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Waterbird and Seed Abundances in Migratory Bird Habitat Initiative and Non-Managed Wetlands in Mississippi and Louisiana

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By

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The USDA Natural Resources Conservation Service (NRCS) implemented the Migratory Bird Habitat Initiative (MBHI) in summer 2010 to provide wetlands for waterbirds inland from the Deepwater Horizon Oil Spill. To evaluate MBHI and associated wetland management practices, I estimated seed and waterbird densities in MBHI and non-managed wetlands in the Mississippi Alluvial Valley (MAV) of Mississippi and Louisiana. Although not statistically different, wetlands enrolled in MBHI contained 1.26 and 1.53 times more seed biomass and seeds consumed by waterfowl than non-managed wetlands, respectively. I also detected 3 times more dabbling ducks and all ducks combined on MBHI wetlands. When I combined density data for all waterbird species, MBHI wetlands contained more than 2 times as many birds than control wetlands. Management via MBHI increased waterbird and potential food abundances, suggesting NRCS consider sustaining MBHI and provide financial incentives to landowners for management of wetlands in the MAV and United States.

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CHAPTER I

MOIST-SOIL SEED TAXA AND BIOMASS IN WETLANDS ENROLLED IN THE MIGRATORY BIRD HABITAT INITIATIVE IN MISSISSIPPI AND LOUISIANA FOLLOWING THE DEEPWATER HORIZON OIL SPILL

To mitigate possible biological, ecological, and environmental impacts of the Deepwater Horizon oil spill from British Petroleum's Macondo Well in the Gulf of Mexico on 20 April 2010, the USDA Natural Resources Conservation Service (NRCS) implemented the Migratory Bird Habitat Initiative (MBHI) in summer 2010. The NRCS allocated $40 million for MBHI to make available and manage wetlands for migratory and resident shorebirds, waterfowl, and other waterbirds and wildlife on private lands in eight states bordering the Atlantic and Gulf Coasts and the Lower Mississippi River Alluvial Valley (MAV). The intent of MBHI was to provide freshwater wetlands and associated food and other habitat resources to attract birds inland of the Gulf of Mexico away from coastal wetlands potentially impacted by spilled crude oil.

Over 190,000 ha of wetlands were enrolled in MBHI in the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, and Texas. Within the MAV of Arkansas, Louisiana, and Mississippi, 52,570.3 ha of USDA Wetlands Reserve Program (WRP) were enrolled in MBHI (i.e., 31,373.3 ha, Arkansas; 16,153.4 ha, Louisiana; 5,043.6 ha Mississippi). The MAV was a focal region for MBHI because of its continental importance to millions of migrating and wintering waterfowl and other waterbirds (Reinecke et al. 1989, NRCS 2013). Landowners received an incentive payment(s) in 2010 and subsequently in some states to manage ricelands and WRP moist-soil wetlands that NRCS and its conservation partners (e.g., U.S. Fish and Wildlife Service, states, Ducks Unlimited, Inc.) deemed suitable habitat for migrating and wintering waterbirds. Additionally, NRCS encouraged landowners to make habitat enhancements on MBHI lands (e.g., flooding, mowing dense vegetation, soil disking, etc.) to increase abundance and quality of foraging habitat and waterbird use in response to active management on these wetlands (e.g., Hagy and Kaminski 2012*a*, Fleming et al. 2012, Schummer et al. 2012).

Historic hydrology of the Mississippi River and its tributaries created extensive wetlands in the MAV, which supported diverse seasonal and year-round communities of wetland adapted plants and wildlife (Reinecke et al. 1989, Fredrickson 2005). However, with anthropogenic interventions, natural hydrology in the MAV has been greatly altered for flood control, agriculture, and urbanization. Consequently, waterbirds have adapted to modified landscapes and now use flooded agricultural lands, moist-soil wetlands, hardwood bottomlands, active and idle catfish ponds, and wetlands restored and managed through NRCS's WRP, MBHI, and other conservation initiatives of the Food, Agriculture, Conservation, and Trade Act of 2008 (Delnicki and Reinecke 1986, Reinecke et al. 1989, Baldassarre and Bolen 2006, Fleming et al. 2012, Pearse et al. 2012).

Energy rich foods are critical for physiological maintenance and survival of waterbirds year around but especially during fall-winter amid freezing temperatures and declining or depleted food resources (Kaminski et al. 2003, Stafford et al. 2006, Hagy and Kaminski 2012*a*). As mentioned, waterfowl and other waterbirds in the MAV use flooded croplands, forested wetlands, and moist-soil wetlands during the non-breeding period (Reinecke et al. 1989). Moist-soil management was first promoted by Low and Bellrose (1944) as a technique to encourage growth primarily of annual plants through management of surface water mimicking natural hydrology and use of soil disturbance to set-back succession and sustain annual plant communities. Managed moist-soil wetlands often contain emergent vegetation (e.g., grasses, sedges, and forbs) that produce seeds and tubers and aquatic invertebrates that are nutrient-rich foods for waterfowl and other waterbirds (Gray et al. 1999, Kaminski et al. 2003, Kross et al. 2008, Fleming et al. 2012, Hagy and Kaminski 2012*a*, Schummer et al. 2012). A major goal of MBHI was to increase availability of seeds and tubers in managed wetlands, because they provide energy for waterfowl and other waterbirds, and energy may be a limited nutrient during fall-winter for these birds (Reinecke et al. 1989, Kaminski et al. 2003). Thus, my objective herein was to estimate abundance of seed and tuber biomasses in MBHI managed and non-managed wetlands in the MAV of Mississippi and Louisiana. This information benefits evaluation of MBHI and the Lower Mississippi Valley Joint Venture of the North American Waterfowl Management Plan (2012), both of which endeavor to obtain contemporary, region-wide estimates of food resources and foraging habitat carrying capacity (i.e., duck-energy days, DEDs; Reinecke et al. 1989, Miller and Eadie 2006) to guide future planning and delivery of habitat conservation and management on private and public lands in the MAV.

Study area

The MAV is a 10-million-ha region spanning 800 km in length along the Mississippi River and varying in width from 32-128 km longitudinally within the states of Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee (Reinecke et al. 1989, Baldassarre and Bolen 2006; Fig 1.1). Forested wetlands were the dominant ecological community in the MAV into the early 20th century (Reinecke et al. 1989, Fredrickson 2005, Schummer et al. 2012). These forests once covered the MAV before human settlement but have since been reduced in area by nearly 80% and converted largely to agricultural lands producing catfish, corn, cotton, grain sorghum, rice, soybean, winter wheat, and other commodities (Reinecke et al. 1989, Hefner et al. 1994, Fredrickson 2005). Although much of the landscape has been altered, WRP has restored nearly 243,000 ha of wetlands in the MAV, now supporting native plant communities (Fleming et al. 2012, Schummer et al. 2012). During my study, plant taxa most commonly encountered in MBHI and unmanaged WRP wetlands were *Cyperus* spp., *Persicaria* spp., *Carex* spp., *Rynchospora* spp., *Setaria* spp., *Echinochloa* spp., *Scirpus* spp., *Digitaria* spp., *Urochloa* spp., *Panicum* spp. and other moist-soil vegetation (Fleming et al. 2012, Schummer et al. 2012).

With assistance from NRCS personnel and availability of wetland sites, I selected 13 MBHI sites (5 in Louisiana, 8 in Mississippi) and 12 non-managed sites (6 in each state) for soil core sampling after the growing season in October 2011 and again in March 2012 (Fig. 1.1). I attempted to select managed contracts and non-managed sites within the same properties, but this approach was not possible at all sites because of site availability. Therefore, I selected 4 non-managed sites within the same property as managed MBHI sites in Louisiana and 3 non-managed sites within the same property as MBHI sites in Mississippi. Additionally, I selected 3 non-managed sites in MS and 2 in LA, and 5 managed in MS and 1 in LA so they would be representative of wetlands in my study area.

