Waste Rice and Natural Seed Abundances in Rice Fields in the Louisiana and Texas Coastal Prairies

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Abstract: Rice and natural seeds are important foods for waterfowl in rice growing regions such as the Gulf Coast Prairies of Louisiana and Texas. We conducted a study from August–November 2010 and collected 2,250 soil cores in 50 farmed and 50 idle rice fields in the Louisiana Chenier Plain (CP) and Texas Mid-Coast (TMC) to estimate biomass of waste rice and natural seeds. Estimates are necessary to assess carrying capacity for waterfowl in this region by the Gulf Coast Joint Venture. Waste rice abundance was greatest in CP farmed fields that produced a second crop of rice (i.e., ratoon) and were not harvested in November (1,014.0 kg/ha; CV = 8.3%). Natural seed abundance was greatest in TMC fall disked idle rice fields in October (957.4 kg/ha; CV = 17.2%). Variation in rice and natural seed abundance in farmed and idled rice fields ranged from CV = 0.3%–97.9% in the CP and TMC, perhaps attributable to the variety of farming practices encountered. We did not observe a significant decline in waste rice and natural seed abundance in harvested rice fields from August–November as was reported for the Mississippi Alluvial Valley (MAV). We estimated an additional 6,000 soil cores would need to be collected and analyzed to achieve our goal for precision (i.e., CV ≤ 15%); hence, we recommend continuation of this study.

Key words: agriculture, Louisiana Chenier Plain, Gulf Coast Prairies, natural seeds, waste rice, rice fields, Texas Mid-coast, waterfowl

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Commercial agriculture has altered landscapes across the southeastern United States including in the Lower Mississippi River Alluvial Valley (MAV) and the Gulf Coast prairies in Louisiana and Texas, wherein rice and other croplands provide habitats used by waterfowl and other waterbirds when flooded (Reinecke et al. 1989, Hobaugh et al. 1989, Huner et al. 2002, Dahl 2011, Marty 2013). Rice inadvertently not collected by harvesters (i.e., waste rice) is an important energy source for migrating and wintering waterfowl in these and other regions worldwide (Kaminski et al. 2003; Stafford et al. 2006a, 2010; Manley 2008; Elphick et al. 2010; Marty 2013; Petrie 2014). Additionally, ricelands are a global example of integrated agriculture (i.e., rice and crayfish [*Procambarus clarki*]) and habitat conservation (Huner et al. 2002, Manley 2008, Elphick et al. 2010, Petrie 2014). Indeed, many rice producers strive to be adaptive conservationists by flooding and otherwise managing farmed rice fields and those temporarily idled from production for migrating and wintering waterfowl and other waterbirds (Manley et al. 2004, Kross et al. 2008a, Manley 2008, Havens et al. 2009, Marty 2013).

Waterfowl and other waterbirds acquire waste rice, natural seeds, aquatic invertebrates, and browse from rice lands (Delnicki and Reinecke 1986; Manley et al. 2004; Stafford et al. 2006a, 2010). In the southeastern United States, rice agriculture extends from southeastern Missouri south- and westward through Arkansas and Mississippi in to the Chenier Plain (CP) in western Louisiana and eastern Texas and the Texas Mid-Coast (TMC; Hobaugh et al. 1989). The CP and TMC are within the geography of the North American Waterfowl Management Plan's (NAWMP; U.S. Department of the Interior et al. 2012) Gulf Coast Joint Venture (GCJV). The GCJV endeavors to provide foraging habitat for about 14 million ducks and 1.6 million geese annually during winter, emphasizing the importance of these regions for NAWMP and sustainment of North American waterfowl and waterbird populations (Esslinger and Wilson 2001, U.S. Department of the Interior et al. 2012).

Spatio-temporal dynamics of waste rice for foraging waterfowl have been studied in the MAV (Manley et al. 2004, Stafford et al. 2006b, Manley et al. 2008, Greer et al. 2009), where a 71% decline in waste rice was documented from time of harvest (271 kg [dry]/ha; mid-late September) through late fall (78.4 kg [dry]/ha; late November–early December; Stafford et al. 2006b). These results have important implications for waterfowl habitat conservation planning and implementation, because ricelands account for 12% of the estimated habitat carrying capacity for wintering waterfowl in the MAV (Stafford et al. 2006b, 2010; A. Mini, Lower Mississippi Valley Joint Venture [LMVJV], personal communication). However, ricelands in coastal Louisiana and Texas account for approximately 42% of the estimated carrying capacity for wintering waterfowl in the GCJV region; thus, precise estimates of rice and natural seed abundance are necessary for effective habitat conservation planning and implementation.

