EFFECTS OF MANAGEMEMT AND HYDROLOGY ON VEGETATION, WINTER WATERBIRD USE, AND WATER QUALITY ON WETLANDS RESERVE PROGRAM LANDS, MISSISSIPPI

By

Kathryn Sarah Fleming

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Approved:

Richard M. Kaminski Professor of Wildlife/Associate Dean College of Forest Resources (Director of Thesis)	Todd E. Tietjen Limnologist/Adjunct Professor (Committee Member)
Gary N. Ervin Professor of Biology (Committee Member)	Kevin D. Nelms Wildlife Biologist (Committee Member)
Bruce D. Leopold Professor of Wildlife/Department Head (Graduate Coordinator)	George M. Hopper Dean College of Forest Resources

Name: Kathryn Sarah Fleming

Date of Degree: May 1, 2010

Institution: Mississippi State University

Major Field: Wildlife and Fisheries Science

Major Professor: Dr. Richard M. Kaminski

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No evaluations of plant and wildlife communities in Wetlands Reserve Program wetlands have been conducted in the Mississippi Alluvial Valley. Therefore, I evaluated active and passive moist-soil management (MTYPE) and early and late draw-down on plant communities, waterbird use, and water quality on 18 WRP lands, Mississippi, 2007-2009. Active-early sites had greater waterfowl Vegetative Forage Quality (VFQI), percentage occurrence of grass, plant diversity, and structural composition than passively managed sites ($P < 0.10$). I modeled variation in densities of wintering waterbirds; the best model included VFQI*MTYPE and decreased % woody vegetation ($w_i \geq 0.79$). Additionally, waterbird densities varied positively with active-late management ($R^2 \leq 0.27$), as did duck species richness with flooded area ($R^2 = 0.66$). I compared water quality parameters among managed wetlands and drainage ditches but did not detect differences due to variability. Therefore, wetland restoration on WRP lands should focus on active management and maximizing wetland area.

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CHAPTER I

PLANT-COMMUNITY RESPONSES TO MANAGEMENT AND HYDROLOGY ON WETLANDS RESERVE PROGRAM LANDS IN MISSISSIPPI

The North American Waterfowl Management Plan (NAWMP; 1986) provides a conceptual, continental framework for research and conservation of important waterfowl habitats and populations (U.S. Fish and Wildlife Service 2006). The Lower Mississippi Valley Joint Venture (LMVJV) is a partnership within NAWMP, involving federal and state agencies, nongovernmental organizations, and landowners which implement local and landscape-scale habitat conservation in the Mississippi Alluvial Valley (MAV) benefiting waterfowl and other wildlife. Wetland-conservation initiatives serve an important role meeting habitat goals of NAWMP and LMVJV by fostering development and restoration of habitats for waterfowl and other wildlife (Reinecke et al. 1989, Kushlan et al. 2002, King et al. 2006). Additionally, restoration efforts often focus on restoring renewable ecosystem services including sustaining or improving biodiversity, water quality, hydrology, and carbon sequestration (Whigham 1999, Zedler and Kercher 2005, Mitsch and Gosselink 2007). Current federal and state policies in the United States focus on protection and restoration of wetlands to sustain or enhance indigenous wildlife and plant communities (Zedler and Kercher 2005).

Wetlands provide important ecological benefits, such as, foraging and other habitats for millions of wildlife worldwide, as well as, many ecosystem services (Smith et al. 2004, Mitsch and Gosselink 2007, O'Neal et al. 2008). However, loss and degradation of wetlands have led to significant hydrological alterations and environmental impacts (Mitsch and Gosselink 2007). Efforts to restore wetlands throughout the United States, especially on private lands, were enhanced by the Food, Agriculture, Conservation, and Trade Act (1990; i.e., Farm Bill; Natural Resources Conservation Service [NRCS] 2007). Several important wetland conservation programs, including the Wetlands Reserve Program (WRP), are managed under the Farm Bill. There are >9,900 WRP projects on nearly 728,434 ha in the United States (Kaminski et al. 2006, King et al. 2006, NRCS 2007). Most WRP lands are in the MAV of Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee, where >161,000 ha of previously farmed lands have been restored to native wetlands (Ducks Unlimited 2006, King et al. 2006). The MAV is a focal area for WRP because this region is continentally important for migrating and wintering waterfowl, and wetland drainage, deforestation, river channelization, agriculture, and urbanization have substantially changed natural hydrology and decreased available habitat and food resources for wildlife (Reinecke and Heitmeyer 1988, King et al. 2006).