Landowners or lessees managed MBHI sites by flooding, disking, mowing vegetation, or a combination of these practices. I was not able to control for the type(s) of management imposed on wetlands, but I assumed random selection of managed wetlands within a property lessened any possible bias associated with management and waterbird use. Non-managed sites did not receive any form of management. Boards were left in water-control structures when present and hydrology was dependent on rainfall and residual water from previous rain and flooding. The MBHI and non-managed wetlands varied in size from 0.1-229.8 ha.

Methods

Core sampling apparatus

I designed and fabricated a core sampler that collected 98 cm3 of substrate per sample, approximately 14% of the volume collected by devices used in previous similar studies (700 cm3; Stafford et al. 2006, Kross et al. 2008, Hagy et al. 2011, Hagy and Kaminski 2012*b*, Olmstead et al. 2013). I used a smaller apparatus to reduce sample processing time in the laboratory because of financial constraints associated with my study.

My corer was fabricated of steel conduit and measured 5 cm in diameter and 1.31 m in length (Figure 1.2). I designed a detachable coring piece to facilitate sample removal; this attachment enabled me to push the sample out toward the threaded side to collect the top 5 centimeters of substrate, in which >90% of moist soil seeds tend to exist (Olmstead 2013; Figure 1.2).

Soil-core sampling

I collected core samples from one wetland within 10 of the 13 MBHI contracts in Mississippi and Louisiana and 2 wetlands per contract from 3 of the 13 MBHI contracts in both states. Additionally, I collected soil cores from one wetland per contract from 10 of the 12 non-managed contracts and 2 wetlands per contract from 2 out of the 12 non-managed contracts in both states. I collected 5 core samples from each MBHI and each non-managed wetland at random locations within the wetlands. When wetlands were flooded, I began at the mudflat zone and continued across the wetland toward the opposite shoreline. When wetlands were dry, I sampled across the entire wetland basin.

For each sample, I plunged the core sampler perpendicular to the surface to a depth >5 cm until I reached firm substrate to ensure the core remained within the device. On top of the apparatus, an opening allowed a vacuum to be created to further secure the core in the device when the aperture was sealed by hand. After removing the device from the substrate, I unscrewed the end of the tube which held the core and then removed the core with a PVC plunger so that the top 5 cm of substrate was exposed. I removed the core, placed it in a freezer bag, and stored all samples on ice while in the field to minimize seed and tuber decomposition. I preserved all samples in a freezer at Mississippi State University.

Laboratory methods

Technicians and I removed core samples from the freezer in an order relative to sequence of field collection and processed them following published techniques (Kross et al. 2008, Hagy et al. 2011, Hagy and Kaminski 2012*a*). However, to provide some details here, I thawed core samples using hot tap water (49° C) then added a solution of 3% hydrogen peroxide (H2O2), baking soda, and water to dissolve clay for ease of processing (Bohm 1979, Kross et al. 2008). I washed soil cores through 3 sieve sizes: #50 (0.03 mm aperture), #10 (1.65 mm), and #4 (4.75 mm; Kross et al. 2008, Hagy et al. 2011). I then air dried samples for 24-48 hrs. Next, I removed seeds and tubers from the sample, placed them in a small aluminum pan, and then oven dried the sample at 80° C for 24 hours to a constant mass (Gray et al. 1999). I weighed seeds and tubers to the nearest 0.01 gram, and identified seeds and tubers to genus or species using pictorial descriptions in Schummer et al. (2012).

Statistical analyses

I determined wetland areas using ArcGIS 10.1. I calculated seed mass per wetland hectare by averaging seed weight in the five core samples taken per wetland and multiplying the volume of the core by the wet area of the wetland (area holding water). When one wetland within a contract was sampled, I averaged seed and tuber masses combined from the five samples to derive a single mass datum for each of these wetlands. When two wetlands within a contract were sampled and a total of 10 cores were collected (i.e., five from each wetland), I averaged seed and tuber masses from the 10 samples to generate the datum analyses. I calculated total seed and tuber mass combined per ha of wetland and total mass of seeds and tubers commonly consumed by waterfowl (Hagy and

Kaminski 2012*a*, Hagy and Kaminski 2012*b*). I designated an alpha level of 0.10 a priori because of limited sample size, assuming that 90% confidence was adequate for inference making in my management oriented study (Tacha et al. 1982, Riffell et al. 2001, Kross et al. 2008).

I analyzed seed densities using analysis of variance (ANOVA) with repeated measures, designating October 2011 and March 2012 sampling events as the repeated factor (SAS 9.3.1. 2012). I quantified seed species or generic richness as the mean number of species or genera per soil core sample. Before analysis, I natural log transformed data to achieve normality. I used a first order autoregressive (AR) covariance structure due to the time series nature of my data sets. I tested Toeplitz and unstructured covariance structures using PROC MIXED Models in SAS (SAS 9.3 2012); however, Akaike's Information Criterion was lowest with AR 1, inferring that model best fit the data. Specifically, I tested the null hypothesis of no effects of treatment (i.e., MBHI or non-managed), October or March surveys (1 or 2), and the interaction of these on variation in moist-soil seed mass and species-genera richness.

Results

I recorded a total of 39 genera or species of moist-soil plants in core samples from MBHI and non-managed wetlands (Table 1.1). Thirty-one and 33 taxa were detected in samples from MBHI and non-managed wetlands, respectively. The ten most frequently recorded taxa in MBHI wetlands were flatsedge (*Cyperus* spp.; 47%), smartweed/knotweed (*Persicaria* spp.; 42%), sedge (*Carex* spp.; 25%), *beaksedge* (*Rhynchospora corniculata*; 23%), cockspur grass (*Echinochloa* spp.; 23%), signalgrass (*Urochloa* spp.; 23%), bristlegrass (*Setaria* spp.; 20%), panicgrass (*Panicum* spp.; 20%), bulrush (*Scirpus* spp.; 18%), and crabgrass (*Digitaria* spp.; 18%). Seeds from all these taxa are known to be eaten by waterfowl (Hagy and Kaminski 2012*b*). The most frequently encountered plants in non-managed wetlands were flatsedge (66%), smartweed/knotweed (49%), sedge (32%), shortbristle horned beaksedge (29%), bristlegrass (23%), cockspur grass (20%), bulrush (20%), bigpod sesbania (*Sesbania herbacea*; 17%), crabgrass (14%), and primrose-willow (*Ludwigia* spp.; 11%). Mean percent occurrences of seeds known to be waterfowl foods were similar between MBHI (25.9 ± 3.2% [SE, n = 10]) and non-managed wetlands (27.0 ± 5.8%, n = 11). Bigpod sesbania and primrose-willow were two of the top ten most frequently encountered plants in non-managed wetlands and have not been recorded as foods of waterfowl (Hagy and Kaminski 2012*b*).

Densities of all moist-soil seeds and those commonly consumed by waterfowl did not differ between October and March sampling periods ($P \geq 0.47$; Tables 1.2-1.4). Although no treatment effect was detected for samples collected in either October or March ($P \geq 0.52$; Table 1.2), wetlands enrolled in the MBHI contained, on average, ≥1.26 times more biomass of seeds commonly consumed by waterfowl than non-managed wetlands in October 2011 (Table 1.3). In March 2012, MBHI wetlands contained ≥1.53 times more total seed biomass and seeds consumed by waterfowl than non-managed wetlands (Table 1.4). Additionally, I did not detect any interactions of treatment and survey on seed densities in October 2011 and March 2012 ($P \geq 0.32$; Table 1.2).

Seed species richness neither differed between MBHI and non-managed wetlands nor between October and March sampling surveys ($P \geq 0.25$; Table 1.2). October core samples from MBHI wetlands averaged ~3 species per core while non-managed wetlands averaged ~5 species per core. March core samples contained ~4 species per core for MBHI wetlands compared to ~5 species in non-managed wetlands.