Rice agriculture practices differ among U.S. regions and are influenced by physiography, climate, water and soil resources, length of growing season, economics, and other region-specific factors (Manley et al. 2004, Manley 2008, Stafford et al. 2010). In the CP and TMC, rice producers regularly grow and harvest a second crop from the original planting of rice (i.e., ratoon crop), which generally is not possible in the MAV because of a shortened growing season (Bollich and Turner 1988, Hobaugh et al. 1989, Eadie et al. 2008, Havens et al. 2009, Stafford et al. 2010). Growers also regularly idle rice fields in the CP and TMC for one or more years because soil characteristics (e.g., shallow clay pan) and climate limit options for rotational cropping, unlike in the MAV where soybeans are regularly rotated with rice. In idled rice fields, natural grasses, sedges, and forbs (i.e., moist-soil vegetation [Low and Bellrose 1944, Fredrickson and Taylor 1982, Schummer et al. 2012]) typically produce abundant seeds and tubers, and aquatic invertebrates flourish when fields flood (Kross et al. 2008b, Hagy and Kaminski 2012, Marty 2013).

The aforementioned differences in rice growing practices in the GCJV and MAV regions have important implications for habitat conservation planning and implementation by the GCJV and private landowners managing ricelands (U.S. Department of the Interior and Environmental Canada 1986, Esslinger and Wilson 2001, Wilson and Esslinger 2002, U.S. Department of the Interior et al. 2012). Prior to this study, estimates of abundance of waste rice and natural seeds in the GCJV region lacked temporal replication (T. C. Michot and W. Norling, U.S. Geological Survey, unpublished data). Given need for region-specific estimates, we initiated a spatially stratified survey to generate contemporary estimates of waste rice and natural seed abundances in the CP of Louisiana and TMC comparable to that for the MAV (Stafford et al. 2006b).

Study Area

Our study area included the CP of Louisiana (29° 31′–31° 00′ N; 91° 57′–93° 54′ W) and the TMC (27° 48′–30° 13′ N; 94° 43′–97° 54′ W). Specifically, in 2010 we sampled farmed and idled rice fields in Acadia, Allen, Evangeline, Jefferson Davis, St. Martin, and Vermilion parishes, Louisiana, because they accounted for approximately 90% of the total rice production in south Louisiana in 2009 (USDA 2010). The TMC extends from Galveston Bay to Corpus Christi, Texas, and inland approximately 170 km. In Texas, we sampled farmed and idled rice fields in Colorado, Matagorda, and Wharton counties, which produced 75% of all rice in the TMC in 2009 (USDA 2010). We sampled only in the CP of Louisiana and TMC due to an abbreviated survey and limited access to producers in fall 2010.

Methods

Sampling Design

We used a stratified multi-stage sampling design with three sampling units: 1) *primary*, the farm; 2) *secondary*, rice fields within farms; and 3) *tertiary*, soil cores collected from within rice fields (Stafford et al. 2006a, b). Our sampling universe of Louisiana and Texas farmers was derived from Louisiana rice producers who cooperated with the Louisiana State University Agricultural Center (LSUAC) and Texas producers who cooperated with Ducks Unlimited, Inc. (DU) in the Texas Prairie Wetlands Project. Our selection of cooperating producers was limited to these databases because we did not have access to a comprehensive list of all rice producers within our study region. We considered these databases to provide a representative sample of rice producers within our study region because local agronomists advised that agricultural practices employed by them were indeed representative of the larger population of rice producers within our study region (S. D. Linscombe, LSUAC, personal communication). We used PROC SURVEYSELECT in SAS v9.2 (SAS Institute 2009) to select farmers randomly with replacement (Stafford et al. 2006a, b), and we stratified samples into CP and TMC regions to ensure geographic representation. We sampled farms roughly in proportion to rice production acreage in each region in 2009 (CP [60%], $n=15$ farms; TMC [40%], $n=10$). We randomly selected and sampled two farmed and two idle rice fields from each farm (Stafford et al. 2006b). We defined a field as an area of varying size surrounded by exterior levees that contained rice or temporarily idled land.