The WRP is a voluntary program, administered through the NRCS, by which landowners receive technical and financial assistance to protect, enhance, and restore wetland areas recently farmed (NRCS 2004, Haufler 2005). One of three major waterfowl habitats identified for wetland conservation and restoration by the LMVJV is moist-soil wetlands (Fredrickson and Taylor 1982, Loesch et al. 1995). Natural or managed moist-soil wetlands are seasonally flooded areas which produce early successional plant communities dominated by grasses (e.g., *Panicum* spp., *Paspalum* spp.), sedges (*Cyperus* spp., *Carex* spp.), and other herbaceous plants (Fredrickson and Taylor 1982, Smith et al. 1989, Nelms 2007, Kross et al. 2008). The term moist-soil management originated in the 1940s and describes hydrological management of wetlands to stimulate germination and growth of seeds under mudflat conditions (Low and Bellrose 1944). Nowadays, moist-soil management is frequently applied throughout the MAV and southern United States to provide habitat for waterfowl and wetland wildlife (Fredrickson and Taylor 1982, Smith et al. 1989).

A primary goal of moist-soil management on WRP sites is to increase production of annual grasses and sedges that produce seeds and tubers rich in energy for foraging waterfowl (Fredrickson and Taylor 1982, Reinecke et al. 1989, Kaminski et al. 2003). Active management of moist-soil wetlands includes annual or regular soil disturbance, seasonal hydrological management, and control of undesirable plants (Nelms 2007). Management guidelines provided to landowners by NRCS state that an annual draw-down of water to create mud flats in spring-summer is critical to produce early succession plant communities. Additionally, draw-down date, rate, duration, and depth of flooding influence vegetative composition, diversity, propagule production, and subsequent wildlife responses (Fredrickson 1991, Strader and Stinson 2005, Nelms 2007). Kross et al. (2008) reported actively managed moist-soil wetlands contain, on average, nearly 560 kg/ha (dry mass) of seeds and tubers. The NRCS landowner guidelines for management of moist-soil plant communities in the southeastern United States are based on dates and timing of water draw-down as follows: (1) early season draw-down (15 March – 15 June,

(2) late draw-down (after 15 June), and (3) in contrast to early and late draw-downs, slow draw-down (2-6 week duration) or natural evapotransportation.

Effectiveness of management efforts, such as those applied to the WRP lands, can be evaluated by monitoring and quantifying metrics of vegetative communities (White 1987). Evaluations of plant communities can be employed by assigning rankings among sites based on predetermined characteristics (Adamus et al. 1987). For example, Floristic Quality Assessment Indices (FQAI) are used to assess native vegetative communities, monitor restoration success, and evaluate broader ecological conditions of sites through biomonitoring approaches (Matthews et al. 2005, Bourdaghs et al. 2006). The FQAI is an important tool used to quantify restoration success based on predetermined values assigned to characteristics of the floristic communities (sensu Andreas and Lichvar 1995, Matthews et al. 2005, Ervin et al. 2006). Values are assigned to individual plant species characteristics (i.e., site fidelity, native status, etc.) and combined in an index to develop relevant criteria for evaluations and comparisons (Taft et al. 1997, Andreas et al. 2004). A FQAI can provide biologists and managers with a simple, effective method to assess local and landscape-level vegetative communities on lands enrolled in conservation programs while simultaneously evaluating successes of restoration which can provide a tool for long-term monitoring (Taft et al. 2006).