Discussion

My objective was to estimate abundance of seed biomass in MBHI managed and non-managed wetlands in the MAV of Mississippi and Louisiana. I failed to reject my null hypotheses that seed densities and species richness would not differ between MBHI and non-managed wetlands. I am not able to explain this outcome with certainty, but speculate that the single or combined, uncontrolled applications of management practices by landowners to MBHI wetlands and lack thereof for non-managed wetlands, coupled with great variability in seed and tuber masses, decreased precision of biomass estimates and precluded detection of significant differences. Despite this variability, abundance of seeds consumed by waterfowl was 1.25-1.53 times greater than on non-managed wetlands in October 2011 and March 2012, and total seed biomass was 1.56 times greater on MBHI than non-managed wetlands in March 2012. Management may have contributed to the slightly greater seed abundance in MBHI than non-managed wetlands.

I failed to reject my null hypotheses that seed biomasses significantly differed between October and March sampling periods. I expected March seed densities to be significantly lower than October due to decomposition and predation by waterfowl (Hagy and Kaminski 2012*b*); however neither MBHI nor non-managed wetlands contained a significantly lower seed density in March. Core sampling protocol was the same in October 2011 and March 2012 but locations of random samples within wetlands in fall and spring differed due to differences in extent and depth of flooding between periods. In October, four of 13 MBHI complex wetlands were dry. During the same time, only one of 12 non-managed wetlands was dry. In March, all MBHI and non-managed wetlands were flooded. Wetlands remaining dry longer into fall-early winter may have acted to preserve seeds from decomposition, render them not or less accessible to predation by waterfowl, or a combination of these possibilities may have contributed to the slightly increased seed densities in March 2012. Additionally, as wetland size increased with additional flooding during winter, transport of seed via surface water flow and waterfowl may have contributed to increased seed abundance in March 2012 (Figuerola and Green 2002, Mueller and van der Valk 2002, Neff and Baldwin 2005, Soons et al. 2008, Brochet et al. 2009). Finally, the pattern of increased seed abundance in March 2012 may have been merely a consequence of sampling different sites within wetlands in fall and spring.

Although densities for seed species commonly consumed by waterfowl did not differ between MBHI and non-managed wetlands, the 10 most frequently observed species in MBHI were all known waterfowl foods (Hagy and Kaminski 2012*b*). In non-managed wetlands, 2 of the top 10 species were not commonly consumed by waterfowl. This difference may be explained by substrate disturbance and managed hydrology in MBHI wetlands. Disturbance sets the stage for primary succession to occur, facilitating growth of moist-soil plants commonly consumed by ducks (Fredrickson and Taylor 1982, Kross et al. 2008). Plant species richness was not significantly different between MBHI and non-managed wetlands; non-managed wetlands averaged about 5 species of seed per soil core whereas MBHI averaged roughly 3 species. This result may be related to non-managed wetlands having more aquatic vegetation (e.g., American water plantain [*Alisma subcordatum*] and marsh mallow [*Hibiscus* spp.]) incorporated into the diversity and adding to the richness. Because MBHI wetlands are managed, aquatic vegetation often does not establish as in semi- or permanently flooded non-managed wetlands.

Although other studies have reported reduced seed densities in the spring compared to fall due to seed decomposition, predation, and germination (i.e., Nelms and Twedt 1996, Hagy and Kaminski 2012*b*), few studies, if any, have reported an increase in the spring. In retrospect, I should have marked each sampling location within wetlands in October and sampled adjacent to those sites in March, creating paired sample locations between fall and spring. Additionally, my sample size was relatively small which also may have biased my sampling. Future researchers should consider spatially paired sampling to avoid these possible biases.

Management implications

Previous moist-soil research revealed that active management increased seed density (Kross et al. 2008, Fleming et al. 2012, Hagy and Kaminski 2012*a*, Olmstead et al. 2013); however, few studies also have suggested the importance of integrating non-managed wetlands into habitat complexes in the MAV to enhance habitat diversity and thus waterfowl and other waterbird species richness diversity (cf., Fleming 2012). For seeds commonly consumed by waterfowl (Hagy and Kaminski 2012*a*), MBHI wetlands contained 1.3 times greater seed densities in October and 1.5 times greater densities in March. Coupled with greater densities of waterfowl and other waterbirds on MBHI than non-managed wetlands (Chapter 2), I recommend management of wetlands to increase waterfowl and other waterbird use of WRP wetlands. Specifically, I recommend partial mowing of vegetation during autumn, which indicated that 2-3 times more dabbling ducks used mowed and disked plots than control plots in the MAV (Hagy and Kaminski

2012*b*). For managers interested in providing more invertebrates, Hagy and Kaminski (2012*a*) reported 1.6-2 times greater invertebrate mass in control than mowed and disked plots, respectively. I recommend sampling paired sites instead of random sampling between time periods so potential differences in spatial distributions and abundance of seeds through time would not be confounded with management treatment effects.

Table 1.1 Frequency of seed occurrence (%, n = 125 cores) in Migratory Bird Habitat Initiative (MBHI) and non-managed wetlands

Common name	Scientific name	MBHI	Non-managed
Flatsedge	*Cyperus* spp.	47	66
Smartweed/knotweed	*Persicaria* spp.	42	49
Sedge	*Carex* spp.	25	32
Shortbristle horned beaksedge	*Rhynchospora corniculata*	23	29
Bristlegrass	*Setaria* spp.	20	23
Cockspur grass	*Echinochloa* spp.	23	20
Bulrush	*Scirpus* spp.	18	20
Crabgrass	*Digitaria* spp.	18	14
Signalgrass	*Urochloa* spp.	23	9
Panicgrass	*Panicum* spp.	20	8
Bigpod sesbania	*Sesbania herbaccea*	10	17
Dallisgrass	*Paspalum* spp.	15	9
Primrose-willow	*Ludwigia* spp.	12	11
Carolina coralbead	*Coccolus carolinus*	10	6
Balloon vine	*Cardiospermum halicacabum*	7	8
Mudplantain	*Heteranthera* spp.	5	9
Cocklebur	*Xanthium strumarium*	7	5
Groundcherry	*Physalis* spp.	[a]	11
Buttercup	*Ranunculus* spp.	2	8
Redvine	*Brunichia ovata*	2	8
Verbena	*Verbena brasiliensis*	8	2
Pigweed	*Amaranthus* spp.		8
Sprangletop	*Leptochola* spp.	5	2
Ragweed	*Ambrosia* spp.	3	3
Sumpweed	*Iva annua*	3	3
Beggarticks	*Bidens* spp.	2	3
Grain sorghum	*Sorghum bicolor*	3	2
Daisy	*Eclipta* spp.	5	
Prickly sida	*Sida spinosa*	5	
Canarygrass	*Phalaris* spp.		3
Soybean	*Glycine max*		3
Marsh mallow	*Hibiscus* spp.		2
Buttonbush	*Cephalanthus occidentalis*		2
Peppervine	*Ampelopsis arborea*		2
American water plantain	*Alisma subcordatum*		2
Sorrel	*Rumex* spp.	2	
Blackberry	*Rubus* spp.	2	
Sunflower	*Heliathus* spp.	2	
Boneset	*Eupatorium perfoliatum*	2	

[a] Blanks denote <1% occurrence

Table 1.2 Repeated measures ANOVA of seed densities (kg [trt]/ ha) and seed species richness

	Effect	*F*	df	*P*
	Trt	0.28	1, 27	0.60
All Seeds	Survey	0.23	1, 21	0.64
	trt x survey	1.04	1, 21	0.32
	Trt	0.43	1, 27	0.52
Duck foods	Survey	0.53	1, 21	0.47
	trt x survey	0.12	1, 21	0.73
	Trt	1.36	1, 27	0.25
Species richness	Survey	0.83	1, 21	0.37
	trt x survey	1.19	1, 21	0.29

Results of repeated measures analysis of variance of seed densities (kg [trt]/ ha) and species richness for wetlands in Mississippi and Louisiana (October 2011 and March 2012), testing effects of treatment (i.e., Migratory Bird Habitat Initiative [Trt] vs. non-managed wetlands), survey date (October or March), and their interactions. Duck foods were identified by Hagy and Kaminski (2012*b*) as seeds commonly consumed by waterfowl in the Mississippi Alluvial Valley (MAV).