Field Sampling

In each selected field, we established a single random directional (1°–180°) transect and extracted 10 soil cores (10 cm diameter and depth) at evenly spaced intervals (Manley et al. 2004, Stafford et al. 2006b) between 15–30 August 2010 (CP, $n=600$; TMC, $n=400$), 6–8 October (CP and TMC, $n=250$), and 1–22 November 2010 (CP, $n=600$; TMC, $n=400$). We selected these calendar periods to coincide with dates used by the GCJV for its fall-winter objectives for waterfowl habitat conservation planning (M. G. Brasher, GCJV, personal communication). We collected soil cores from rice fields 1 – 7 days after harvest or upon maturation of rice plants if farmers indicated the crop would not be harvested and left as a forage base for crawfish or waterfowl. We categorized farmed and idle rice fields as: 1) fields harvested once in July–August; 2) fields harvested twice per season (i.e., in July–August and in October–November [harvested ratoon]); 3) fields in which a ratoon crop was grown but not harvested and left standing for crawfish aquaculture or waterfowl forage (standing ratoon); 4) idle rice fields with standing natural vegetation (standing idle); and 5) disked idled fields (disked idle).

Laboratory Procedures

We washed cores through a series of sieves containing mesh sizes 4 (4.75 mm), 10 (2.0 mm), and 50 (300 μm) to facilitate removal of rice and natural seeds containing whole or partially intact endosperm (i.e., ≥50% of seed remaining; Stafford et al. 2006b). We considered germinated seeds to be potential waterfowl food if the primary root was less than or equal to the length of the seed and if the endosperm was firm (Stafford et al. 2006b). We dried seed samples to constant mass (± 0.5 mg) at 87 C before weighing to the nearest 0.0001g (Manley et al. 2004, Stafford et al. 2006b).

Statistical Analyses

We applied size-specific, seed bias correction factors to account for rice and natural seed destruction during sieving or nonrecovery of seeds by technicians (Hagy et al. 2011). We applied correction factors at the core sample level, because it was the level at which most bias was detected (Hagy et al. 2011). We used PROC SURVEYMEANS in SAS v9.3 (SAS Institute 2011) to estimate waste rice and natural seed abundances and extrapolated estimates to kg (dry mass)/ha. We analyzed data collected under the multistage survey design by incorporating appropriate weights and selection probabilities corresponding to the three stages of sampling (Stafford et al. 2006b). The probability of selecting a farmer was n_i/N_i, where n_i and N_i were numbers of farmers selected and included in the database in each stratum (i.e., GCJV initiative area). The probability of selecting a field was m_i/M_i, where m_i was the number of fields (2/farm) randomly selected among M_i fields of a farmer i. Finally, the probability of selecting a soil core within a field was $10/(K_{ij}/8.107 \times 10^{-7})$, where the number of cores collected in each field was 10 and the potential number of cores was the area (K_{ij}; ha) of field$_j$ within farmer$_i$ divided by the area of a core sample (8.107×10^{-7} ha; Stafford et al. 2006b). The inverse of the product of the three selection probabilities was the sampling weight used in the SURVEYMEANS procedure (Stafford et al. 2006b). We used PROC MEANS in SAS v9.3 (SAS Institute 2011) to estimate variance among farms to derive an optimal (i.e., lowest variance and minimal cost) number of primary sample units (Stafford et al. 2006a). To estimate optimal secondary and tertiary sample sizes, we computed variance components associated with each of the primary (farmer), secondary (field within a farmer), and tertiary (soil core within a field) sampling units using Type I sums of squares in PROC VARCOMP between sampling periods and field types (farmed or idle; Cochran 1977:288, Milliken and Johnson 1992:419, Stafford et al. 2006a, SAS Institute 2011). To index precision of estimates of waste rice and natural seed abundance, we computed coefficients of variation (CV [%] = Standard Error [SE]/estimate × [100]; Stafford et al. 2006a).

Results

Louisiana Chenier Plain

Rice Abundance. In farmed rice fields following first harvest in late July–August 2010, waste rice abundance was 164.2 kg/ha (CV = 50.2%; Figure 1). Rice abundance was least and variable in single harvested fields in November 2010 (i.e., no ratoon, 159.7 kg/ha, CV = 66.6%; Figure 1). In November 2010, waste rice abundance in fields with a harvested ratoon crop was 332.4 kg/ha, and variation in abundance decreased to CV = 22.2% (Figure 1). We found greatest rice abundance in fields with an unharvested ratoon crop, where abundance was 1,014.3 kg/ha in November 2010 and varied least among sampling periods and management practices (CV = 8.3%; Figure 1). Some rice volunteered from a previous year's planting in disked idle rice fields, but it was minimal at 0.2 kg/ha (CV = 32.9%) in August and increased to 3.4 kg /ha in November (CV = 55.0%; Figure 1). Similarly, volunteer rice in idle fields with standing vegetation was 0.4 kg /ha and greatly variable in August (CV = 90.7%). Rice in these fields increased in November but variability declined by half (1.6 kg /ha [CV = 45.8%]; Figure 1).