Assessment and analyses of vegetation on restored wetlands play important roles in determining habitat value and meeting conservation program objectives (Brown 1999). Evaluating plant characteristics of moist-soil areas is warranted to determine effects of varied management regimes on conservation lands, which may be an important factor related to the availability of quality food for waterfowl and other wildlife in accordance with the conservation requirements established by the NAWMP. Therefore, based on NRCS landowner management guidelines, I evaluated plant community metrics of moist-soil wetlands subjected to different management regimes (i.e., active and passive) and relative date of draw-down (i.e., early and late season; see management descriptions below). An important goal of the WRP in the MAV is to provide quality foraging habitat for migrating and wintering waterfowl. Thus, I developed a Vegetative Forage Quality Index (VFQI) based on the FQAI to evaluate moist-soil plant communities as potential forage for waterfowl (e.g., Kaminski et al. 2003, Andreas et al. 2004, Taft et al. 2006). Evaluations of moist-soil plant communities may help determine the effect of different conservation and management regimes on habitat suitability.

Study Area

My study wetlands (n = 54) were located on private lands enrolled in WRP in the MAV of Mississippi distributed across Grenada, Sharkey, Sunflower, Tallahatchie, and Yazoo Counties, and the boarder of Tunica/Quitman Counties (Figure 1.1). Total area of all WRP properties ranged from 22.7-1,448.6 ha, and each WRP property had 3-22 moist-soil wetlands from 0.4-67.8 ha. Topography, wetland characteristics, and financial resources varied among landowners which influenced their intensity of management. Fifty-one (94%) of my study wetlands had water control structures in levees, which enabled draining or retaining water on wetlands. Wetland flooding originated from several sources including rivers, ditches, pumps, runoff, and rain. No wetlands had any interconnected hydrology and minimum distance between wetlands was $\geq$ 50m. Therefore, wetlands were considered discrete, independent survey and analytical units.

Common vegetation occurring in wetlands primarily consisted of native species adapted to seasonal flooding and drainage (moist-soil conditions), including grasses (e.g., *Echinochloa*, *Panicum*, and *Paspalum* spp.), forbs (*Polygonum* spp., *Bidens cernua*), vines (*Brunnichia cirrhosa, Ipomoea* spp.), sedges and rushes (*Cyperus* spp., *Juncus* spp.), trees and shrubs (*Quercus spp.*, *Salix nigra*, *Cephalanthus occidentalis*), aquatics (*Ludwigia* spp., *Potamogeton* spp.), and planted wildlife food plot crops.

Methods

Study Design

Following field reconnaissance during spring to early-summer 2008 and 2009, I designated management of WRP wetlands as: (1) active management with early draw-down when drainage was completed by 15 June (i.e., active-early), (2) active management with late (i.e., active-late; ≥ 3 weeks after active-early draw-down dates), and (3) passive management with natural draw-down by evaporation within wetlands with or without a water-management structure(s). I assigned active management to moist-soil wetlands when managers followed NRCS contract guidelines, which generally included a combination of monthly inspections of sites, annual soil disturbance (e.g., disking), and control of plants with little or no known value as waterfowl forage (e.g., *Sesbania* spp.), supporting a goal of improving foraging habitat for waterfowl (Brasher et al. 2007, Kross et al. 2008). Passively managed wetlands received infrequent soil disturbance (≥ 5 years), limited or no control of undesirable plants, and minimal to no hydrological management (Brasher et al. 2007, Kross et al. 2008).

I designated the 6 aforementioned counties as blocks which were distributed from north to south MAV in western Mississippi, and each contained three replicate wetlands with active-early and active-late draw-downs and passive management. I used Arcview (ArcGIS 9.2) to locate and select sites with active-early management from the NRCS Mississippi WRP federal database. Six active-early WRP sites existed in 2008; therefore, I selected these for study. I based selection and geographical matching of active-early, active-late, and passive sites on three criteria**:** (1) all replicate sites were located within the same block (i.e., multiple adjoining WRP properties occurred in each block); (2) a distance of <20 km occurred among all 3 management replications within a block, because I assumed this distance would reduce variability in environmental conditions among sites (e.g., weather, flood events); Jorde et al. 1983, Cox and Afton 1996, Legagneux et al. 2009); and (3) a minimum of three moist-soil units with functional levee structures within each site (Kross et al. 2008). I randomly selected active-late and passive sites to pair with each of the six active-early sites. If sites did not meet predetermined criteria, I randomly selected replacement sites within the distance criterion.