Table 1.3 October natural log back-transformed mean ($\bar{x}$) and lower and upper confidence limits (LCL, UCL) for moist-soil seed mass (kg[dry]/ha)

	MBHI (*n* = 13)			Non-managed (*n* = 12)		
	$\bar{x}$	LCL	UCL	$\bar{x}$	LCL	UCL
All seeds	225.9	110.7	459.9	226.7	114.1	449.4
Duck foods	95.7	39.2	231.8	76.2	32.2	178.9
Species/genera richness (*n*/soil core)	2.5	0.9	5.3	5.2	2.5	9.9

Natural log back-transformed mean ($\bar{x}$) and lower and upper confidence limits (LCL, UCL) for moist-soil seed mass (kg[dry]/ha) during the October 2011 sampling survey of Migratory Bird Habitat Initiative and on-managed wetlands enrolled in the Wetlands Reserve Program in Louisiana and Mississippi. Duck foods were seeds commonly consumed by waterfowl in the Mississippi Alluvial Valley (Hagy and Kaminski 2012*b*).

Table 1.4 March natural log back-transformed mean ($\bar{x}$) and lower and upper confidence limits (LCL, UCL) for moist soil seed mass (kg[dry]/ha)

	MBHI (*n* = 13)			Non-managed (*n* = 12)		
	$\bar{x}$	LCL	UCL	$\bar{x}$	LCL	UCL
All seeds	254.3	129.1	500.0	162.9	81.9	323.4
Duck foods	131.5	56.7	302.9	85.4	36.1	200.1
Species/genera richness (*n*/soil core)	3.5	1.5	7.1	5.1	2.4	9.7

Natural log back-transformed mean and lower and upper confidence limits (LCL, UCL) for moist soil seed mass (kg[dry]/ha) during the March sampling survey of Migratory Bird Habitat Initiative and non-managed wetlands enrolled in the Wetlands Reserve Program in Louisiana and Mississippi. Duck foods were seeds commonly consumed by waterfowl in the Mississippi Alluvial Valley (Hagy and Kaminski 2012*b*).

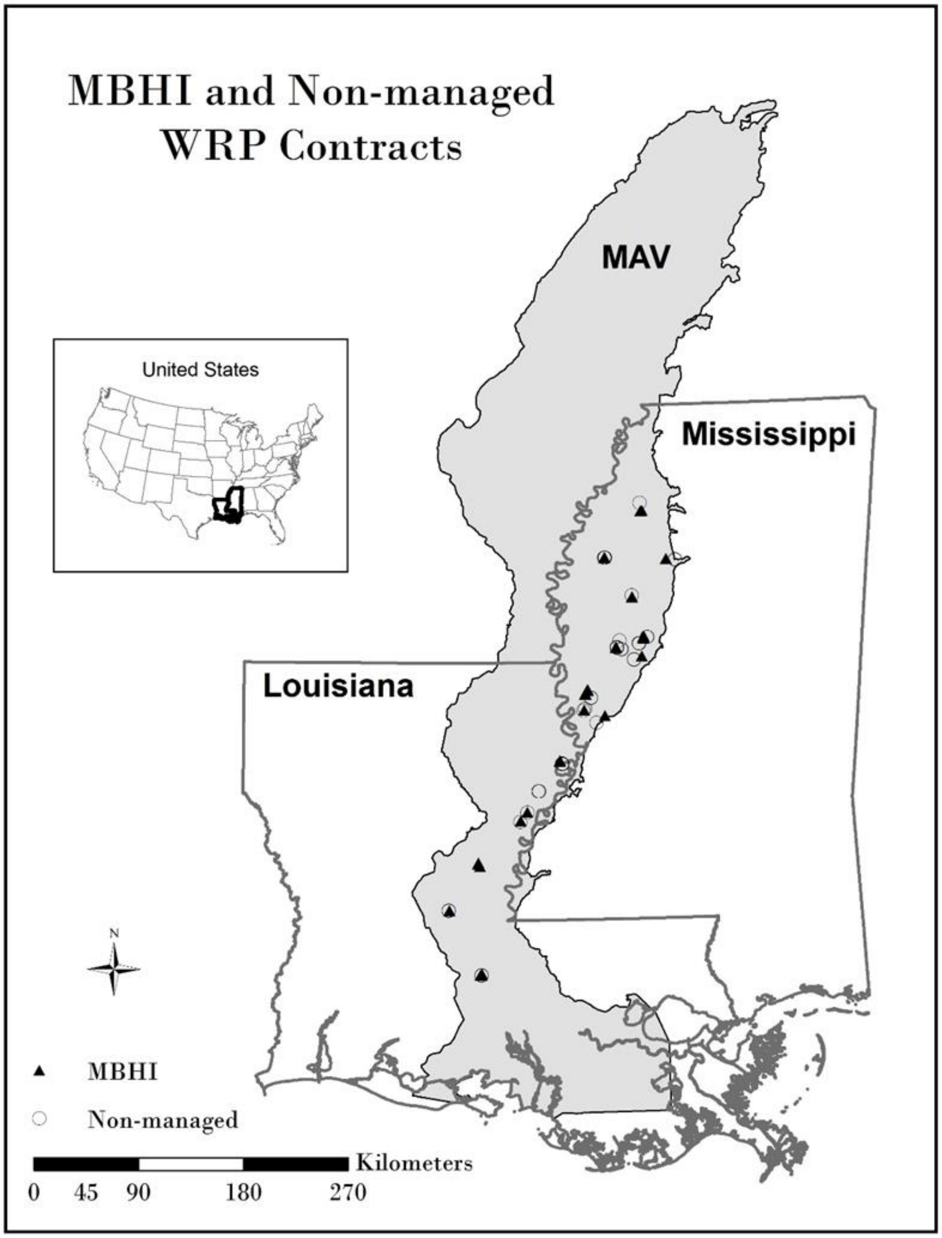

Figure 1.1 Locations of 18 Migratory Bird Habitat Initiative (MBHI; solid triangle) Wetlands Reserve Program sites and 22 unmanaged (open circle) Wetlands Reserve Program sites in Mississippi and Louisiana, 2011-2012

Figure 1.2 Soil-core sampling apparatus

The threaded end piece facilitated removal of core sample from the detachable portion. Each core sample was pushed through the tube with a PVC plunger to collect the top 5 cm of substrate (Olmstead et al. 2013). The main tube measured 109 cm and the threaded end measured 22 cm for a total length of 131cm and weight of 3.6 kg.

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CHAPTER II

WATERBIRD USE OF PRIVATE WETLANDS ENROLLED IN THE MIGRATORY BIRD HABITAT INITIATIVE IN MISSISSIPPI AND LOUISIANA FOLLOWING THE DEEPWATER HORIZON OIL SPILL

To mitigate possible biological and environmental impacts of the Deepwater Horizon Oil Spill from British Petroleum's Macondo Well in the Gulf of Mexico on 20 April 2010, the USDA Natural Resources Conservation Service (NRCS) implemented the Migratory Bird Habitat Initiative (MBHI) in summer 2010. The NRCS allocated $40 million to MBHI to create wetlands for waterbirds and other wetland wildlife on private lands in eight states bordering the Atlantic and Gulf Coasts and the Lower Mississippi River Alluvial Valley (MAV). Herein, I use the term waterbirds to include waterfowl (Anseriformes), marsh birds (Gruiformes), wading birds (Ciconiiformes), and shorebirds (Charadriiformes). The intent of MBHI was to provide freshwater wetlands to attract migratory and resident waterbirds north and inland of the Gulf of Mexico away from coastal wetlands potentially impacted by oil from the spill.

