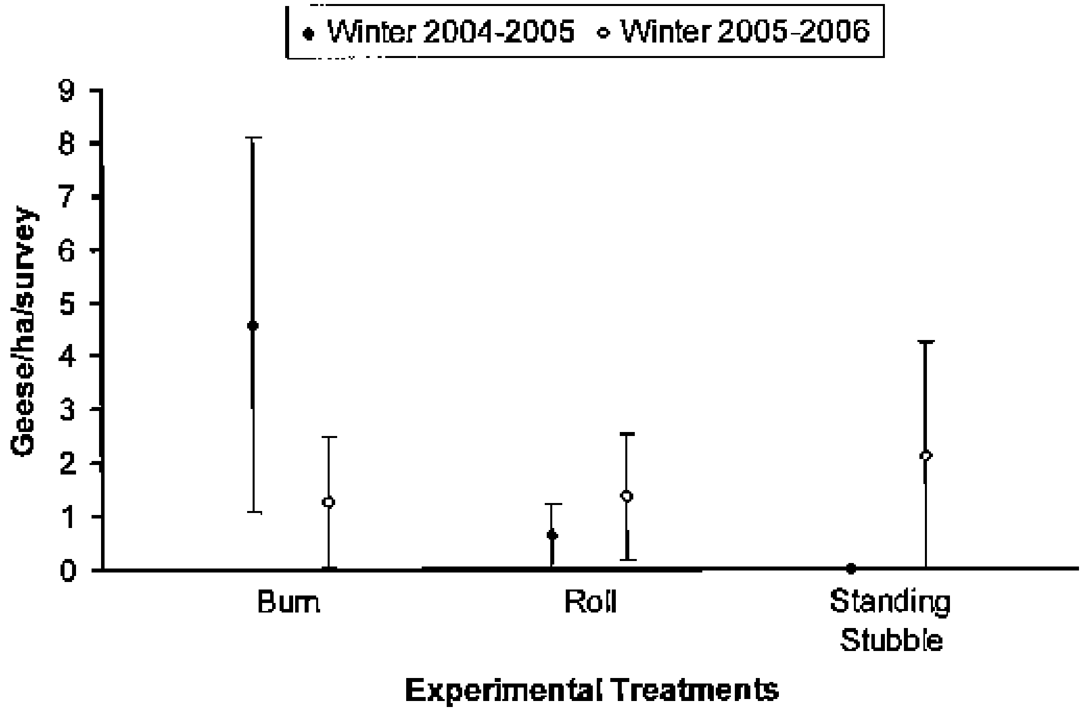

Figure 1.2. Mean ($\bar{x}$) indices (and SE bars) of diurnal use by snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) combined of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006.

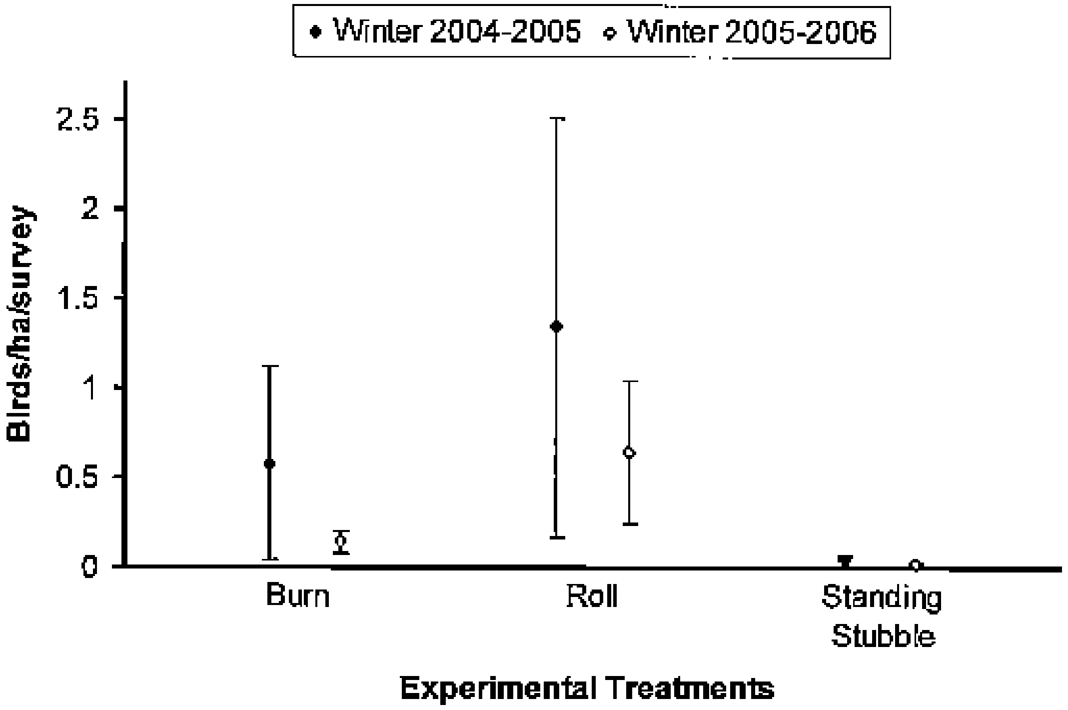

Figure 1.3. Mean ($\bar{x}$) indices (and SE bars) of diurnal use by waterbirds of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006. Waterbirds consisted of American coot (*Fulica Americana*), common snipe (*Gallinago gallinago*), great blue heron (*Ardea herodius*), great egret (*Ardea alba*), greater yellowlegs (*Tringa melanoleuca*), killdeer (*Charadrius vociferus*), and "peeps" (family Scolopacidae).

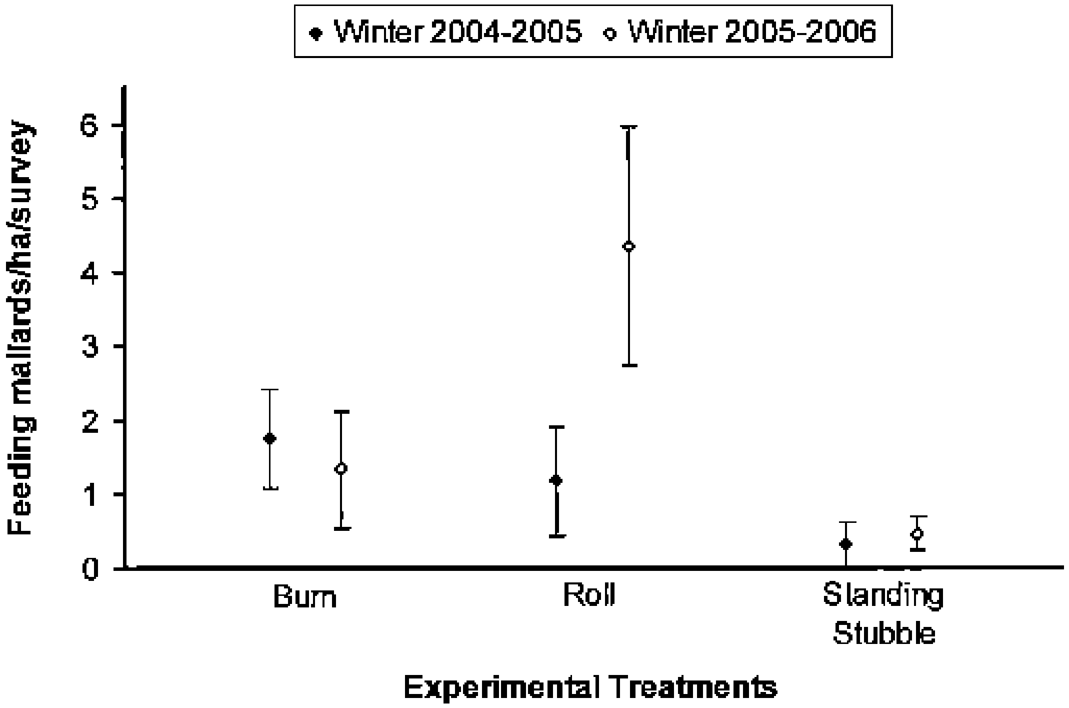

Figure 1.4. Mean ($\bar{x}$) indices (and SE bars) of diurnal use by feeding mallards (*Anas platyrhynchos*) of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006.

