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Management and Conservation Note: Conserving Waste Rice for Wintering Waterfowl in the Mississippi Alluvial Valley

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Conserving Waste Rice for Wintering Waterfowl in the Mississippi Alluvial Valley

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ABSTRACT Rice lost before or during harvest operations (hereafter waste rice) provides important food for waterfowl in the Mississippi Alluvial Valley, USA, but >70% of waste rice is lost during autumn. We conducted experiments in 19 production rice fields in Arkansas and Mississippi during autumns 2003 and 2004 to evaluate the ability of common postharvest practices (i.e., burn, mow, roll, disk, or standing stubble) to conserve waste rice. We detected a postharvest treatment effect and a positive effect of initial abundance of waste rice on late-autumn abundance of waste rice ($P \leq 0.022$). Standing stubble contained the greatest abundance of waste rice followed by burned, mowed, rolled, and disked stubble. We recommend standing stubble or burning to maximize waste rice abundance for wintering waterfowl. (JOURNAL OF WILDLIFE MANAGEMENT 72(6):1383–1387; 2008)

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The Mississippi Alluvial Valley (MAV), USA, is an internationally important migration and wintering region for North American waterfowl (Reinecke et al. 1989). The Lower Mississippi Valley Joint Venture (LMVJV) assumes food availability is the primary factor influencing carrying capacity of wintering waterfowl in this region (Reinecke and Loesch 1996). Because much of the MAV was converted from a seasonally flooded bottomland–hardwood ecosystem to a landscape dominated by agriculture, the LMVJV has incorporated estimates of the abundance of agricultural seeds such as rice into habitat conservation plans (Reinecke et al. 1988, Fredrickson et al. 2005). Biologists designed these plans to provide sufficient food when waterfowl populations attain levels of abundance targeted by the North American Waterfowl Management Plan (Lower Mississippi Valley Joint Venture Management Board 1990, Reinecke and Loesch 1996).

Rice is an important crop in the MAV (i.e., >800,000 ha planted in the MAV of AR, LA, MS, and MO in 2003 and 2004 [National Agricultural Statistics Service 2004]) and is an energy-rich food for waterfowl (Reinecke et al. 1989). Manley et al. (2004) reported that rice lost before or during harvest (hereafter waste rice) in Mississippi fields was less abundant in early winter than previously estimated in the 1980s (i.e., 180 kg/ha [dry mass]; Reinecke and Loesch 1996). To obtain a contemporary estimate of the abundance of waste rice for conservation planning by the LMVJV, Stafford et al. (2006) sampled >150 harvested fields throughout the MAV and reported that waste rice averaged only 78 kg/ha in early winter 2000–2002. Knowledge of decreased availability of waste rice is crucial because, when rice abundance declines to approximately 50 kg/ha, energetic costs may exceed nutritional benefits of foraging and ducks may cease or give-up feeding in rice fields (Reinecke et al. 1989, Rutka 2004). Thus, the difference between waste-rice abundance in early winter and the giving-up density of 50 kg/ha is <30 kg/ha, and waterfowl carrying capacity of harvested rice fields is <20% of the earlier estimated value (Stafford et al. 2006).

Manley et al. (2004) and Stafford et al. (2006) recommended evaluating common stubble-management practices conducted postharvest to determine the potential of treatments to differentially conserve waste rice. Stafford et al. (2005) conducted pilot experiments in test plots in Mississippi and a retrospective analysis of data from sample surveys of waste-rice abundance in MAV rice fields where stubble was burned, disked, rolled, or left standing after initial harvest. Stafford et al. (2005) reported no statistical difference among treatments from their retrospective analysis or plot experiments in 2003, yet mean abundance of waste rice in fields with standing stubble was nearly twice that of other field manipulations during late autumn. We expanded on this pilot study to test experimentally differences among field manipulations as suggested by Stafford et al. (2005). We conducted experiments in production rice fields in Mississippi and Arkansas in 2003 and 2004 to compare mean abundance (dry mass) of waste rice among 5 common postharvest management practices (i.e., burn, mow, roll, disk, or no treatment of stubble).