A total of >190,000 ha of wetlands were enrolled in MBHI in states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, and Texas and 52,570 ha in the MAV, an important region for millions of migrating and wintering North American waterfowl and other waterbirds (Reinecke et al. 1989, NRCS 2013). Landowners received an incentive payment(s) in 2010 and subsequently in some states to manage private agricultural lands (e.g., ricelands) and wetlands (e.g., Wetlands Reserve Program [WRP]) that NRCS deemed suitable habitat for migrating and wintering waterbirds. Additionally, NRCS suggested and required habitat enhancements on MBHI lands (e.g., flooding, mowing dense vegetation, soil disking, etc.).

Historic hydrology of the Mississippi River and its tributaries created extensive wetlands in the MAV, which supported diverse seasonal and year-round communities of wetland plants and animals (Reinecke et al. 1989, Fredrickson 2005). However, with agricultural and other anthropogenic interventions, natural hydrology in the MAV has been greatly altered for flood control and agriculture. Consequently, waterbirds have adapted to the landscape dynamics and now use flooded agricultural lands, moist-soil wetlands, hardwood bottomlands, catfish ponds, and wetlands restored and managed through NRCS's WRP, MBHI, and other conservation initiatives of the Food, Agriculture, Conservation, and Trade Act of 2008 (i.e., The Farm Bill, Delnicki and Reinecke 1986 Reinecke et al. 1989, Baldassarre and Bolen 2006, Fleming et al. 2012, Pearse et al. 2012). Within the MAV, nearly 243,000 ha were enrolled in WRP through 2012 (Schummer et al. 2012).

Since creation of WRP in 1992, enrolled lands have provided habitat for many species of birds and other wildlife during all or parts of their annual cycle in the United States. In New York, Kaminski et al. (2006) reported waterfowl use of managed WRP wetlands in central New York was over twice greater than on wetlands not managed in the vicinity, and wetland area was positively correlated with species richness of waterbirds. In addition, Kaminski et al. (2013) reported that hen mallards nesting in WRP wetlands and associated grasslands experienced 100% and 50% net success compared to 40% and 22% in non-WRP wetlands and grasslands, respectively. Nesting waterfowl, sandpipers (*Calidris* spp.), marsh wrens (*Cistothorus palustris*), and American woodcock (*Scolopax minor*) were all detected on WRP lands in Wisconsin (Anderson 1991). LaGrange and Dinsmore (1989) recorded 11 waterbird species within two years of initial flooding of four restored Iowa wetlands. Fleming (2010) reported a positive correlation between waterbird species richness and WRP wetland area in the Mississippi MAV. Additionally, active management of WRP wetlands combined with early-summer drawdown and decreased woody vegetation correlated with increased waterbird abundance (Fleming 2010). Indeed, WRP and MBHI have increased wetland habitat and wildlife use generally wherever implemented to date.

As mentioned, NRCS allocated $40 million to implement MBHI after the Deepwater Horizon Oil Spill; thus, need existed to evaluate waterbird use of MBHI and other wetlands. Specifically, my objective was to quantify seasonal waterbird use of MBHI lands in the MAV of Louisiana and Mississippi and compare these data with similar data from (a) sites not managed through MBHI, and (b) the literature to evaluate effects of MBHI.

Study area

The MAV is a 10-million-ha region spanning 800 km in length along the Mississippi River and varying in width from 32-128 km longitudinally within the states of Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee (Reinecke et al. 1989, Baldassarre and Bolen 2006; Fig 1.1). Forested wetlands were the dominant ecological community in the MAV into the early 20th century (Reinecke et al. 1989, Fredrickson et al. 2005, Schummer et al. 2012). These forests once covered the

MAV before human settlement but have since been reduced in area by nearly 80% and converted largely to agricultural lands producing catfish, corn, cotton, grain sorghum, rice, soybean, winter wheat, and other commodities (Reinecke et al. 1989, Hefner et al. 1994, Fredrickson 2005). Although much of the landscape has been altered, WRP has restored nearly 243,000 ha of wetlands in the MAV, now supporting native plant communities (Fleming et al. 2012, Schummer et al. 2012). During my study, plant taxa most commonly encountered in MBHI and unmanaged WRP wetlands were *Cyperus* spp., *Persicaria* spp., *Carex* spp., *Rhynchospora* spp., *Setaria* spp., *Scirpus* spp., *Echinochloa* spp., *Sesbania* spp., *Digitaria* spp., *Juncus* spp., and other moist-soil vegetation (Chapter 1, Fleming et al. 2012, Schummer et al. 2012).

I assessed waterbird abundance and species richness on 12 MBHI and 16 non-managed (i.e., control) WRP contracts in Mississippi, extending south from the cities of Clarksdale to Vicksburg; and in Louisiana on 6 MBHI and 6 unmanaged contracts from the cities of Tallulah south to Opelousas (Fig 1.1). I randomly selected MBHI wetland contracts in Mississippi and Louisiana from July – September 2011. I selected non-managed sites as near as possible (i.e., 1- ≤20 km) to managed MBHI sites to help control for potential spatial and environmental influences of waterbird use. Most wetlands had a flashboard riser present to manage hydrology. Landowners or lessees managed MBHI sites by flooding, disking, mowing vegetation, or a combination of these. I was not able to control for type(s) of management imposed on wetlands, but I assumed random selection of managed wetlands lessened any confounding or bias associated with type(s) management and waterbird use. Non-managed sites did not receive any management during years 2011-2012. Boards were left in control structures and hydrology depended on rainfall and residual water from previous rain and flooding. Because of financial constraints, I selected and surveyed waterbirds on 1-5 wetlands per WRP contract area (i.e., n = 37 total MBHI wetlands, n = 33 total control wetlands). Wetland size varied from 0.1 ha to 229.8 ha.

Methods

Ground survey of waterbirds

I obtained a list of MBHI contracts in Mississippi from the NRCS state office and initially randomly selected 30 contracts. After calling landowners to ask permission to work on their property and being rejected in some cases, I randomly chose 12 of the remaining landowners in Mississippi who granted permission. I used the same process for Louisiana landowners and randomly selected 6 MBHI contracts. Again, I selected 30 non-managed contracts to be paired with the MBHI contracts and eventually reduced the number to 16 non-managed contracts in Mississippi. Similarly, I selected 6 non-managed contracts in Louisiana to pair with the 6 MBHI contracts. I selected the nearest non-managed WRP contract to each MBHI wetland as a control unit. I surveyed managed MBHI and non-managed WRP wetlands for all species of waterbirds twice monthly from August 2011 to April 2012 in Mississippi. I did not initiate surveys in Louisiana until October 2011 because of delays in acquisition of landowner information. I surveyed MBHI and non-managed wetlands in Louisiana twice monthly from October 2011 through April 2012.

I surveyed wetlands between sunrise and sunset with routes reversed and randomized to control for the possible effect of time of day on waterbird use of wetlands. I conducted whole area counts using the Integrated Waterbird Management and

Monitoring Program developed by the United States Geological Survey and the U. S. Fish and Wildlife Service (USFWS 2010). In accordance with the protocol, I recorded the following metrics for each survey but did not include these data in analyses because of small sample size of wetlands: temperature, Beaufort wind scale, percent ice cover on wetlands, disturbance severity and source, percent flooded and depth category, and waterbird abundance by species. I recorded weather-related data at the beginning of surveys of wetlands. For each wetland survey, I estimated percentages of basin flooded and depth of inundation (i.e., dry, saturated mudflat, 0-10, 10-30, 30-122, and >122 cm).