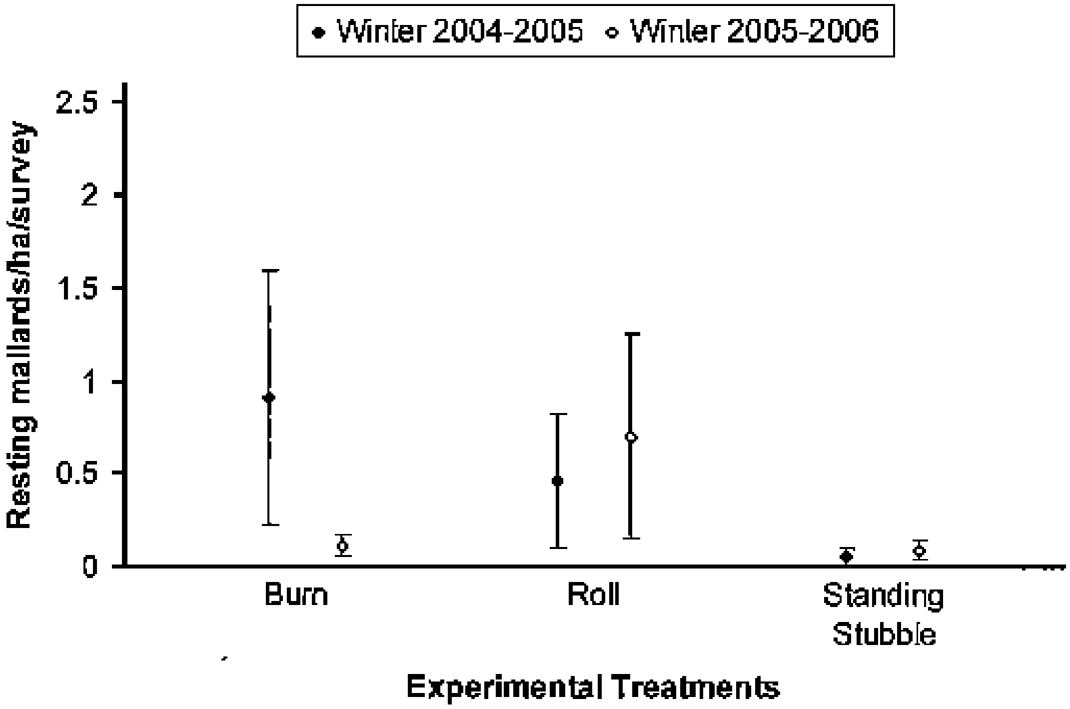

Figure 1.5. Mean ($\bar{x}$) indices (and SE bars) of diurnal use by resting mallards (*Anas platyrhynchos*) of different post-harvest managed rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winters 2004-2006.

CHAPTER II

WINTER ABUNDANCE OF WASTE RICE IN POST-HARVEST MANAGED RICE FIELDS IN ARKANSAS

Historically, the Mississippi Alluvial Valley (MAV) was a vast bottomland-hardwood ecosystem (>10 million ha) extending from southern Illinois and southeast Missouri to the coastal plain of Louisiana (Reinecke et al. 1989, Fredrickson et al. 2005). Overflows from the Mississippi River and its tributaries regularly flooded the MAV during winter and spring (Reinecke et al. 1988). This ecosystem provided diverse habitat and other resources (e.g., food) for resident and migratory waterfowl and other species of wetland wildlife (Reinecke et al. 1989, Heitmeyer et al. 2005). Flood-management projects dating from the late 1920s to the present have reduced the extent and dynamics of seasonal flooding in the MAV (Reinecke et al. 1988). Additionally, flood management has facilitated forest clearing and conversion of the MAV from largely lowland forests to croplands (Bonney et al. 1999). Despite conversion of most of the forested MAV to agricultural land, it has remained a critical ecoregion for migrating and wintering waterfowl wherein waterfowl have adapted to forage on agricultural seeds, such as rice (Delnicki and Reinecke 1986, Reinecke et al. 1989).

Rice is an important crop and food for waterfowl in the MAV (Reinecke et al. 1989, Stafford et al. 2006). In 2006, producers planted 874,930 ha of rice in Arkansas, Mississippi, Louisiana, and Missouri, accounting for 76% of the rice production in the

United States (National Agriculture Statistics Service 2006). Rice fields are used by waterfowl and other waterbirds (Delnicki and Reinecke 1986, Reinecke et. al. 1989), and rice field infrastructure (i.e., levees, pumps) and associated rice agricultural practices facilitate creating flooded cropland habitat for these birds during winter (Twedt and Nelms 1999, Manley et al. 2004). Rice provides 3.34 kcal/g (dry mass) in true metabolizable energy for mallard ducks (*Anas platyrhynchos*) which is slightly less than corn (3.67 kcal/g) but greater than soybean (2.65 kcal/g; Reinecke et al. 1989, Kaminski et al. 2003). Additionally, rice resists decomposition when flooded; 74% of the rice in samples placed in wetlands during winter persisted after 120 days of flooding whereas soybeans nearly deteriorated after 90 days (~86%; Neely 1956, Shearer et al. 1969, Nelms and Twedt 1996). In short, flooding harvested rice fields during winter is a valuable management practice to provide foraging and resting areas for migrating and wintering waterfowl and other waterbirds, derive agronomic and economic benefits for farmers through straw decomposition, winter-weed control, and waterfowl hunting leases, and improve water quality through sediment filtration and runoff reduction (Nelms and Twedt 1996, Manley 1999, Manley et al. 2004).

Rice that falls to the ground before or during harvest operations (i.e., waste rice) is a primary forage component used by the Lower Mississippi Valley Joint Venture (LMVJV) to estimate carrying capacity of wintering waterfowl habitat in the MAV (Reinecke et al. 1989, Loesch et al. 1994). Manley et al. (2004) documented significant loss of waste rice in Mississippi fields from 492 kg/ha after harvest to < 60 kg/ha in early December. Subsequently, in a landscape-scale sample survey of waste rice in the MAV, Stafford et al. (2006) documented a 71% decline in waste-rice abundance from time of harvest (271 kg/ha; mid-late September) through early winter (78.4 kg/ha; early December) when waterfowl arrive in significant numbers. These published early winter abundances of waste rice were less than half of the estimate used previously by the LMVJV (i.e., 180 kg/ha) for conservation planning (Reinecke and Loesch 1996). Increased harvest efficiency and earlier planting and harvest of contemporary rice producers are likely responsible for this decline in waste rice during fall. Earlier planting and harvesting of rice increase the number of autumn exposure days and losses to post-harvest germination, decomposition, and granivory (Stafford et al. 2006).