My final study design for summers 2008-2009 had unbalanced replications, because one landowner changed management from passive to active-late after I initiated plant surveys in 2008. Therefore, in 2008, five blocks contained all three management categories, whereas one block had active-early and active-late, but no passive sites. In 2009, a property changed ownership and management was changed from passive to active-early. Therefore, in 2009, four blocks contained all three management categories, whereas two blocks had active-early and active-late, but no passive sites. I surveyed 54

WRP wetlands (i.e., sampling units; 6 blocks x 3 management regimes per block x 3 replicate moist-soil wetlands per management regime).

Vegetation Surveys

At each site, I randomly selected 3 moist-soil wetlands in which to measure vegetation characteristics of plant communities. I sampled plant communities at monthly intervals from June - October 2008. I sampled plant communities only in July and October 2009 due to logistical constraints and because 2008 data justified reduced sampling frequency (see results). I used a species accumulation curve after each sampling period to determine sample sizes to represent plant species accurately in communities (Roberts-Pichette and Gillespie 1999). My analyses indicated ~50 sampling points within wetlands contained 100% of all detected plant species. Therefore, I established 50 – 64 random sampling points along equally spaced transects within each wetland. At each random point, I indentified and recorded each plant to the lowest taxonomic level (i.e., genus or species) touching a 3 cm diameter x 165-cm plastic PVC pipe (Laubhan and Fredrickson 1992, Sherfy and Kirkpatrick 1999, Ervin et al. 2006).

I quantified plant species richness as number of species or genera encountered at each sampling point. I calculated plant community richness as total number of species or genera detected per wetland. I calculated diversity using the Shannon-Weaver Index, where measure of relative abundance of each plant species/genus was its proportional occurrence across all survey points in a wetland (Hair 1980). I also quantified vegetative composition (COMP) as mean number of plant growth-forms per sampling point (i.e., grasses, sedges/rushes, aquatics, vines, woody vegetation, wildlife food crops, and broadleaves; Johnson and Montalbano 1984, Kross et al. 2008). Further, management recommendations for moist-soil wetlands usually discourage woody vegetation and encourage graminoid species (Strader and Stinson 2005, Nelms 2007, Kross et al. 2008). Therefore, I calculated proportional occurrence of grass (i.e., Poaceae family; %GRASS) and woody vegetation (%WOODY) within each wetland.

Vegetative Forage Quality Index

I calculated a Vegetative Forage Quality Index (VFQI) equation for each wetland using waterfowl forage quality coefficient values (C) which were modified from FQAI coefficients of conservatism (Taft et al. 1997). The C values were calculated as a weighted forage coefficient based on relative nutritional values (e.g., true metabolizable energy [TME]; Miller and Reinecke 1984) of seeds or tubers of the plant species (or genus) for waterfowl (Fredrickson and Taylor 1982, Kaminski et al. 2003, Strader and Stinson 2005). Availability of TME values is limited for moist-soil plant species (Kaminski et al. 2003, Bourdaghs et al. 2006), thus C values for each plant species/genus were obtained from ratings by a panel of waterfowl and wetland experts with doctoral degrees and ≥5 years experience in moist-soil wetland and waterfowl ecology and management. I contacted each expert twice by e-mail. My first contact described the study and requested participation. If no response was received after two weeks, I sent a reminder to the panelist. I received responses from 14 (70%) of 20 panelists, and requested all panelists to keep surveys confidential in compliance with Mississippi State University’s Institutional Review Board for the Protection of Human Subjects in Research.

The panel of experts received a plant list composed of all plant species (or genera) observed during my 2008 and 2009 vegetation surveys. I requested panelists to score each plant as either 1, 2, or 3 corresponding to a relative nutritional value for waterfowl (1 = poor, 2 = neutral, 3 = excellent, and UK = unknown; Naylor et al. 2005; Strader and Stinson 2005). From these ranks, I calculated mean C values for use in calculating the VFQI for each taxon (Table 1.1). Finally, I calculated VFQI as the sum of proportional occurrence of each plant species multiplied by its respective ranked C value (relative forage coefficient), divided by plant richness (*N*), and weighted by square root *N*, following Andreas and Lichvar (1995).