I used an all-terrain vehicle and drove through and around wetlands to enhance detection and identification of birds using binoculars when necessary (Twedt and Nelms 1999, Heitmeyer 2006, Kaminski et al. 2006). When wetlands had to be surveyed from more than one location, I observed where birds flew and alighted after being flushed to avoid duplicating counts of the same birds (Kaminski and Prince 1981). Depending on size of wetlands, I surveyed them in 1-10 minutes and over 4 days within each state.

Statistical analyses

I compiled field data in a Microsoft Excel 2010 workbook, wherein I calculated densities of all detected waterbirds by species by dividing species-specific relative abundance of birds by flooded area (ha) within each wetland basin and survey. I likely did not detect all waterbirds within surveyed wetlands, but I assumed my errors and omissions were similar among wetlands. Also, my estimates of relative abundance suffice for statistical comparison of waterbird use of MBHI and non-managed wetlands. I surveyed one wetland per contract from 4 of 18 MBHI contracts and 2-3 wetlands per contract from 14 of 18 MBHI contracts in Mississippi and Louisiana combined. I surveyed one wetland per contract from 8 of 22 non-managed contracts and 2-5 wetlands per contract from 14 out of 22 non-managed contracts in both states. When multiple wetlands within a contract were surveyed, I averaged waterbird densities for each survey and subsequent analysis. I designated an alpha level of 0.10 a priori because of limited sample size (Tacha et al. 1982, Riffell et al. 2001, Kross et al. 2008).

I analyzed all waterbird densities and species richness using analysis of variance (ANOVA) with repeated measures (SAS 9.3.1 2012). I quantified species richness as the mean number of waterbird species per wetland hectare. Before analysis, I subjected data to natural log transformation to normalize data sets. I created the following taxonomic groups for analysis to reduce zero values in the data sets while maintaining important groups for analysis: dabbling ducks, diving ducks, all ducks, shorebirds, waterbirds other than ducks and shorebirds, and all waterbirds combined. I used a first order autoregressive (AR) covariance structure due to the time series nature of my data sets. I tested Toeplitz and unstructured covariance structures on the Proc Mixed Models in SAS; however, Akaike's Information Criterion was lowest with AR 1, inferring that model best fit the data. With repeated measures ANOVA, I tested the null hypothesis of no effects of treatment (i.e., MBHI or non-managed), survey date (1, 2, 3…*n*), and the interaction of these on variation in waterbird densities and species richness.

Results

During 17 surveys of 70 WRP wetlands in Mississippi and Louisiana between August 2011 and April 2012, I detected 17, 097 waterbirds (American Ornithologists' Union 1983, Chesser et al. 2013). The ten most abundant species were American green-winged teal (*Anas crecca*; 3,646), American coot (*Fulica americana*; 3,185), gadwall

(*Anas strepera*; 2,365), blue-winged teal (*A. discors*; 2,085), mallard (*A. platyrynchos*; 1,658), northern shoveler (*A. clypeata*; 1,031), Wilson's snipe (*Gallinago delicata*; 659), white ibis (*Eudocimus albus*; 641), killdeer (*Charadrius vociferus*; 273), and double-crested cormorant (*Phalacrocorax auritus*; 175). Combined, these species comprised 92% of all waterbirds detected during surveys.

I tested the effects of MBHI management (i.e., treatment), survey date, and their interactions on variation in waterbird densities. No interactions were detected ($0.368 < P < 0.9082$); however, waterbird densities varied in relation to treatment and survey date. I observed nearly three times more dabbling ducks and all ducks combined on MBHI than control wetlands ($0.0014 < P < 0.0015$; Table 1.1). Waterbirds other than waterfowl and shorebirds were nearly twice more abundant on MBHI than control wetlands ($P = 0.0938$; Table 1.1). When I combined density data for all waterbird species, MBHI wetlands contained over twice more birds than control wetlands ($P = 0.0009$; Table 1.1). I did not detect any additional differences for shore- and other waterbird densities in relation to MBHI management ($0.1083 < P < 0.4387$; Table 1.2).

Densities of dabbling ducks, diving ducks, total ducks, waterbirds, and species richness varied by survey date on MBHI and non-managed wetlands ($P < 0.01$; Table 1.2, Figure 1.2). Densities of ducks on MBHI wetlands peaked in early February 2012 at a mean of 11.3 birds per wetland ha. Duck densities in control wetlands peaked two weeks later at 6.2 ducks per wetland ha but were nearly two times less dense than on MBHI wetlands. Densities of other waterbirds peaked in late February 2012 at 6.4 birds per wetland hectare on MBHI wetlands and 2.9 birds on control wetlands. Although shorebird densities did not vary by survey date on MBHI and non-managed wetlands combined (P = 0.4425; Table 1.2, Figure 1.2), shorebird densities in control wetlands peaked in August 2011 at 0.7 birds per wetland ha, whereas they peaked on MBHI 2.5 months later with 0.9 shorebirds per wetland ha.

Waterbird species richness did not vary between MBHI and control wetlands (P = 0.4136) but did vary relative to survey date ($P < 0.0001$; Table 1.2). Species richness peaked in February 2012 for both the MBHI (2.0 species per wetland ha) and non-managed (2.2 species).

Discussion

My objectives were to quantify seasonal waterbird use of MBHI moist-soil wetlands in the MAV in Louisiana and Mississippi and compare these data with similar data from (a) nearby sites not managed through MBHI and (b) the literature to evaluate effects of MBHI. Dabbling ducks accounted for 65.0% of all waterbirds recorded during surveys, followed by other waterbirds (31.4%), shorebirds (2.5%), and diving ducks (1.1%). This majority is consistent with recent findings by Hagy and Kaminski (2012*a*), who reported that 92% of all waterbirds in managed moist-soil wetlands were dabbling ducks. Dabbling duck densities were 2.76 times greater on MBHI wetlands than non-managed wetlands. The MBHI wetlands received at least some form of management (i.e., flooding, disking, or mowing) promoting growth of moist-soil plants which provided increased seed resources and cover for migrating and wintering dabbling ducks and other waterbirds (Fredrickson and Taylor 1982, Reinecke et al. 1989, Kross et al. 2008). Similarly, Fleming (2010) reported that managed WRP wetlands in Mississippi attracted twice the number of dabbling ducks than passively or non-managed wetlands. In addition, Hagy and Kaminski (2012*a*) reported dabbling duck use being 3 times greater on managed than control wetlands, similar to Fleming (2010) and this research. Thus, the MBHI was successful in provisioning habitat for significantly more ducks in Mississippi and Louisiana than nearby non-managed wetlands.

Although seed abundances did not differ significantly between MBHI and non-managed wetlands, MBHI wetlands had greater seed biomass than non-managed wetlands. Additionally, I documented more species of plants in MBHI wetlands, perhaps resulting in more food and structural cover. The greater seed biomass and species richness in MBHI wetlands may have influenced the resulting significant difference in bird densities between MBHI and non-managed wetlands.

I documented twice greater mean densities of waterbirds other than ducks in MBHI wetlands than in control wetlands. The American coot (*Fulica americana*) comprised a large percentage (18.6%) of other waterbirds. Although coots can dive for food, they feed on vegetation and seeds floating on the surface when available, which may have attracted coots to MBHI wetlands (McKnight 1998). In addition, MBHI wetlands provided a state of primary succession, promoting annual vegetation typical of managed moist-soil wetlands (e.g., grasses and sedges), which may have increased abundance of aquatic invertebrates and other prey for waterbirds including crawfish, frogs, snakes, and turtles (Gonzáles-Solís et al. 1996).