Faced with increasing evidence of decreased waste rice in winter, Rutka (2004:17) conducted an experiment to evaluate a preliminary threshold value of rice availability believed to limit foraging efficiency and ultimately result in abandonment of rice fields by ducks and geese (50 kg/ha; Reinecke et al. 1989). Rutka (2004:33) reported the "giving-up" density of rice for waterfowl was 48.7 kg/ha in Arkansas rice fields. Her estimate did not differ from the hypothesized threshold. The relatively small difference (i.e., buffer) in waste-rice abundance and waterfowl "giving up" density (i.e., ~30 kg/ha) underscored the importance of examining the dynamics of waste rice and waterfowl use of harvested rice fields flooded during winter.

Manley et al. (2004) and Stafford et al. (2006) recommended evaluation of post-harvest treatments of rice fields to determine if different practices would differentially conserve waste rice between harvest and early winter. Kross (2006) compared abundance of waste rice among 5 post-harvest management practices used in the MAV (i.e., burning, disking, mowing, rolling, and no manipulation [control]) and found that leaving rice stubble standing yielded the greatest amount of waste rice in late autumn. I extended Kross's (2006) study and conducted an experiment to examine variation in winter abundance of waste rice in relation to these post-harvest management practices and diurnal waterfowl use (i.e., density) in experimental rice paddies on a production farm in Arkansas. My specific objective was to test the null hypothesis that abundance of waste rice would not vary during winter in relation to post-harvest field treatments while accounting for variation in waterfowl density in the same experimental paddies. I assumed that waterfowl would forage on waste rice and reduce its abundance in the paddies during winter, hence my use of waterfowl density as a covariate of waste rice dynamics.

STUDY AREA

I conducted my experiment in 3 harvested rice fields on the Monsanto Farm and Wildlife Management Center during winter 2004-2005. The Monsanto property is a 1,214-ha farm in the Arkansas Grand Prairie, approximately 8 km south of Stuttgart, Arkansas (Arkansas County; 34° 30' N, 91° 33' 4" W). I selected this site because of the area's importance for rice production, winter waterfowl abundance, and Monsanto's interest and willingness to cooperate in the study. The goal of the farm and center is to demonstrate profitable coexistence of agriculture, forestry, and wildlife management. The farm annually produces corn, rice, soybean, and wheat. With about 364 ha of winter flooded hardwood bottomland and 200 ha of winter flooded croplands, the farm attracts a diversity of waterfowl and other wetland wildlife. The remaining 650 ha is not flooded during winter. Waterfowl hunting was allowed in the bottomland-hardwood forest during morning hours only and in a few selected croplands during mornings or afternoons but never in my experimental rice fields.

METHODS

Experimental Design and Field Methods

I used a randomized complete block design for my experiment and designated individual rice fields as blocks. In fall 2004, the manager of the Monsanto farm provided 3 separate rice fields for my study. Each of the 3 fields was typical of production agriculture rice fields with contour levees in the Arkansas Grand Prairie. I used levees between adjacent paddies to separate randomly assigned post-harvest treatments to paddies (Kross 2006:5). Because treatments were applied to paddies, I designated paddies as experimental units for data analyses. Monsanto farm staff harvested rice fields with a conventional combine and applied treatments to the entire area of selected paddies (0.4-4.2 ha) from 10-24 September 2004. Farm staff applied 5 post-harvest treatments (i.e., burning, disking, mowing, rolling, and no treatment of rice stubble [control]) to each field (Kross 2006:5). Farm staff used a levee disk in constructing a firebreak around paddies receiving the burned treatment to contain fire in designated treatment areas. Farm staff ignited fires with drip torches and monitored fires until they burned across paddies. Farm staff was not able to burn one paddy in a field due to a fire ban (Kross 2006:6). For disked paddies, farm staff tilled paddies twice with a disk to ensure rice stubble was flattened and partially incorporated into the soil. For mowed paddies, farm staff cut rice stubble about 15 cm above ground with a rotary mower. For rolled paddies, farm staff pulled a smooth roller over paddies until rice stubble was flattened on the ground. Farm staff flooded paddies in mid-November 2004, creating rice-field wetlands that varied in depth from 3.9-18.6 cm.

I collected 10 soil core samples (10 cm diameter and depth; 785.4 cm^3) from random points in each treated and control paddy of each field. I sampled fields in late November 2004 to establish a baseline abundance of waste rice in experimental paddies and again in late December 2004, late January 2005, and mid-February 2005. I selected sampling periods to encompass the time-frame when rice fields were flooded and could potentially be used by wintering waterfowl and other waterbirds. Farm staff drained fields immediately after the mid-February sampling event to ready fields for spring planting.

Laboratory Methods

Following procedures of related studies (Manley et al. 2004; Stafford et al. 2005, 2006; Kross 2006:6), I stored core samples in a freezer at -10°C until processed. I thawed and soaked samples in a mixture of ≤ 250 cm^3 of baking soda and ~ 1 liter of water to oxidize clays. I rinsed samples with water through a series of 3 graduated sieves (sizes 4 [4.75-mm aperture], 18 [1.0-mm aperture], and 50 [300-µm aperture]) to separate seeds from rice straw and sediments and used a 3% solution of hydrogen peroxide (H_2O_2) to further oxidize and wash clay particles away from seeds (Bohm 1979:117). I assumed this processing mixture did not affect the mass of rice seeds in samples, because Reinecke and Hartke (2005) found that mass of barnyardgrass (*Echinochloa crusgalli*) seeds were not affected by similar techniques. However, if these agents did affect mass of rice seeds, I assumed the effects would be similar among treatments and control samples, and contend that a measure of mean abundance of waste rice was adequate for my experimental purposes. I removed rice seeds from each sample, dried them to a constant mass at 87°C for 24 hours, and weighed seeds to the nearest 0.0001 g.

Statistical Methods

I calculated mean dry mass (kg/ha) of waste rice based on 10 core samples extracted from each of 5 experimental paddies in 3 fields over 4 sampling periods. I used a factorial repeated measures analysis of covariance (ANCOVA) to test the null hypothesis that mean abundance of waste rice at the paddy level was not influenced by field treatment, sampling period, or their interactions (PROC MIXED; SAS Institute, 1999). I designated the previous month's abundance of waste rice and the current month's combined diurnal duck and goose density as covariates. I also included the interaction of treatment and each covariate to test if the effect of the covariate varied among treatments (Gotelli and Ellison 2004). When model effects and their interactions were not significant ($P > 0.10$), I deleted them from subsequent analyses.

I also performed statistical analyses of the percentage change in mean abundance of waste rice in experimental paddies between successive sampling periods. I tested the null hypothesis that percentage change in mean abundance of waste rice was not influenced by field treatment, sampling period, or their interactions (PROC MIXED; SAS Institute, 1999). I designated the current month's combined diurnal duck and goose density as a covariate and followed the same protocol as described above for the test of treatment-covariate interactions and significance level.

Because only 3 fields were available for my experiment and estimates of waste rice were often imprecise (Stafford et al. 2006), I expected statistical power would be low to detect differences among treatments. Therefore, I chose (a priori) a Type I error rate of $\alpha = 0.10$ similar to other management-oriented experiments with small sample size (Tacha et al. 1982). To test homogeneity of variances, I used a Levene's test for each response variable (PROC GLM; SAS Institute 1999). I was unable to reject the null hypothesis that the variances were equal among treatments and sample periods separately for mean abundance of waste rice and percentage change in waste-rice abundance ($F_{4,25} = 1.62$, $P = 0.189$; $F_{2,25} = 0.62$, $P = 0.541$ [waste-rice abundance]; $F_{4,25} = 1.37$, $P = 0.263$; $F_{2,25} = 1.47$, $P = 0.242$; [percentage change in waste-rice abundance]); hence, I assumed homogeneous variances existed among treatments and sampling periods. Although my data sets did not meet the assumption of normality, I assumed ANOVA and ANCOVA were robust to violation of this assumption, and did not transform my data owing to this assumption and lack of evidence of heterogeneous variances (Freund and Wilson 2003:237). I used the small-sample version of Akaike's Information Criterion (AIC_c) to select the autoregressive temporal covariance structure (Burnham and Anderson 2002). When I detected a treatment effect ($P \leq 0.10$), I performed all pair-wise comparisons of means using a Tukey's test (Freund and Wilson 2003:256).