Natural Seed Abundance. In farmed rice fields following harvest in late July–August 2010, natural seed abundance was 190.3 kg/ha (CV = 47.7%; Figure 1). In November 2010, natural seed abun-

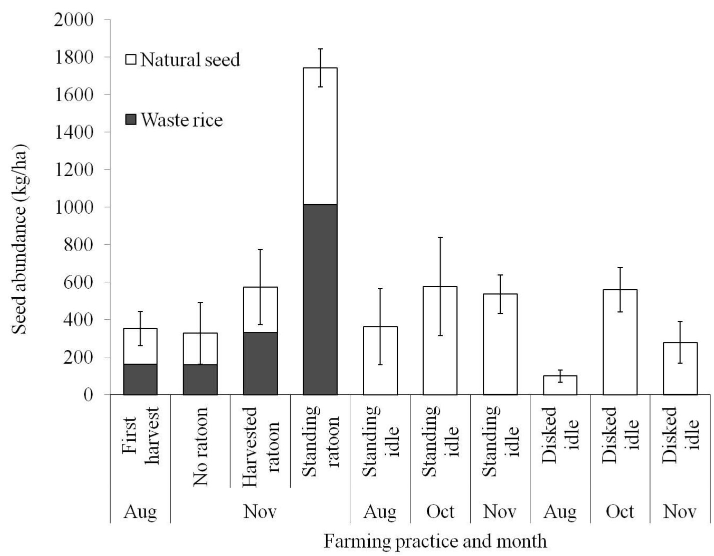

Figure 1. Waste rice and natural seed abundance in farmed and idle rice fields in the Louisiana Chenier Plain, August–November 2010.

dance in fields with a standing, unharvested ratoon crop increased to 730.4 kg/ha and variation decreased >5 fold (CV = 8.3%; Figure 1). In November, natural seed abundance in farmed rice fields with a harvested ratoon crop was 243 kg/ha (CV = 43.3%). Among farmed rice fields, natural seed abundance was least in fields without a ratoon crop (168.6 kg/ha, CV = 41.9%; Figure 1). In idle rice fields with standing vegetation, natural seed abundance increased 59% from August (362.3 kg/ha, CV = 33.7%) to October (576.4 kg/ha, CV = 63.6%) but declined 7% by November (534.8 kg/ha, CV = 19.4%; Figure 1). In disked idle rice fields, natural seed abundance increased 462% from 99.7 kg/ha in August (CV = 32.9%) to 561.0 kg/ha in October (CV = 21.1%) and then declined 50% by October–November (276.2 kg/ha, CV = 39.7%; Figure 1).

Texas Mid-Coast

Rice Abundance. In farmed rice fields following harvest in late July–August 2010, waste rice abundance was 252.6 kg/ha (CV = 32.9%; Figure 2). In November 2010, waste rice in fields with a harvested ratoon crop did not change significantly but variation decreased three-fold (i.e., 224.8 kg/ha, CV = 9.6%; Figure 2). In idle rice fields with standing vegetation, volunteer rice abundance was 3.0 kg/ha in August (CV = 99.0%) and 2.2 kg/ha in November (CV = 65.2%; Figure 2). Volunteer rice in disked idle rice fields was negligible and variable (i.e., August, none; November, 6.2 kg/ha [CV = 88.8%]; Figure 2).

Natural Seed Abundance. In farmed rice fields following harvest in late July–August 2010, natural seed abundance was 110.3 kg/ha (CV = 19.9%) but decreased 17% to 91.5 kg/ha in November (CV = 20.2%; Figure 2). In idle rice fields with standing vegetation, natural seed abundance increased 31% from August (309.7 kg/ha, CV = 23.3%) to October (407.8 kg/ha, CV = 19.6%) and further increased 32% in November (538.6 kg/ha, CV = 20.3%; Figure 2), In disked idle rice fields, natural seed abundance increased 161% from August (365.5 kg/ha, CV = 0.3%) to October (957.4 kg/ha, CV = 17.2%) and then declined 52% from October to November (458.7 kg/ha, CV = 56.0%; Figure 2).