As expected, I observed a significant effect of survey date on temporal variation in species richness and densities of all waterbird groups except shorebirds. Most species of waterbirds that used WRP wetlands were migratory, moving south toward wintering grounds in fall and back north to breeding grounds in spring. Thus, I would expect to detect significant differences in waterbird species richness and densities among summer-spring seasons. Although I observed a significant difference in seasonal species richness, I did not observe a significant difference for species richness between MBHI and non-managed wetlands. This result is different from Fleming (2010), who detected 32.7 % more in actively than passively managed WRP wetlands. In mid- to late August 2011, species diversity was low; many of the detected species in August 2011 may have been summer residents (e.g., great blue heron [*Ardea herodias*], great egret [*A. alba*], cattle egret [*Bubulcus ibis*], green heron [*Butorides virescens*], little blue heron [*Egretta caerulea*]), which contributed to decreased waterbird species richness in late summer compared to greater richness in spring 2012 due to use by resident and migratory birds. I did not detect a significant effect of date on the shorebird surveys; this result may have been related to when I commenced and conducted surveys (i.e., mid-August and October in Mississippi and Louisiana, respectively). Shorebirds are early migrants, often arriving in Mississippi and Louisiana in early July-September (Reid et al. 1983, Twedt et al. 1998). My results indicate that peak shorebird numbers for my surveys were in November (Fig. 1.2); however, because shorebirds are early migrants in fall, I may have missed peak shorebird numbers on their southward migration in summer 2011. Thus, future surveys should start in early July to assess shorebird migration in Mississippi and Louisiana accurately.

The greatest density of all waterbirds occurred in February, following close of the waterfowl season in Mississippi and Louisiana. This phenomenon suggests that disturbance from waterfowl and deer hunting activities, which occurred on all my WRPs during 2011-2012, may have influenced waterbird use during December-January. However, I was not able to quantify disturbance because surveying duration was short for each wetland (5-10 minutes). Other researchers have reported effects of hunting-related disturbances may cause waterbirds to move to sanctuaries and areas with less anthropogenic pressures (Dooley et al. 2010, St. James et al. 2013).

Management implications

My results indicated significantly greater numbers of waterbirds used MBHI than non-managed wetlands enrolled in WRP. Ducks constituted >50% of all detected waterbirds. Management by mowing or disking, followed by flooding, created habitats that attracted more than twice the number of ducks than non-managed wetlands, similar to observations by Hagy and Kaminski (2012*a*) for moist-soil wetlands in the MAV. Additionally, the MBHI program was successful in providing habitat for waterbirds inland from crude oil that contaminated the Gulf after the Deepwater Horizon Oil Spill. When future environmental disasters occur, a program such as the MBHI would benefit waterbirds and other wetland wildlife. Moreover, because MBHI managed wetlands were used more by waterbirds than non-managed WRP wetlands, I suggest that USDA NRCS consider sustaining MBHI or another similar program to provide financial incentives to landowners for management, given that much infrastructure (e.g., levees, water management controls, etc.) were provided to landowners and sometimes the infrastructure is under- or not utilized.

My research indicates that although waterbird densities were greater in managed wetlands, species richness was not significantly different. Fleming (2010) recommended inclusion of non-managed wetlands within WRP complexes to increase habitat and avian diversity (Fleming 2010). Additionally, because non-managed wetlands often contain water year around, they play an important role in providing wetlands for residents and migrants especially during drought periods. Finally, managers seeking to diversify the habitat to meet needs of different species should implement a management scheme that provides varied water depths.

Table 2.1 Mean ($\bar{x}$) waterbird densities from August 2011-April 2012

	MBHI (*n* = 245)			Non-managed (*n* = 282)		
Taxa	$\bar{x}$	LCI	UCI	$\bar{x}$	LCI	UCI
Dabblers (*Anas platyrynchos* + *A. fulvigula* + *A. acuta* + *A. americana* + *A. strepera* + *A. clypeata* + *A. discors* + *A. crecca* + *Aix sponsa* + *Dendrocygna autumnalis* + unknown dabblers	1.52	1.05	2.12	0.55	0.28	0.89
Divers (*Aythya collaris* + *A. valisineria* + *A* spp. + *Bucephala albeola* + *Oxyura jaimaicensis*)	0.10	0.03	0.17	0.06	0.00	0.13
All ducks (dabbler + diver)	1.66	1.14	2.31	0.60	0.31	0.96
Shorebirds (*Charadrius vociferus* + *Gallinago delicata* + *Himantopus mexicanus* + *Unknown Tringa* spp. + *Unknown Limnodromus* spp. + *Unknown "peeps"*)	0.26	0.12	0.41	0.11	0.00	0.23
Other waterbirds (*Ardea herodias* + *A. alba* + *Egretta caerulea* + *E. tricolor* + *E. thula* + *Bubulcus ibis* + *Butorides virescens* + *Platalea ajaja* + *Mycteria americana* + *Eudocimus albus* + *Plegadis falcinellus* + *Fulica americana* +*Rallus limicola* + *R. elegans* + *Botaurus lentiginosus* + *Pelecanus erythrorhynchos*	1.11	0.73	1.58	0.67	0.39	1.02
All birds (waterfowl + shorebirds + other waterbirds)	3.65	2.62	4.97	1.54	1.01	2.21
Species richness	0.69	0.52	0.88	0.60	0.45	0.76

Natural log back-transformed mean ($\bar{x}$) and lower and upper confidence limits (LCL, UCL) for waterbirds densities (i.e., birds/wet ha) during 17 surveys of Migratory Bird Habitat Initiative and non-managed wetlands enrolled in the Wetlands Reserve Program in Louisiana and Mississippi, August 2011-April 2012.

Table 2.2 Repeated measures ANOVA of waterbird densities and species richness, testing effects of treatment, survey date, and their interactions

	Effect	*F*	df	*P*
Dabbling ducks	Trt	11.63	1, 39	0.0015
	Survey	4.60	16, 454	<0.0001
	trt x survey	1.08	16, 454	0.368
Diving ducks	Trt	0.61	1, 39	0.4387
	Survey	2.97	16, 454	<0.0001
	trt x survey	1.00	16, 454	0.4519
Shorebirds	Trt	2.70	1, 39	0.1083
	Survey	1.01	16, 454	0.4425
	trt x survey	0.98	16, 454	0.4726
All ducks	Trt	11.88	1, 39	0.0014
	Survey	5.30	16, 454	<0.0001
	trt x survey	0.97	16, 454	0.4923
Other waterbirds	Trt	2.95	1, 39	0.0938
	Survey	5.16	16, 454	<0.0001
	trt x survey	0.57	16, 454	0.9082
All birds	Trt	12.79	1, 39	0.0009
	Survey	6.00	16, 454	<0.0001
	trt x survey	0.91	16, 454	0.5605
Species richness	Trt	0.68	1, 39	0.4136
	Survey	5.80	16, 454	<0.0001
	trt x survey	0.52	16, 454	0.9379

Results of repeated measures ANOVA of waterbird densities and species richness on wetlands in Mississippi and Louisiana (August 2011- April 2012), testing effects of treatment (i.e., Migratory Bird Habitat Initiative [trt] vs. non-managed wetlands), survey date, and their interactions.