Vegetative Forage Quality Index calculation:

$$\text{VFQI} = \sum_{i=1}^{n} \left(\frac{\text{C}_i \, [\text{PO}]_i}{N} \right) \text{x} \sqrt{N} \qquad (1\text{-}1)$$

Where:

VFQI	=	Vegetative Forage Quality Index
C_i	=	Mean relative forage quality coefficient for plant taxa per wetland
PO_i	=	Proportional occurrence of plant taxa per wetland
N	=	Plant species/genera richness for each wetland

Statistical Analyses

Year-specific analyses.

The NRCS guidelines for moist-soil wetland management encourage a monitoring program where landowners annually evaluate their plant communities to ensure desired plant response to management. Therefore, I evaluated plant communities monthly between June and October 2008 to evaluate efficacy of conducting monthly plant surveys. I used a block design to evaluate if year specific differences existed in plant species/genera richness, diversity, and VFQI among management types. Results of 2008 surveys allowed for adjustment of 2009 survey efforts (see results). I used PROC MIXED (SAS 9.2.2) for analysis which is appropriate for a block design with unbalanced replication and allows for interactions in repeated measures of plant metrics through time (SAS Institute 2009, Littell et al. 2007). I performed an analysis of variance (ANOVA) on the aforementioned response variables for each monthly survey within years (PROC MIXED; SAS Institute 2009). I designated $\alpha = 0.10$ *a priori* which has been used in field studies without large sample sizes, (i.e., $n < 26$; Tacha et al. 1982, Kross et al. 2008). I performed a posteriori mean comparisons to test if plant richness, diversity, and VFQI varied among active-early, active-late and passively managed wetlands within years (Zar 1974).

To evaluate homogeneity of variances within years, I plotted residuals of summer 2008 and 2009 plant richness, diversity, and VFQI data against predictor variables and examined residuals for clustering and uniform distribution. Variances for 2008 and 2009 VFQI and 2009 diversity appeared unequal based on examinations; therefore, I natural log transformed VFQI and diversity data sets before analyses (Zar 1974). Transformations resulted in homogeneity of variances. Visual inspections of residuals for 2008 and 2009 richness and 2008 diversity data supported homogeneity of variance and thus were not transformed. I evaluated covariance structures of dependent variables based on Akaike's Second Order Information Criteria (AIC_c). Competing covariance structures were ranked according to Δ AIC_c values, and my selection was based on the least Δ AIC_c value and biological interpretation of the covariance matrix. I specified compound symmetry (cs) covariate structure, because variances (transformed or not) were homogenous over time.

I performed ANOVA to test null hypotheses of no difference in plant richness, diversity, and VFQI among management types (active-early, active-late, and passive) and survey months (June-October 2008, and July and October 2009; PROC MIXED, SAS 9.2.2). I designated management types and months as fixed effects, blocks and private properties nested within blocks as random effects, and survey months as repeated measures. I tested all main effects and interactions, removed non-significant interactions ($P > 0.10$), and re-analyzed remaining models. I detected a management type by survey month interaction for log-transformed VFQI in 2008 and 2009; therefore, I performed pair wise multiple comparisons among management types within months using the slice function in PROC MIXED (SAS 9.2.2).

Across-years analyses.

Analyses of 2008 and 2009 data revealed differences in plant community diversity and VFQI were not detected for any months except October ($P \leq 0.10$; see results). Therefore, I used October data for across year analyses to develop simplified management recommendations based on average environmental conditions. I performed ANOVA in PROC MIXED (SAS 9.2.2) to test the null hypothesis of no difference in October values of richness, diversity, VFQI, and other plant community metrics (see below) across years among active-early, active-late, and passive management. Similar to within-year analyses, I designated management types as fixed effects, blocks and private properties nested within blocks as random effects, and year as the repeated measure. Year was included as a covariate of plant richness, diversity, VFQI and other community metrics to adjust for variations attributed to differences between years. Additionally, because the October plant community most likely represented most potentially available habitat and forage for wintering waterfowl, I evaluated additional plant community metrics that may influence winter waterfowl and waterbird use (i.e., mean number of plant growth-forms per sampling point; COMP), percentage woody cover per wetland [%WOODY], and percentage grass [%GRASS]; Weller and Fredrickson 1974, Kaminski et al. 2003, Brasher et al. 2007, Kross et al. 2008). I natural log transformed VFQI data because its variances were unequal, whereas those of the other response variables appeared homogenous based on inspections described above.