STUDY AREA

We conducted our experiment in 6 harvested rice fields in 2003 and 13 fields in 2004 in the MAV regions of Mississippi ($n = 10$) and Arkansas ($n = 9$; Kross 2006),

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USA. We selected rice fields on private ($n = 11$) and public lands (National Wildlife Refuges [NWR]; $n = 8$), where we received cooperation of landowners or NWR staff to apply prescribed treatments. We used fields containing linear ($n = 5$) or contour ($n = 14$) levees, and crops were harvested using stripper-header ($n = 7$) or conventional ($n = 12$) combines. Whether fields were on public or private lands, producers used management practices representative of rice agriculture in the MAV (e.g., Miller and Street 2000). Farmers planted common varieties of rice including Priscilla, Wells, Cocodrie, Clearfield, and Francis, and we had no control over varieties planted.

METHODS

We used a randomized complete block design and designated rice fields as blocks to control for anticipated variation among fields (e.g., harvest and treatment dates, rice variety, yield). We chose 5 paddies (i.e., area between levees) within each field to apply treatments, designated paddy as the experimental unit, and randomly assigned 1 of the 5 treatments to each paddy. Landowners or NWR staff treated $\geq$0.4 ha of rice stubble in each paddy 1–7 days after harvest. They burned paddies assigned to that treatment by igniting rice stubble with a drip torch after disking firebreaks between experimental paddies where needed. For disked treatment, cooperators tilled paddies with an offset disk 1 or 2 times and, for mowed treatment, they cut stubble approximately 15 cm above the ground with a rotary mower. For rolled treatment, cooperators pulled a smooth roller over paddies 1 or 2 times until most rice stubble was flattened.

One to 3 days after treatments were applied, we collected 10 randomly located soil core-samples (10-cm diam and depth; 785.4 cm^3) from each experimental paddy using standard core-sampling techniques to estimate abundance of waste rice (Manley et al. 2004, Stafford et al. 2006). We collected the early autumn samples (hereafter postharvest) between 12 September–15 October 2003 and 11 September–17 October 2004 depending on weather and dates of harvest and treatment applications. We collected the second set of samples (hereafter late autumn) between 22–23 November 2003 and 12–21 November 2004. We chose the latter dates in concurrence with flooding periods desired by producers or managers providing flooded rice fields for wintering waterfowl.

We stored core-samples in a freezer at $-10°$ C until processed. We thawed and soaked samples for 1 hour in a 3% solution of hydrogen peroxide (H_2O_2), a mixture of $\leq$250 cm^3 of baking soda and approximately 1 L of water, or a combination of these, to oxidize clays and facilitate washing sediments through sieves (Bohm 1979). In a post hoc experiment, we determined that use of any combination of reagents did not influence mass of individual rice seeds (H. M. Hagy and R. M. Kaminski, Mississippi State University, unpublished data). We removed rice seeds from samples and dried and weighed seeds following procedures in related studies (Manley et al. 2004; Stafford et al. 2005, 2006). We defined waste-rice abundance as dry mass of seeds (Stafford et al. 2006).

We deleted 3 paddies from analyses because wet conditions prevented burning stubble in one paddy, hazardous dry conditions prevented burning stubble in one paddy, and one mowed paddy was inadvertently burned. We designated the paddy as the experimental unit and performed statistical analyses on mean dry mass of rice seeds from 10 core-samples per paddy collected in each of 2 time periods, 5 treatments, and 19 fields. We did not correct means for rice seeds not recovered during sample processing because our primary objective was to compare relative abundance of waste rice among postharvest treatments, and we assumed any bias from nonrecovery of seeds was the same among treatments.

Because estimates of waste-rice abundance in fields can be imprecise, we expected low statistical power (Stafford et al. 2006). Therefore, we designated an a priori Type I error rate of $\alpha = 0.10$, which is considered acceptable for management-oriented experiments (Tacha et al. 1982). Plotting residuals against predicted values from preliminary models indicated variances were heterogeneous; therefore, we transformed ($\log_e$) the aforementioned means before analyses and, after transformations, errors appeared less heteroscedastic via residual plots (Zar 1974). We did not formally test for normality of errors because analysis of variance (ANOVA) is robust to this assumption when sample sizes are large (i.e., Central Limit Theorem; Gotelli and Ellison 2004).