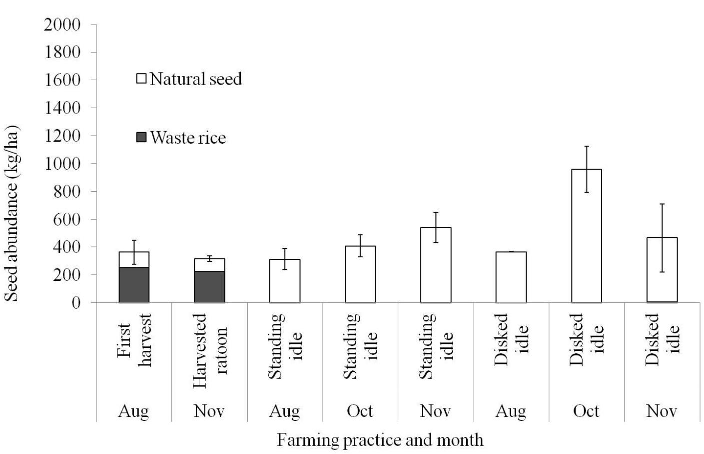

Figure 2. Waste rice and natural seed abundance in farmed and idle rice fields in the Texas Mid-Coast, August–November 2010.

Discussion

Seed Abundance

Our preliminary findings suggest abundance of waste rice in November 2010 in the CP and TMC was twice greater than in the MAV (Manley et al. 2004, Manley 2008, Stafford et al. 2006b, Havens et al. 2009), but similar to amounts in the Sacramento Valley, California (Miller et al. 1989, Miller and Wylie 1996). The extended growing season in the CP and TMC enabled a ratoon crop which generally is not feasible in other rice-growing regions. We did not observe a significant decline in waste rice abundance from August–November, as occurs in the MAV (Stafford et al. 2006b). Instead, November estimates of waste rice increased likely because of waste grain from the ratoon harvest.

Waste rice in unharvested ratoon fields (i.e., standing ratoon; only in the CP) was on average ≥3 times greater than in other farmed ricelands in November. Some farmers did not harvest the ratoon crop but instead left it to provide a forage base for crawfish aquaculture in those rice fields (McClain and Romaire 2004, McClain et al. 2007). Waste rice in rice-crawfish fields likely would have been available to migrating and resident waterfowl and other waterbirds during re-growth of ratoon crops before farmers flooded fields more deeply (20–60 cm) for crawfish harvesting beginning in winter (McClain and Romaire 2004).

In most cases, abundance of natural seed in CP and TMC idle fields was greater than that reported for the same regions in the 1960s (364 kg /ha; Davis et al. 1961). This result is remarkable considering that producers nowadays grow glyphosate-resistant varieties of rice to impede recruitment of natural seeds into seed banks. Abundance of natural seed increased from August to October in idle fields with standing vegetation (CP = 59%; TMC = 32%) and those where vegetation was disked and seed incorporated into the soil (CP = 462%; TMC = 161%), presumably because most seeds finished maturing (Reinecke and Hartke 2005, Kross et al. 2008b). Despite an increasing trend in natural seed in disked idle rice fields from August–October, seed abundances declined from October to November in both regions. This decline may have been influenced by decomposition, germination, granivory, and/or disking; the latter of which may have incorporated seed into the substrate beyond depths of our core samplers (Hagy and Kaminski 2012).

Biomass of waste rice and natural seed in our study either remained unchanged or increased during fall in both farmed and idle ricelands unlike patterns in the MAV (Manley et al. 2004, Stafford et al. 2006b). Thus, CP and TMC ricelands provide abundant food resources for waterfowl and other waterbirds if these habitats are flooded naturally, by landowners, or through programs such as the U.S. Department of Agriculture, Natural Resources Conservation Service's Migratory Bird Habitat Initiative (Marty 2013). Clearly, we recommend continuation of this study to improve reliability of estimates of rice and natural seeds for use by conservation partners in the Gulf Coast region.

Sample Size Estimation

The greatest variation component in estimates of seed abundance was attributed to cores (45.4%–82.1%), whereas variances associated with farms and fields within farms were 12.1%–47.0% and 0.5%–26.8%, respectively. To achieve our desired *a priori* precision (CV ≤ 15%) for rice and natural seeds, 10–100 farms would be required depending on summer-fall sampling period and field type (farmed rice or idle). For the number of fields within farms, estimated optimum number of sample units was one; whereas, for soil cores, optimum numbers of sample units ranged from 6–722 per field depending on sampling period and field type.

Variation related to waste rice and natural seed abundance ranged from 8.3% to 90.7% in ricelands in the CP and 0.3% to 97.9% in the TMC, perhaps attributable to the variety of field management practices in the regions (Marty 2013). Based on survey design and results from Stafford et al. (2006b), Marty (2013) estimated an additional 6,000 soil cores should be collected across fields and regions to achieve our goal for precision and be comparable to levels of precision obtained from previous studies in the MAV (i.e., CV ≤ 15%).

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