Results

Year-specific analyses and results.

I analyzed data from vegetation surveys conducted June-October 2008. When I designated and evaluated month as a repeated measure, I did not detect differences in plant species/genera richness per wetland among active-early ($\bar{x}$ = 15.32 ± 1.53 [SE]), active-late ($\bar{x}$ = 16.22 ± 1.50), and passively managed sites ($\bar{x}$ =16.00 ± 1.66; $F_{2, 9.06}$ = 0.16, P = 0.85). However, I detected an interaction between management type and month for VFQI ($F_{6, 153}$ = 2.33, P = 0.03) and diversity ($F_{6, 153}$ = 1.82, P = 0.09). I detected a difference among management types only for October 2008 data for VFQI ($F_{2, 41.2}$ = 2.51, P = 0.09; Figure 1.2) and diversity ($F_{2, 29.5}$ = 3.81, P = 0.03; Figure 1.3). Mean October VFQI and diversity values were nearly 50% greater on active-early than passive sites (P = 0.03, P = 0.01, respectively; Table 1.2, Figures 1.2 and 1.3). I did not detect any other differences in VFQI and diversity among management types ($P \geq 0.13$; Figures 1.2 and 1.3).

I analyzed data from vegetation surveys conducted in July and October 2009. When I designated month as a repeated measure and evaluated effect of management on VFQI, I detected a management by month interaction, consistent with 2008 results, where differences among management types were observed for only October 2009 ($F_{2, 50.6}$ = 2.82, P = 0.07; Figure 1.4). Mean VFQI for October 2009 for active-early sites was 42% greater than active-late sites (P = 0.01), but no differences were observed between active-early and passive sites (P = 0.11) and active-late and passive sites in October (P = 0.27, Figure 1.4). I did not observe any difference in plant species/genera richness among management types, active-early ($\bar{x}$ = 14.61 ± 1.45 [SE]), active-late ($\bar{x}$ = 13.32 ± 1.44), and passive sites ($\bar{x}$ = 14.44 ±1.84), for 2009 data ($F_{2, 8.41}$= 0.18, P = 0.84). Similarly, there was no difference in plant diversity among management types, 2009 ($\bar{x}$ active-early = 2.56 ± 1.12, $\bar{x}$ active-late = 2.23 ± 1.12, and $\bar{x}$ passive = 2.98 ± 1.15; $F_{2, 47.8}$ = 1.68, P = 0.20).

Across-years analyses and results.

I designated year as a repeated measure and a covariate in analyses of effect of management across October 2008 and 2009 for VFQI, diversity, richness, COMP, %WOODY, and %GRASS (Table 1.2). I observed an effect of management for VFQI ($F_{2, 8.20}$ = 7.74, P = 0.01), diversity ($F_{2, 9.39}$ = 4.54, P = 0.04), COMP ($F_{2, 9.72}$ = 4.71, P = 0.03), and %GRASS ($F_{2, 8.70}$ = 3.63, P = 0.07; Table 1.3). Mean diversity and %GRASS in active-early sites were ≥ 42% greater than for passive sites (P = 0.04, P =0.09, respectively). Mean VFQI and COMP for active-early sites was ≥ 17% greater than active-late and passive sites ($P \leq 0.04$ and $P \leq 0.08$, respectively). I did not detect any other differences in plant community metrics among management types ($P \geq 0.14$; Table 1.3).