We performed ANOVA on the transformed postharvest means to determine factors influencing variation in postharvest rice abundance (PROC MIXED, SAS version 8.02 [SAS Institute, Inc., Cary, NC]). As explanatory variables, we included fixed effects of stubble treatment and, because Stafford et al. (2006) reported waste-rice abundance differed between stripper-header and conventional combines, we added parameters for this effect and its interactions with treatment. We designated year and rice fields nested within combinations of years and combine types as random effects to account for use of different fields in 2003 and 2004 and to ensure PROC MIXED (SAS version 8.02) used the appropriate error term for testing effects of explanatory variables.

We performed analysis of covariance (ANCOVA) on transformed means to determine factors influencing variation in late-autumn rice abundance. As explanatory variables, we included treatment and transformed postharvest rice abundance as a covariate. We tested for an interaction between the covariate and treatment to determine if the former effect varied among treatments and removed this term from the model if $P > 0.10$ (Gotelli and Ellison 2004). We included year and field as random effects for the reasons given previously. We did not include combine type in the ANCOVA because variation in postharvest abundance of waste rice was not influenced by this variable (see Results). Based on results reported by Stafford et al. (2005), we formulated an a priori contrast to

Table 1. Results of analysis of variance and analysis of covariance to explain variation in abundance of waste rice after harvest and in late autumn from 19 rice fields in the Mississippi Alluvial Valley, USA, 2003–2004.

Variable	Postharvest			Late autumn		
	F	df	P	F	df	P
Stubble treatment	0.74	4,65	0.566	3.08	4,68	0.022
Combine type	0.05	1,16	0.826			
Treatment × combine type	0.58	4,65	0.677			
Covariate[a]				24.97	1,68	<0.001
Treatment × covariate[b]				1.58	4,64	0.189

[a] Postharvest abundance of waste rice in individual paddies (experimental unit) within rice fields.
[b] Removed from final analysis.

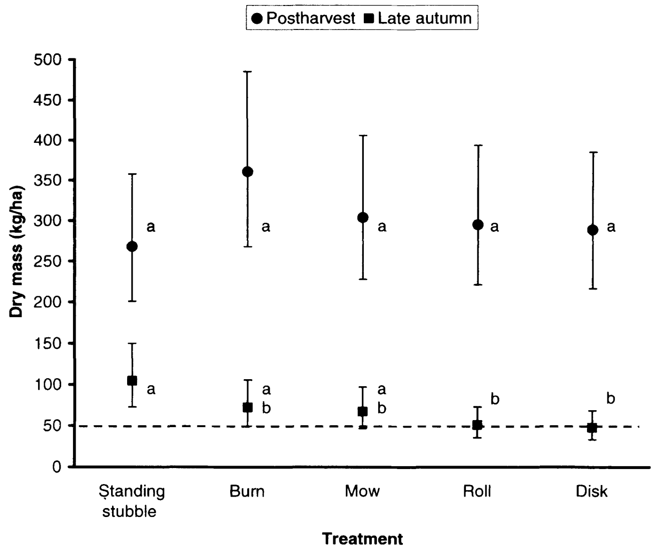

Figure 1. Postharvest and late-autumn least-square means for abundance of dry mass (kg/ha) and 90% confidence intervals (back-transformed from $\log_e$ values) for experimental treatments applied in harvested rice fields in Arkansas and Mississippi, USA, in autumns 2003 and 2004. Horizontal dashed line at 50 kg/ha represents the giving-up density at which waterfowl generally cease foraging in rice fields (Reinecke et al. 1989, Rutka 2004). Letters indicate results of pair-wise comparisons of mean amount of waste rice between treatments within sampling period.

test if mean abundance of waste rice in standing stubble in late autumn was greater than mean abundance across the remaining treatments. We also performed pair-wise multiple comparisons of differences among all transformed late-autumn means using an adjusted Tukey's test when we detected an overall treatment main effect ($P \leq 0.10$).