RESULTS

Waste-Rice Abundance

I tested for significance of 2 covariates simultaneously (i.e., the previous month's abundance of waste rice and the current month's diurnal mean density of all waterfowl), along with the main effects of post-harvest treatment, sampling period, and their interactions on variation in monthly abundance of waste rice. I neither detected an effect of previous month's abundance of waste rice ($F_{1,14} = 1.39$, $P = 0.258$) nor an interaction of treatment and this covariate ($F_{4,14} = 2.14$, $P = 0.130$). Additionally, I did not detect an effect of the current month's diurnal waterfowl density ($F_{1,14} = 0.00$, $P = 0.969$), an interaction of treatment and this covariate ($F_{4,14} = 0.88$, $P = 0.499$), or an interaction between both covariates ($F_{1,14} = 0.00$, $P = 0.960$).

Subsequently, I analyzed each covariate individually with the main effects of treatment and sampling period and their interactions. I did not detect an effect of the previous month's abundance of waste rice ($F_{1,20} = 1.47$, $P = 0.239$) or an interaction of treatment and this covariate ($F_{4,20} = 1.60$, $P = 0.214$). Additionally, I did not detect an effect of the current month's diurnal waterfowl density ($F_{1,20} = 0.59$, $P = 0.453$) or an interaction of treatment and this covariate ($F_{4,20} = 0.49$, $P = 0.742$). Therefore, I deleted both covariates from subsequent analyses and tested main effects of treatment and sampling period and their interaction.

For winter 2004-2005, I detected an interaction of post-harvest treatment and sampling period on variation in waste-rice abundance ($F_{8,25} = 2.05$, $P = 0.081$). Averaged across sampling periods, waste-rice abundance in paddies with standing stubble was 1.3-2.0 times greater than that in other treatments (Table 2.1). Averaged across treatments, abundance of waste rice in late November was 4.9-7.1 times greater than that in December 2004 and January and February 2005 (Table 2.1).

Percentage Change in Waste Rice

I tested for significance of the covariate (i.e., current month's diurnal mean density of all waterfowl) with the main effects of treatment, sampling period, and their interactions. I neither detected an effect of the covariate ($F_{1,24} = 0.20$, $P = 0.661$) nor an interaction of treatment and the covariate ($F_{4,20} = 1.67$, $P = 0.195$). Therefore, I deleted the covariate from subsequent analysis and tested the main effects of treatment, sampling period, and their interaction. For winter 2004-2005, percentage change in waste-rice abundance varied among sampling periods ($F_{2,25} = 10.67$, $P \leq 0.001$), but neither detected an effect of post-harvest treatment ($F_{4,25} = 0.84$, $P = 0.515$) nor an interaction of treatment and sampling period ($F_{8,25} = 1.66$, $P = 0.159$). Among periods, waste-rice abundance declined 79.8 % from 180.5 kg/ha (SE = 18.38) in November 2004 to 36.5. kg/ha (18.38) in late December 2004, then it declined further to 29.7 kg/ha (18.38) in late January 2005 and to 25.3 kg/ha (18.38) in mid-February 2005 (Figure 2.1A).

DISCUSSION

The Monsanto Farm and Wildlife Management Center is a production agriculture farm; therefore, standard farming and land management practices were used on all experimental rice fields. Regionally common rice varieties were planted, and entire fields were harvested using conventional combines. Post-harvest field manipulations were applied to experimental paddies in the same manner that rice farmers apply these practices to entire fields. Therefore, my experimental fields were representative of rice fields on the Monsanto Farm and in the surrounding Grand Prairie of Arkansas. However, my results may not broadly apply to the scale of the MAV.

I recorded a significant decline in abundance of waste rice during winter 2004-2005. In late December 2004, I observed great densities of snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) using experimental paddies ($\bar{x}$ = 16.94 birds/ha/day, Chapter 1). The significant decline in waste-rice abundance may have been due to depredation of the grain by geese. Following heavy use of experimental paddies by geese, but before most ducks began using paddies ($\bar{x} < 1$ duck/ha/day; Chapter 1), waste-rice abundance declined in late December 2004 nearly 80% from the late November value and was 27% below the "giving-up" density of 50 kg/ha for foraging waterfowl (Figures 2.1A and B). Reinecke et al. (1989) and Rutka (2004:17) reported that ducks cease foraging in rice fields when the density of grain falls below this apparent threshold value.

Nelms and Twedt (1996) concluded that rice is the cereal grain most resistant to decomposition during winter flooding. Seventy-four percent of rice seed mass persisted after submersion for 120 days while 50-60% of corn remained after 100 days and soybean almost completely deteriorated after 90 days (Nelms and Twedt 1996). Persistence of rice seeds was comparable to that of 6 species of natural plant seeds commonly consumed by waterfowl (i.e., 50-70% of seed mass remained after 120 days of inundation; Nelms and Twedt 1996). This suggests that the decline in waste-rice abundance during December 2004 may have been linked to goose granivory. Although I did not detect a significant effect of waterfowl density on variation in waste-rice abundance or percentage change in waste rice, total waterfowl density in winter 2004-2005 was greatest in burned paddies and least in paddies with standing stubble (Chapter 1), whereas waste-rice abundance for winter 2004-2005 was greatest in paddies with standing stubble and least in burned paddies. Relatively high densities of waterfowl using burned paddies may have contributed to the relatively low abundances of waste rice found in these paddies. Additionally, the relatively high abundances of waste rice found in standing stubble paddies may have been a result of relatively low densities of waterfowl using these paddies.

I did not observe waterfowl abandonment of experimental paddies after waste-rice abundance declined below the "giving-up" density for foraging waterfowl (Reinecke et al. 1989, Rutka 2004:17). Specifically, I observed that all waterfowl used experimental paddies and mallards continued to forage in treated and control paddies after waste-rice abundance declined below the "giving-up" density (Chapter 1). In addition to foraging, I observed mallards exhibiting alert behavior, chasing and defending mates, courting, engaging in locomotion, preening, and resting in experimental paddies before and after reaching the "giving-up" density.

MANAGEMENT AND RESEARCH IMPLICATIONS

I recommend winter management of rice fields on the Monsanto Farm and Arkansas Grand Prairie reflect knowledge about late-autumn abundance of waste rice at the scale of the MAV (Kross 2006:10) and my information on diurnal use of rice fields by waterfowl on the Monsanto Farm (Chapter 1). Specifically, I recommend managers burn rice fields after harvest, because this "natural" strategy (*sensu* Weller 1981) conserved more waste rice than mowing, rolling, or disking stubble (Kross 2006:10), was more economical than mechanical treatments (Kross 2006:16), was attractive to waterfowl and other waterbirds (Chapter 1), and remains an accepted and legal practice in the MAV. Although rice fields left in standing stubble in the MAV conserved the greatest abundance of waste rice (Kross 2006:10) and accrue environmental and agronomic benefits (Manley et al. 2005), mallards used burned or rolled paddies more than paddies left in standing stubble (Chapter 1). When burning rice fields is not feasible or desired, I recommend rolling rice stubble because waterfowl and other waterbirds in this study were attracted most to rolled paddies in winter 2005-2006. Burning and rolling resulted in an interspersion of emergent rice stubble and open water attractive to waterfowl (Chapter 1, Kaminski and Prince 1981, Smith et al. 2004). I do not recommend disking or mowing rice stubble because of the expense of implementation (Kross 2006:16) and decreased abundance of waste rice and avian use (Kross 2006:24, Chapter 1).