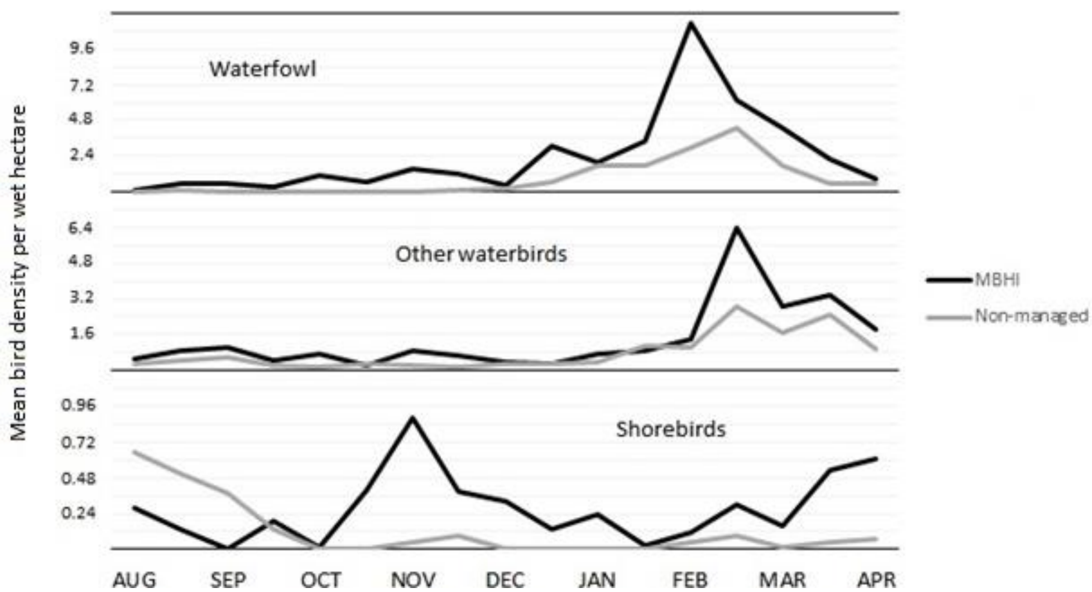

Figure 2.1 Mean ($\overline{x}$) waterbird densities, August 2011-April 2012

Natural log back-transformed mean ($\overline{x}$) for waterbird densities (i.e., birds/wet ha of wetland) on Migratory Bird Habitat Initiative and non-managed wetlands enrolled in the Wetlands Reserve Program in Louisiana and Mississippi.

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CHAPTER III

SYNTHESIS AND EXECUTIVE SUMMARY

To mitigate possible biological and environmental impacts of the Deepwater Horizon oil spill in the Gulf of Mexico on 20 April 2010, the USDA Natural Resources Conservation Service (NRCS) established the Migratory Bird Habitat Initiative (MBHI). The MBHI allocated $40 million to create and manage wetland habitat for waterbirds and wetland wildlife on private lands inland from the Gulf oil spill. Landowners received an incentive payment for managing private lands that NRCS deemed potentially beneficial to migrating and wintering waterbirds. Additionally, NRCS prescribed management for enrolled MBHI lands (e.g., flooding, mowing dense vegetation, soil disking, etc.). Over 190,000 ha of wetlands were enrolled in MBHI in the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, Missouri, and Texas. Within the MAV of Arkansas, Louisiana, and Mississippi, 52,570 ha of USDA Wetlands Reserve Program (WRP) were enrolled in MBHI (i.e., 31,373.3 ha, Arkansas; 16,153.4 ha, Louisiana; 5,043.6 ha Mississippi). Specifically, my objectives were to 1) estimate the abundance of seed and tuber biomasses in MBHI and non-managed wetlands in the MAV, and 2) quantify seasonal waterbird use of MBHI lands in the MAV of Louisiana and Mississippi and compare these data with similar data from (a) sites not managed through MBHI and (b) the literature to evaluate effects of MBHI.

In Chapter 1, I analyzed seed densities in MBHI and non-managed wetlands. Mean percent occurrence of seeds known to be waterfowl foods were similar between MBHI (25.9 ± 3.2% [SE, *n* =10]) and non-managed wetlands (27.0 ± 5.8%, *n* = 11). Contrary to predictions, densities of all moist-soil seeds and those commonly consumed by waterfowl did not differ between October 2011 and March 2012 sampling periods (Chapter 1; $P > 0.10$; Table 1.2).

In Chapter 2, I analyzed waterbird densities by treatment. I detected nearly three times more dabbling ducks and all ducks combined on MBHI than control wetlands (Chapter 2; $0.0014 < P < 0.0015$; Table 1.1). Additionally, waterbirds other than waterfowl and shorebirds were nearly twice more abundant on MBHI than control wetlands (Chapter 2; $P = 0.0938$; Table 1.1). Densities of dabbling ducks, diving ducks, total ducks, waterbirds, and species richness varied by survey date on MBHI and non-managed wetlands (Chapter 2; $P < 0.01$; Table 1.2, Figure 1.2). Waterbird species richness did not vary between MBHI and control wetlands ($P = 0.4136$) but did vary relative to survey date ($P < 0.0001$; Table 1.2). Species richness peaked in February 2012 for both MBHI (~2.0 species per wetland ha; non-managed wetlands ~2.2 species).

Combining data on seed densities from Chapter 1 and waterfowl densities from Chapter 2, I performed regression and Akaike Information Criterion analyses to evaluate if waterfowl densities varied with seed densities and management or no management for 25 wetlands. I conducted 4 separate regressions using each mean waterfowl density averaged from December 2011 to mid-March 2012 as the dependent variable and October seed density (kg[dry]/ha) and treatment (MBHI [1] or non-managed [0]) as independent variables. The four models were: (1) waterfowl density regressed on seed density, (2) waterfowl density on treatment, (3) waterfowl density on seed density + treatment, and (4) waterfowl density on the interaction of seed density and treatment (Table 3.1). Waterfowl densities varied with moist-soil seed density; most support existed for model 1 ($w_i = 0.77$) and none of the other models explained much variation in waterfowl density (<17%).

Because my sample number of wetlands was small ($n = 25$) and variability in waterfowl use and seed densities was great, I did not detect a strong relationship between waterfowl and seed densities. I did observe a slight inverse relationship between waterfowl and seed densities, suggesting that waterfowl densities increased with decreased wetland seed densities. However, the relationship was not significant and could have resulted from variability and several outliers influencing the regression (Table 3.1).

For seeds commonly consumed by waterfowl (Hagy and Kaminski 2012*b*), MBHI wetlands contained 1.3 times greater seed densities in October and 1.5 times greater densities in March. Coupled with greater densities of waterfowl and other waterbirds on MBHI than non-managed wetlands (Chapter 2), I recommend active management consisting of early fall mowing of moist-soil vegetation to increase waterfowl and other waterbird use of WRP wetlands (Hagy and Kaminski 2012*a*). Mowing of robust vegetation allows access for waterfowl and other waterbirds. Additionally, the MBHI program was successful in providing habitat for waterbirds inland from the Deepwater Horizon Oil Spill. When future environmental disasters occur, a program such as the MBHI would benefit waterbirds and other wildlife. Moreover, because MBHI managed wetlands were used more by waterbirds than non-managed WRP wetlands, I suggest that

USDA NRCS consider sustaining MBHI or another similar program to provide financial incentives to landowners for management, given that much infrastructure (e.g., levees, water management controls, etc.) was provided to landowners and sometimes the infrastructure is under- or not utilized. Finally, managers seeking to diversify the habitat to meet needs of different species should implement management schemes that provide a complex of seasonally drawndown and naturally fluctuating wetlands with varying water depths and plant communities (Fleming 2010, Fleming et al. 2012).

Table 3.1 Models explaining variation in waterfowl densities

Model	*k*	AICc	ΔAICc	w_i
Seed density	2	218.6	0.0	0.77
1 or 0	2	221.6	3.0	0.17
Seed density + 1 or 0	3	224.1	5.5	0.05
Seed density x 1 or 0	4	227.6	9.0	0.01

Models explaining variation in waterfowl densities on Mississippi and Louisiana wetlands enrolled in the Wetland Reserve Program and managed (1) or not (0) under the Migratory Bird Habitat Initiative in relationship to seed density, treatment, seed density and treatment, and the interaction of seed density and treatment. For each model, Akaike's Second Order Information Criteria (AICc), ΔAICc, and model weights (w_i) are presented.

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