RESULTS

We did not detect effects of treatment, combine type, or an interaction between treatment and combine type on postharvest abundance of waste rice (Table 1). The overall back-transformed mean and confidence limits (CL) for postharvest abundance of waste rice was 304.3 kg/ha (90% CL = 267.7, 345.9). Late-autumn abundance of waste rice varied by treatment, postharvest abundance of waste rice, and the effect of this covariate did not differ among treatments (Table 1). We found a positive effect of the covariate ($\hat{\beta} = 0.749$, SE = 0.150). Results of our a priori contrast indicated mean abundance of waste rice in standing stubble ($\bar{x}$ = 104.6 kg/ha; 90% CL = 72.8, 150.2) was greater than the mean over all other treatments ($\bar{x}$ = 58.8 kg/ha; 90% CL = 45.6, 75.8; $F_{1,68} = 8.21$; $P = 0.006$; Fig. 1). Our pair-wise comparisons revealed mean abundance of waste rice in standing stubble was >2 times that in rolled ($\bar{x}$ = 51.0 kg/ha; 90% CL = 35.5, 73.1; $t_{68} = 2.85$; $P = 0.045$) or disked stubble ($\bar{x}$ = 47.7 kg/ha; 90% CL = 33.3, 68.4; $t_{68} = 3.11$; $P = 0.022$). We did not detect a difference in mean abundance of waste rice between standing and mowed stubble ($\bar{x}$ = 67.4 kg/ha; 90% CL = 46.7, 97.4), standing and burned stubble ($\bar{x}$ = 72.4 kg/ha; 90% CL = 49.6, 105.8), or any other pair-wise comparisons of means ($P \geq 0.435$; Fig. 1). The mean for late-autumn abundance of waste rice across all treatments ($\bar{x}$ = 66.1 kg/ha, 90% CL = 53.6, 81.5) was 78% less than the overall postharvest mean.

DISCUSSION

Standing stubble contained the greatest mean abundance of waste rice potentially available for waterfowl during late autumn compared to the average abundance of other field manipulations as was inferred in a pilot study (Stafford et al. 2005). Individually, we were unable to detect a difference in waste-rice abundance between standing stubble and burned and mowed treatments during late autumn, although mean abundance of waste rice for mowed and burned paddies was 35% and 31% less than standing stubble, respectively. Unlike Stafford et al. (2005), we detected statistical differences between standing stubble and disked and rolled treatments during late autumn.

Interestingly, fires often produced a patchwork of burned and unburned stubble within rice fields that, after flooding, provided an interspersion of stubble and open water that has been reported as attractive to waterbirds in natural wetlands and winter-managed rice fields (Kaminski and Prince 1981, Smith et al. 2004, Havens 2007). However, we caution that the future of burning rice stubble in the MAV is uncertain because burning has been prohibited in other rice-growing regions (Lindberg 2003). Managers can create limited designed openings in stubble by mechanical means while accounting for equipment wear and general costs of $10–20/ha depending on equipment used (Laughlin and Spurlock 2003, Mississippi Agricultural and Forestry Experiment Station 2004). Additionally, treatment of stubble should be avoided above drainage structures so stubble can slow water flow and retain soil and nutrients (Manley 1999).

Evidence that waterfowl give up feeding in rice fields when seed abundance is <50 kg/ha also is an important consideration in determining strategies for managing harvested fields as winter foraging habitat (Reinecke et al. 1989, Rutka 2004). Mean abundance of waste rice was >50 kg/ha in standing, burned, mowed, and rolled stubble in late autumn, but standing stubble was the only treatment with a lower confidence level exceeding this value. Additionally, in terms of the duck energy days (DEDs), a common method of expressing forage availability as energy available to support mallard-sized ducks and accounting for the

giving-up density (Reinecke et al. 1989, Stafford et al. 2006), the average standing stubble treatment contained 625 DEDs/ha, burned treatment contained 256 DEDs/ha, mowed treatment contained 199 DEDs/ha, rolled treatment contained 11 DEDs/ha, and disked treatment contained no DEDs.