Because abundance of waste rice in the MAV generally decreases greatly during fall before waterfowl arrive in large numbers (Stafford et al. 2006), I recommend increasing acreage of actively managed moist-soil wetlands in the MAV (Fredrickson and Taylor 1982). This management practice has potential in the MAV to produce, on average, over 500 kg/ha (dry mass) of natural seeds and tubers as well as other plant and animal foods for waterfowl and other waterbirds (Penny 2003:60, Kross 2006:36). Thus, moist-soil seeds can mitigate decreased availability of waste agricultural seeds (Kaminski et al. 2005, Stafford et al. 2006). I also recommend further investigation of "giving-up" densities for waterfowl food resources in cropland and natural wetlands (e.g., moist-soil, hardwood bottomlands). Other related areas for future research include determination of (1) waterfowl activities in harvested and flooded rice fields and other wetlands relative to "giving-up" food densities, (2) rice varieties and other crops (e.g., grain sorghum) capable of producing a second crop (i.e., ratoon) after initial harvest (Livingston and Coffman 1997, Muzzi 2005), (3) timing of fall flooding fields and impacts on winter waste-grain abundance, (4) habitat management to attract ducks while deterring goose use (i.e., water depth, flooding crops less preferred by geese [e.g., grain sorghum]), and (5) differential effectiveness of goose deterrent techniques (e.g., frightening devices, hunting, lure crops; VerCauteren et al. 2005).

LITERATURE CITED

Bohm, W. 1979. Methods of studying root systems. Springer-Verlag, Berlin, Germany.

Bonney, R., D. N. Pashley, R. J. Cooper, and L. Niles, editors. 1999. Strategies for Bird Conservation: The Partners in Flight Planning Process. Cornell Lab of Ornithology.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

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.

Fredrickson, L. H., S. L. King, and R. M. Kaminski, editors. 2005. Ecology and management of bottomland hardwood systems: the state of our understanding. University of Missouri-Columbia, Gaylord Memorial Laboratory Special Publication Number 10, Puxico, Missouri, USA.

______, and T. S. Taylor. 1982. 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, San Diego, California, USA.

Gotelli, N. J., and A. M. Ellison. 2004. A primer of ecological statistics. Sinauer Associates, Inc, Sunderland, Massachusetts, USA.

Heitmeyer, M. E., R. J. Cooper, J. G. Dickson, and B. D. Leopold. 2005. Ecological relationships of warmblooded vertebrates in bottomland hardwood ecosystems. Pages 281-306 *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 Number 10, Puxico, Missouri, USA.

Kaminski, R. M., J. B. Davis, H. 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.

_____, A. T. Pearse, J. D. Stafford, and K. J. Reinecke. 2005. Where have all the mallards gone? Delta Wildlife 13:23-26.

_____, and H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45:1-15.

Kross, J. K. 2006. Conservation of waste rice and estimates of moist-soil seed abundance for wintering waterfowl in the Mississippi Alluvial Valley. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Livingston, S. D., and C. G. Coffman. 1997. Ratooning grain sorghum on the Texas gulf coast. Texas Agricultural Extension Service Publication L-5168:1-4.

Loesch, C. R., K. J. Reinecke, and C. K. Baxter. 1994. Lower Mississippi Valley Joint Venture Evaluation Plan. U.S. Fish and Wildlife Service, Lower Mississippi Valley Joint Venture, Vicksburg, Mississippi, USA.

Manley, S. W. 1999. Ecological and agricultural values of winter-flooded ricefields in Mississippi. Dissertation, Mississippi State University, Mississippi State, Mississippi, USA.

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

_____, R. M. Kaminski, K. J. Reinecke, and P. D. Gerard. 2005. Agronomic implications of waterfowl management in Mississippi ricefields. Wildlife Society Bulletin 33:981-992.

Muzzi, D. 2005. Let the sun shine in: Flail mowing, rolling may help boost ratoon crop by reducing shade. Rice Farming, May 2005: 8, 11, 18.

National Agricultural Statistics Service. 2006. Crop production summary 2006. U.S. Department of Agriculture, National Agricultural Statistics Service, Agricultural Statistics Board, Washington, D.C., USA.

Neely, W. W. 1956. How long do duck foods last underwater? Transactions of the North American Wildlife and Natural Resources Conference 21:191-198.

Nelms, C. O., and D. J. Twedt. 1996. Seed deterioration in flooded agriculture fields during winter. Wildlife Society Bulletin 24:85-88.

Penny, E. J. 2003. Estimating moist-soil plant seed availability in the Mississippi Alluvial Valley. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

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.

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

_____, 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.

_____, and C. R. Loesch. 1996. Integrating research and management to conserve wildfowl (Anatidae) and wetlands in the Mississippi Alluvial Valley, USA. Gibier Faune Sauvage 13:927-940.

Rutka, D. M. 2004. Waste rice depletion by waterfowl wintering in the Mississippi Alluvial Valley. Thesis, Southern Illinois University, Carbondale, USA.

SAS Institute. 1999. SAS/STAT User's Guide. SAS Institute, Cary, North Carolina, USA.

Shearer, L. A., B. J. Jahn, and L. Lenz. 1969. Deterioration of duck foods when flooded. Journal of Wildlife Management 33:1012-1015.

Smith, L. M., D. A. Haukos, and R. M. Prather. 2004. Avian response to vegetative pattern in playa wetlands during winter. Wildlife Society Bulletin 31:474-480.

Stafford, J. D., R. M. Kaminski, K. J. Reinecke, M. E. Kurtz, and S. W. Manley. 2005. Post-harvest field manipulations to conserve waste rice for waterfowl. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 59:155-163.

_____, 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.

Twedt, D. J., and C. O. Nelms. 1999. Waterfowl density on agricultural fields managed to retain water in winter. Wildlife Society Bulletin 27:924-930.

VerCauteren, K. C., R. A. Dolbeer, and E. M. Gese. 2005. Identification and management of wildlife damage. Pages 740-778 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Weller, M. W. 1981. Estimating wildlife and wetland losses due to drainage and other perturbations. Pages 337-346 *in* B. Richardson, editor. Select Proceedings of the Midwest Conference on Wetland Values and Management. Minnesota Water Planning Board, St. Paul, Minnesota, USA.

Table 2.1 Least squares means ($\bar{x}$) and standard errors (SE) for abundance of waste rice (kg/ha, dry mass) in differently managed rice-field paddies (*n*) post-harvest on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, November 2004-February 2005.

	Control			Disk			Roll			Mow			Burn			Pooled[a]		
Period	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*
Late Nov	257.08	29.56	3	100.36	29.56	3	215.66	29.56	3	181.20	29.56	3	148.10	35.10	2	180.48	18.38	5
Late Dec	35.71	29.56	3	46.94	29.56	3	37.78	29.56	3	33.82	29.56	3	28.20	35.10	2	36.49	18.38	5
Late Jan	46.62	29.56	3	29.55	29.56	3	21.19	29.56	3	24.60	29.56	3	26.55	35.10	2	29.70	18.38	5
Mid Feb	47.90	29.56	3	12.39	29.56	3	25.84	29.56	3	17.00	29.56	3	23.56	35.10	2	25.34	18.38	5

[a] Pooled $\bar{x}$ is a grand average and associated SE across 5 treatment categories.