Loss of waste rice during autumn has been attributed to germination, decomposition, and granivory by invertebrates and vertebrates (McGinn and Glasgow 1963, Stafford 2004). When rice is stored commercially, temperature, moisture, and storage duration influence decomposition rates (Brooker et al. 1992, Loewer et al. 2003). We assumed these factors also occur in field environments, and the various paddy manipulations may have produced differing levels of these conditions and the observed differences in loss of waste rice during autumn. For example, standing stubble, mowing, and burning may have inhibited decomposition and germination more than other treatments. Optimum air temperatures for rice germination range from 20° C to 35° C, and dense standing stubble or a litter layer from mowing may have created shade that, in concert with decreasing autumn temperatures, resulted in microclimates deterring decomposition and germination (Northen 1968, Yoshida 1981). As speculated by Stafford et al. (2005), fire in burned plots may have heated rice seeds and killed embryos preventing germination (Loewer et al. 2003). Additionally, cover created by standing stubble and mowing may have inhibited detection of waste rice by granivores, whereas disking and rolling may have exposed seed to loss by stimulating germination or burying seed below the depth of our core sampling (i.e., 10 cm).

Results from our experiment also supported the conclusion of Stafford et al. (2006) that postharvest rice abundance was a significant predictor of late-autumn rice abundance, which indicates producers leaving increased rice in fields at harvest will provide additional food for waterfowl but also suggests future improvements in harvest efficiency may decrease rice availability in winter. Periodic monitoring of harvest efficiency could reveal decreases in waste rice and indicate need for an updated estimate of waste-rice abundance in late autumn and reevaluation of waterfowl carrying capacity in harvested rice fields.

Rice producers in this study used conventional or stripper-header combines to harvest rice. Miller and Wylie (1996) reported stripper-header combines left less waste rice after harvest than conventional combines in California. In contrast, Stafford et al. (2006) reported abundance of waste rice in MAV fields was greater for stripper-header than conventional combines after harvest but not in late autumn. Unlike Stafford et al. (2006), we did not detect an effect of combine type on postharvest abundance of waste rice. Because of inconsistencies in these results among studies, we recommend further evaluation of effects of harvest implements and methods on abundance of waste agricultural seeds and waterfowl carrying capacity.

Rice producers cooperating in our study used standard agricultural practices, planted common rice varieties, and produced rice for the grain market. Our estimate of mean abundance of waste rice in standing stubble in late autumn of 104.6 kg/ha (625 DEDs/ha) was similar to Stafford et al. (2005) estimate for standing stubble ($\bar{x} = 111.7$ kg/ha; 706 DEDs/ha), and our observed decrease in waste-rice abundance between harvest and late autumn averaged 78% over treatments, which was consistent with the 71% decline reported by Stafford et al. (2006). Therefore, we concluded our study fields were representative of rice fields and rice farming in the MAV and our results applicable to this target population.

Although we identified postharvest practices that differentially conserved waste rice, a substantial amount of rice is lost annually between harvest and late autumn (Kross 2006, Stafford et al. 2006). Increased acreage of managed moist-soil wetlands and second autumn crops of rice and other cereals after initial harvests (i.e., ratoon) can help mitigate loss of waste agricultural seeds in the MAV (Stafford et al. 2006). Research in the MAV and elsewhere has shown that managed moist-soil wetlands can provide abundant natural plant and animal foods and, ultimately, several times more potential waterfowl forage than harvested rice fields (Gray et al. 1999, Bowyer et al. 2005, Kross et al. 2008). Farm Bill programs such as the Conservation and Wetland Reserve Programs offered through the Natural Resources Conservation Service can provide private landowners with cost-share opportunities and technical assistance to restore and manage such wetlands. These restored wetlands experience similar or greater waterbird diversity and use compared to natural wetlands or those without hydrological management (Ratti et al. 2001, Kaminski et al. 2006).

Management Implications

We recommend managers leave as much area of standing stubble as possible to conserve waste rice for wintering waterfowl (Stafford et al. 2005; this study). Leaving standing stubble can provide 625 DEDs/ha. As an alternative, burning is economical, provides the second-greatest rice abundance, and 256 DEDs/ha. Managers can also increase waste rice abundance in fields by leaving increased rice in fields at harvest that will provide additional food for waterfowl in late autumn. Mechanical treatment of stubble resulted in the lowest abundance of waste rice in late autumn. We do not recommend mowing, disking, or rolling entire fields of rice stubble because of decreased waste rice abundance.

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LITERATURE CITED

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

Bowyer, M. W., J. D. Stafford, A. P. Yetter, C. S. Hine, M. M. Horath, and S. P. Havera. 2005. Moist-soil plant seed production for waterfowl in Chautauqua National Wildlife Refuge, Illinois. American Midland Naturalist 154:331–341.

Brooker, D. B., F. W. Bakker-Arkema, and C. W. Hall. 1992. Drying and storage of grains and oilseeds. Van Nostrand Reinhold, New York, New York, USA.

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 No. 10, Puxico, USA.

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

Gray, M. J., R. M. Kaminski, G. Weerakkoby, B. D. Leopold, and K. C. Jensen. 1999. Aquatic invertebrate and plant responses following mechanical manipulations of moist-soil plants. Wildlife Society Bulletin 27:770–779.

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

Kaminski, M. R., G. A. Baldassarre, and A. T. Pearse. 2006. Waterbird responses to hydrological management of Wetland Reserve Program habitats in New York. Wildlife Society Bulletin 34:921–926.

Kaminski, R. M., and H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45:1–15.

Kross, J. 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, USA.

Kross, J. P., R. M. Kaminski, K. J. Reinecke, E. J. Penny, and A. T. Pearse. 2008. Moist-soil seed abundance in managed wetlands in the Mississippi Alluvial Valley. Journal of Wildlife Management 72:707–714.

Laughlin, D. H., and S. R. Spurlock. 2003. User's guide for the Mississippi state budget generator version 6.0 for Windows. Agriculture Economic Staff Report No. 2003-01. Department of Agricultural Economics, Mississippi State University, Mississippi State, USA.

Lindberg, J. 2003. 2003 progress report on phase-down of rice straw burning in the Sacramento Valley air basin. California Air Resources Board, California Department of Food and Agriculture December 2003, Sacramento, USA.

Loewer, O. J., D. H. Loewer, G. E. Miller, C. Mutters, J. F. Thompson, and J. Williams. 2003. Managing rice decay during storage. Pages 1–13 *in* Proceedings of the University of California rice quality workshop, Davis, 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, USA.

Manley, S. W., 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.

McGinn, L. R., and L. L. Glasgow. 1963. Loss of waterfowl foods in ricefields in southwest Louisiana. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 17:69–79.

Miller, M. R., and G. D. Wylie. 1996. Preliminary estimate of rice present in strip-harvested fields in the Sacramento Valley, California. California Fish and Game 82:187–191.

Miller, T. C., and J. E. Street. 2000. Mississippi rice growers guide. Mississippi State University Extension Service Publication 2255, Mississippi State, USA.

Mississippi Agricultural and Forestry Experiment Station. 2004. Rice 2005 planning budgets. Budget report, 2004–2006. Department of Agricultural Economics, College of Agricultural and Life Science Extension, Mississippi State, Mississippi, USA.

National Agricultural Statistics Service. 2004. Crop production summary 2004. U.S. Department of Agriculture, National Agricultural Statistics Service, Agricultural Statistics Board, Washington, D.C., USA.

Northen, H. T. 1968. Introductory plant science. Third edition. The Ronald Press, New York, New York, USA.

Ratti, J. T., A. M. Rocklage, J. H. Giudice, E. O. Garton, and D. P. Golner. 2001. Comparison of avian communities on restored and natural wetlands in North and South Dakota. Journal of Wildlife Management 65:676–684.

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, USA.

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

Reinekce, K. J., and C. R. Loesch. 1996. Integrating research and management to conserve wildfowl (Anatidae) and wetlands in the Mississippi Alluvial Valley, U.S.A. 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.

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. 2004. Abundance and conservation of waste rice for wintering waterfowl in the Mississippi Alluvial Valley. Dissertation, Mississippi State University, Mississippi State, USA.

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.

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

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

Yoshida, S. 1981. Fundamentals of rice crop science. The International Rice Research Institute, Los Baños, Laguna, Philippines.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

Associate Editor: Chamberlain.