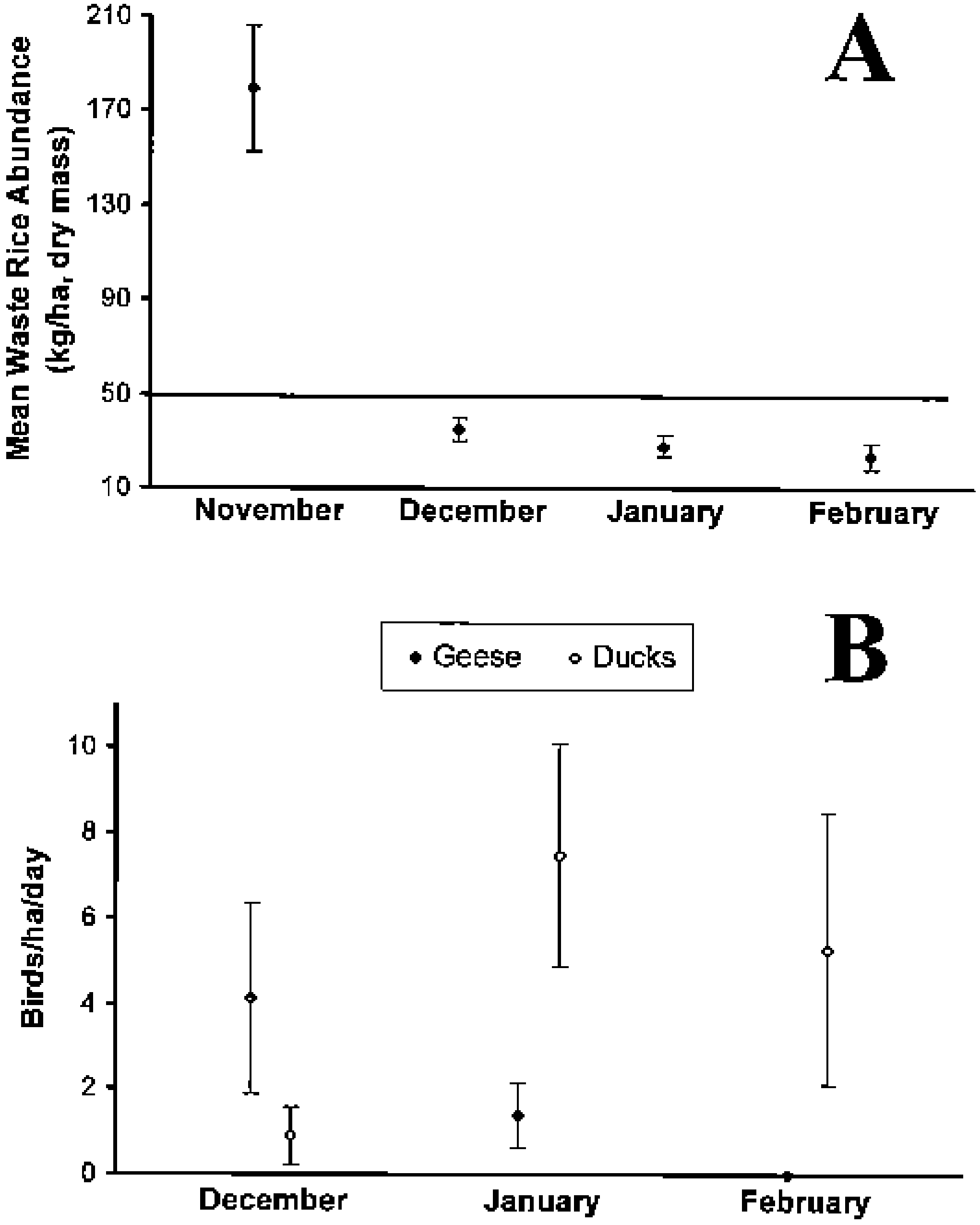

Figure 2.1. Mean abundance ($\bar{x}$) and standard errors (SE) of waste rice in post-harvest manipulated rice fields (A) and mean indices ($\bar{x}$) of diurnal use by waterfowl (B) and standard errors (SE) of post-harvest manipulated rice fields on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005. Horizontal line at 50 kg/ha in Figure 2.1A represents the hypothesized "giving-up" density at which waterfowl cease foraging in rice fields (Reinecke et al. 1989, Rutka 2004).

APPENDIX A

Table A.1. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Burn			Roll			Disk			Mow			Control		
Survey date	$\bar{x}$	SE	n^a	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
4 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
11 Dec 2004	0.45	0.45	2	0.09	0.09	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	0.81	0.81	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
28 Dec 2004	0.81	0.81	2	0.00	0.00	3	1.97	1.97	3	0.00	0.00	3	0.00	0.00	3
7 Jan 2005	7.75	4.70	2	3.34	1.69	3	2.38	1.22	3	4.23	4.11	3	0.16	0.16	3
15 Jan 2005	3.88	1.67	2	0.03	0.03	3	1.25	1.25	3	1.75	1.75	3	0.00	0.00	3
28 Jan 2005	12.25	1.99	2	3.56	3.56	3	2.93	2.21	3	9.05	8.86	3	3.24	3.24	3
11 Feb 2005	10.00	10.00	2	8.33	8.33	3	2.37	2.37	3	0.00	0.00	3	0.00	0.00	3
All surveys	4.49	1.57	16	1.92	1.13	24	1.36	0.50	24	1.87	1.21	24	0.43	0.40	24

[a] n = number of replicate rice field paddies, except for "All surveys" where n = paddies summed over all surveys.

Table A.2. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Roll			Burn			Control		
Survey date	$\bar{x}$	SE	n[a]	$\bar{x}$	SE	n	$\bar{x}$	SE	n
10 Dec 2005	1.59	1.59	3	0.00	0.00	3	0.00	0.00	3
16 Dec 2005	15.81	8.13	3	3.25	2.72	3	3.97	3.22	3
23 Dec 2005	12.57	10.53	3	1.98	0.68	3	0.79	0.29	3
30 Dec 2005	8.63	5.46	3	11.61	6.87	3	3.97	2.01	3
6 Jan 2006	14.46	11.51	3	3.36	1.95	3	2.64	2.61	3
13 Jan 2006	0.49	0.31	3	0.47	0.27	3	0.17	0.17	3
21 Jan 2006	0.53	0.00	1	0.47	0.00	1	0.62	0.00	1
28 Jan 2006	0.00	0.00	3	0.10	0.10	3	0.00	0.00	3
3 Feb 2006	0.00	0.00	3	0.10	0.10	3	0.00	0.00	3
All surveys	6.43	2.27	25	2.52	1.06	25	1.41	0.57	25

[a] n = number of replicate fields, except for "All surveys" when n = the product of n replicate fields and n surveys.

Table A.3. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by other dabbling ducks[a] (Anatini; n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Burn			Mow			Disk			Roll			Control		
Survey date	$\bar{x}$	SE	n[b]	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
4 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
11 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	0.27	0.27	2	0.00	0.00	3	2.01	2.01	3	0.00	0.00	3	0.00	0.00	3
28 Dec 2004	0.22	0.22	2	0.00	0.00	3	10.91	10.91	3	0.00	0.00	3	0.00	0.00	3
7 Jan 2005	12.02	8.30	2	3.58	3.58	3	1.05	0.57	3	0.94	0.68	3	0.16	0.16	3
15 Jan 2005	13.20	8.37	2	19.07	19.07	3	0.85	0.60	3	0.25	0.25	3	0.00	0.00	3
28 Jan 2005	6.82	4.94	2	1.37	1.37	3	0.68	0.44	3	3.39	3.39	3	4.16	4.16	3
11 Feb 2005	3.05	3.05	2	0.13	0.13	3	0.74	0.74	3	4.46	4.46	3	0.00	0.00	3
All surveys	4.45	1.80	16	3.02	2.40	24	2.03	1.36	24	1.13	0.68	24	0.54	0.52	24

[a] American green-winged teal (*Anas carolinensis*), American wigeon (*Anas americana*), gadwall (*Anas strepera*), northern pintail (*Anas acuta*), and northern shoveler (*Anas clypeata*).

[b] n = number of replicate rice field paddies, except for "All surveys" where n = paddies summed over all surveys.

Table A.4. Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by other dabbling ducks[a] (Anatini; *n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Roll			Burn			Control		
Survey date	$\bar{x}$	SE	n^b	$\bar{x}$	SE	n	$\bar{x}$	SE	n
10 Dec 2005	1.20	1.20	3	0.00	0.00	3	0.00	0.00	3
16 Dec 2005	1.82	1.21	3	0.00	0.00	3	0.12	0.12	3
23 Dec 2005	0.22	0.22	3	0.00	0.00	3	0.04	0.04	3
30 Dec 2005	2.00	1.00	3	0.16	0.16	3	0.46	0.46	3
6 Jan 2006	1.01	0.66	3	0.05	0.05	3	0.04	0.04	3
13 Jan 2006	0.09	0.09	3	0.26	0.26	3	0.08	0.08	3
21 Jan 2006	1.73	0.00	1	1.63	0.00	1	0.50	0.00	1
28 Jan 2006	0.00	0.00	3	0.16	0.16	3	0.25	0.25	3
3 Feb 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	0.83	0.26	25	0.14	0.07	25	0.14	0.06	25

[a] American green-winged teal (*Anas carolinensis*), American wigeon (*Anas americana*), gadwall (*Anas strepera*), northern pintail (*Anas acuta*), and northern shoveler (*Anas clypeata*).

[b] n = number of replicate fields, except for "All surveys" when n = the product of n replicate fields and n surveys.

Table A.5. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) combined (n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Burn			Disk			Mow			Roll			Control		
Survey date	$\bar{x}$	SE	n^a	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
4 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
11 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
28 Dec 2004	26.86	26.86	2	27.61	27.61	3	30.97	30.97	3	0.00	0.00	3	0.00	0.00	3
7 Jan 2005	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
15 Jan 2005	0.00	0.00	2	0.00	0.00	3	0.08	0.08	3	0.00	0.00	3	0.00	0.00	3
28 Jan 2005	9.90	9.90	2	8.05	8.01	3	0.00	0.00	3	4.99	4.99	3	0.00	0.00	3
11 Feb 2005	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	4.59	3.50	16	4.46	3.55	24	3.88	3.87	24	0.62	0.62	24	0.00	0.00	24

[a] n = number of replicate rice field paddies, except for "All surveys" where n = paddies summed over all surveys.

Table A.6. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by snow geese (*Chen caerulescens*) and white-fronted geese (*Anser albifrons*) combined (n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Control			Roll			Burn		
Survey date	$\bar{x}$	SE	n[a]	$\bar{x}$	SE	n	$\bar{x}$	SE	n
10 Dec 2005	17.63	17.63	3	9.81	9.81	3	10.30	10.30	3
16 Dec 2005	0.11	0.11	3	1.20	1.20	3	0.08	0.08	3
23 Dec 2005	0.00	0.00	3	0.40	0.40	3	0.00	0.00	3
30 Dec 2005	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
6 Jan 2006	0.00	0.00	3	0.00	0.00	3	0.13	0.13	3
13 Jan 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
21 Jan 2006	0.00	0.00	1	0.00	0.00	1	0.00	0.00	1
28 Jan 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
3 Feb 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	2.13	2.12	25	1.36	1.18	25	1.26	1.23	25

[a] n = number of replicate fields, except for "All surveys" when n = the product of n replicate fields and n surveys.

Table A.7. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by waterbirds[a] (n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Roll			Burn			Mow			Disk			Control		
Survey date	$\bar{x}$	SE	n[b]	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
4 Dec 2004	0.00	0.00	3	0.04	0.04	2	0.09	0.09	3	0.04	0.04	3	0.04	0.04	3
11 Dec 2004	0.02	0.02	3	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	10.14	8.97	3	4.32	4.32	2	0.45	0.45	3	0.60	0.60	3	0.00	0.00	3
28 Dec 2004	0.00	0.00	3	0.00	0.00	2	0.09	0.09	3	0.00	0.00	3	0.00	0.00	3
7 Jan 2005	0.00	0.00	3	0.22	0.22	2	0.31	0.31	3	0.00	0.00	3	0.00	0.00	3
15 Jan 2005	0.00	0.00	3	0.04	0.04	2	0.00	0.00	3	0.00	0.00	3	0.29	0.27	3
28 Jan 2005	0.59	0.59	3	0.00	0.00	2	0.35	0.25	3	0.28	0.25	3	0.00	0.00	3
11 Feb 2005	0.00	0.00	3	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	1.34	1.17	24	0.58	0.54	16	0.16	0.07	24	0.11	0.08	24	0.04	0.03	24

[a] American coot (*Fulica americana*), common snipe (*Gallinago gallinago*), great blue heron (*Ardea herodius*), great egret (*Ardea alba*), greater yellowlegs (*Tringa melanoleuca*), killdeer (*Charadrius vociferus*), and "peeps" (family Scolopacidae).

[b] n = number of replicate rice field paddies, except for "All surveys" where n = paddies summed over all surveys.

Table A.8. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by waterbirds[a] (n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Roll			Burn			Control		
Survey date	$\bar{x}$	SE	n[b]	$\bar{x}$	SE	n	$\bar{x}$	SE	n
10 Dec 2005	3.37	3.10	3	0.00	0.00	3	0.00	0.00	3
16 Dec 2005	0.73	0.59	3	0.11	0.07	3	0.04	0.04	3
23 Dec 2005	0.06	0.03	3	0.28	0.23	3	0.00	0.00	3
30 Dec 2005	0.03	0.03	3	0.36	0.36	3	0.08	0.08	3
6 Jan 2006	1.27	1.08	3	0.27	0.23	3	0.00	0.00	3
13 Jan 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
21 Jan 2006	0.00	0.00	1	0.00	0.00	1	0.00	0.00	1
28 Jan 2006	0.00	0.00	3	0.21	0.21	3	0.00	0.00	3
3 Feb 2006	0.00	0.00	3	0.00	0.00	3	0.04	0.04	3
All surveys	0.65	0.40	25	0.14	0.06	25	0.02	0.01	25

[a] American cool (*Fulica americana*), common snipe (*Gallinago gallinago*), great blue heron (*Ardea herodius*), great egret (*Ardea alba*), greater yellowlegs (*Tringa melanoleuca*), killdeer (*Charadrius vociferus*), and "peeps" (family Scolopacidae).

[b] n = number of replicate fields, except for "All surveys" when n = the product of n replicate fields and n surveys.

Table A.9. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by feeding mallards (*Anas platyrhynchos*; n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Burn			Mow			Roll			Disk			Control		
Survey date	$\bar{x}$	SE	n[a]	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
4 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
11 Dec 2004	0.00	0.00	2	0.09	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	0.76	0.40	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
28 Dec 2004	0.76	0.42	2	0.00	0.00	3	0.00	0.00	3	1.67	1.31	3	0.00	0.00	3
7 Jan 2005	0.84	0.31	2	3.29	1.88	3	1.20	0.62	3	1.46	0.51	3	0.07	0.06	3
15 Jan 2005	1.79	0.69	2	1.45	1.45	3	0.02	0.02	3	0.92	0.90	3	0.00	0.00	3
28 Jan 2005	8.20	2.66	2	5.56	3.00	3	2.93	1.11	3	1.54	0.88	3	2.40	1.62	3
11 Feb 2005	1.64	0.51	2	0.00	0.00	3	5.30	1.97	3	2.13	0.87	3	0.00	0.00	3
All surveys	1.75	0.67	16	1.29	0.79	24	1.18	0.74	24	0.97	0.38	24	0.31	0.30	24

[a] n = number of replicate rice field paddies, except for "All surveys" where n = paddies summed over all surveys.

Table A.10. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by feeding mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Roll			Burn			Control		
Survey date	$\bar{x}$	SE	n^a	$\bar{x}$	SE	n	$\bar{x}$	SE	n
10 Dec 2005	0.75	0.54	3	0.00	0.00	3	0.00	0.00	3
16 Dec 2005	12.01	5.21	3	0.92	0.59	3	1.34	1.01	3
23 Dec 2005	7.10	3.84	3	0.73	0.35	3	0.25	0.14	3
30 Dec 2005	7.09	2.39	3	7.11	2.44	3	1.15	0.46	3
6 Jan 2006	9.16	4.09	3	2.13	0.81	3	1.08	0.70	3
13 Jan 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
21 Jan 2006	0.40	0.27	1	0.00	0.00	1	0.00	0.00	1
28 Jan 2006	0.00	0.00	3	0.05	0.05	3	0.00	0.00	3
3 Feb 2006	0.00	0.00	3	0.10	0.07	3	0.00	0.00	3
All surveys	4.35	1.62	25	1.33	0.80	25	0.46	0.23	25

[a] n = number of replicate fields, except for "All surveys" when n = the product of n replicate fields and n surveys.

Table A.11. Mean ($\bar{x}$) indices (and standard errors [SE, n]) of diurnal use by resting mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Burn			Roll			Disk			Control			Mow		
Survey date	$\bar{x}$	SE	n^a	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n	$\bar{x}$	SE	n
4 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
11 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
28 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
7 Jan 2005	0.21	0.13	2	0.37	0.34	3	0.35	0.17	3	0.00	0.00	3	0.00	0.00	3
15 Jan 2005	0.09	0.09	2	0.00	0.00	3	0.07	0.07	3	0.00	0.00	3	0.00	0.00	3
28 Jan 2005	1.60	1.18	2	0.45	0.31	3	0.40	0.18	3	0.37	0.26	3	0.29	0.17	3
11 Feb 2005	5.37	1.63	2	2.84	1.25	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	0.91	0.68	16	0.46	0.36	24	0.10	0.04	24	0.05	0.05	24	0.04	0.03	24

[a] n = number of replicate rice field paddies, except for "All surveys" where n = paddies summed over all surveys.

Table A.12. Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by resting mallards (*Anas platyrhynchos; n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Roll			Burn			Control		
Survey date	$\bar{x}$	SE	*n*[a]	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*
10 Dec 2005	0.13	0.13	3	0.00	0.00	3	0.00	0.00	3
16 Dec 2005	0.65	0.32	3	0.45	0.32	3	0.18	0.18	3
23 Dec 2005	4.65	3.10	3	0.26	0.13	3	0.21	0.12	3
30 Dec 2005	0.03	0.03	3	0.16	0.08	3	0.37	0.17	3
6 Jan 2006	0.23	0.17	3	0.05	0.05	3	0.00	0.00	3
13 Jan 2006	0.15	0.15	3	0.00	0.00	3	0.00	0.00	3
21 Jan 2006	0.00	0.00	1	0.00	0.00	1	0.00	0.00	1
28 Jan 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
3 Feb 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	0.70	0.55	25	0.11	0.06	25	0.09	0.05	25

[a] *n* = number of replicate fields, except for "All surveys" when *n* = the product of *n* replicate fields and *n* surveys.

Table A.13. Mean ($\bar{x}$) indices (and standard errors [SE, *n*]) of diurnal use by mallards (*Anas platyrhynchos*) engaged in locomotion (*n* birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2004-2005.

	Burn			Mow			Roll			Disk			Control		
Survey date	$\bar{x}$	SE	*n*[a]	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*	$\bar{x}$	SE	*n*
4 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
11 Dec 2004	0.45	0.45	2	0.00	0.00	3	0.09	0.09	3	0.00	0.00	3	0.00	0.00	3
18 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
28 Dec 2004	0.00	0.00	2	0.00	0.00	3	0.00	0.00	3	0.10	0.07	3	0.00	0.00	3
7 Jan 2005	6.14	3.06	2	0.84	0.45	3	1.47	0.60	3	0.24	0.16	3	0.09	0.09	3
15 Jan 2005	1.86	1.29	2	0.15	0.15	3	0.00	0.00	3	0.10	0.10	3	0.00	0.00	3
28 Jan 2005	1.42	1.02	2	1.45	1.04	3	0.14	0.11	3	0.60	0.38	3	0.35	0.24	3
11 Feb 2005	1.07	0.63	2	0.00	0.00	3	0.20	0.08	3	0.13	0.09	3	0.00	0.00	3
All surveys	1.37	0.71	16	0.31	0.20	24	0.24	0.14	24	0.15	0.07	24	0.05	0.04	24

[a] *n* = number of replicate rice field paddies, except for "All surveys" where *n* = paddies summed over all surveys.

Table A.14. Mean ($\overline{x}$) indices (and standard errors [SE, n]) of diurnal use by mallards (*Anas platyrhynchos*) engaged in locomotion (n birds/ha/day) of post-harvest managed rice field paddies on the Monsanto Farm and Wildlife Management Center, Stuttgart, Arkansas, winter 2005-2006.

	Roll			Burn			Control		
Survey date	$\overline{x}$	SE	n[a]	$\overline{x}$	SE	n	$\overline{x}$	SE	n
10 Dec 2005	0.53	0.53	3	0.00	0.00	3	0.00	0.00	3
16 Dec 2005	2.53	1.40	3	1.77	1.03	3	2.45	1.45	3
23 Dec 2005	0.60	0.22	3	0.99	0.42	3	0.33	0.20	3
30 Dec 2005	0.83	0.41	3	3.86	1.60	3	2.20	0.88	3
6 Jan 2006	4.10	1.88	3	0.97	0.57	3	1.31	1.16	3
13 Jan 2006	0.40	0.40	3	0.35	0.35	3	0.00	0.00	3
21 Jan 2006	0.00	0.00	1	0.31	0.20	1	0.00	0.00	1
28 Jan 2006	0.00	0.00	3	0.05	0.05	3	0.00	0.00	3
3 Feb 2006	0.00	0.00	3	0.00	0.00	3	0.00	0.00	3
All surveys	1.09	0.50	25	0.99	0.39	25	0.75	0.33	25

[a] n = number of replicate fields, except for "All surveys" when n = the product of n replicate fields and n surveys.