Discussion

I developed a VFQI focused on waterfowl food, because an important goal of WRP in the MAV is to provide quality foraging habitat for these birds during winter. I evaluated VFQI and plant community metrics of moist-soil wetlands subjected to active and passive management and early and late seasonal draw-downs between spring and early summer, based on NRCS management guidelines (Nelms 2007). I detected differences in VFQI among management types in October, where October active-early sites had nearly 20% greater potential waterfowl forage than passively managed sites, but similar VFQI values existed between active-late and passive sites (Figure 1.4; Table 1.3). The NRCS guidelines and other literature indicate management activity and timing of draw-down can influence increased seed production and species diversity of desirable, waterfowl-food producing, early-successional grasses (e.g., *Panicum* spp., *Paspalum* spp., *Echinochloa* spp.), sedges (*Cyperus* spp., *Carex* spp.), and other herbaceous plants (Fredrickson and Taylor 1982, Strader and Stinson 2005, Nelms 2007). My results also support NRCS's prediction regarding hydrology guidelines because VFQI and %GRASS were >50% greater on actively managed sites with early draw-downs than active-late and passively managed sites in 2008 and 2009 (Table 1.3). Active-early management supported the greatest VFQI values, compared to passively managed sites that had lesser VFQI (Tables 1.2 and 1.3). Therefore, VFQI seems influenced by management intensity, seasonal timing of draw-down and consistent management guidelines (Fredrickson and Taylor 1982, Nelms 2007). The VFQI quantified seasonal plant communities; however, I suggest a need to model variation in plant metrics measured herein and winter responses of waterfowl in relation to growing season hydrological and management activity (e.g., Chapter 2).

My VFQI detected differences in potential waterfowl forage quality as influenced by management of WRP moist-soil wetlands. However, increased VFQI values can be attained by various management strategies including planting of food plots within WRP areas. The WRP allows landowners to plant ≤ 5% of their WRP acreage in wildlife food plots, such as, corn, grain sorghum, and other grain crops. Active management with early draw-down facilitated landowners who desired establishing food plots. Corn occurred on 46% of my active-early wetlands ($n = 18$) and < 5% on my active-late ($n = 21$) and passive ($n = 15$) sites during October 2008 and 2009 surveys. Agricultural seeds are high in TME values for waterfowl (Kaminski et al. 2003) and thus also ranked high among my forage quality coefficients (Table 1.1). However, although sites with wildlife food crops resulted in initial high VFQI values, waterfowl and other granivorous wildlife may deplete high-carbohydrate food plots early-mid-winter (Gray et al. 2009). Future research should examine initial fall VFQI values of moist-soil wetlands with and without food plots and waterfowl food availability periodically during fall and winter.

My forage quality coefficients ranged on a scale from 1-3 and assigned to each plant species by a panel of expert wetland and waterfowl ecologists. The basis for ranking was the panelists' knowledge and judgment of TME values of the plants' seeds or tubers and thus was partly subjective (Andreas and Lichvar 1995, Taft et al. 1997, Bourdaghs et al. 2006). Therefore, continued evaluation of TME and other nutrient components (i.e., fiber content), and waterfowl use and preference of moist-soil seeds and tubers is necessary to refine the application of C values, and ultimately VFQI.

Natural and human induced soil disturbances in moist-soil wetlands vary in frequency, intensity, and duration. Minimal and infrequent disturbances can have negligible effects on plant community diversity, but, as disturbances increase, the result may be predictable changes in plant community characteristics (Taft et al. 1997). Moist-soil management guidelines encourage annual or regular disturbances (e.g., soil disking) to maintain early succession plant communities, increase plant productivity (i.e., seeds), maintain high plant diversity, and reduce encroachment by late-successional plants of lesser food quality (Loucks 1970, Whittaker 1972, Fredrickson and Taylor 1982, Strader and Stinson 2005, Nelms 2007). My results support current moist-soil management guidelines wherein plant diversity was greater on active-early than passively managed sites across 2008-2009. Increased diversity on active-early and active-late sites may have resulted from management promoting germination of seed banks (Fredrickson and Taylor 1982, Nelms 2007).

Managers often are able to manipulate environmental factors that influence plant communities, such as flood duration. Managing water levels on moist-soil wetlands is used to increase production of natural foods, thereby enhancing the quality of foraging habitat for birds (Meeks 1969, Fredrickson Taylor 1982, Smith et al. 1989, Nelms 2007). Draining wetlands during the first 45 days of the growing season (i.e., mid-March-May in Mississippi) may produce more food than natural draw-downs (i.e., passive management; Brown 1999, Nelms 2007, Kross et al. 2008). Conversely, draining wetlands before May may reduce effectiveness as undesirable plants (e.g., *Brunnichia cirrhosa*) may become established prior to desirable species (*Echinochloa*, *Panicum*, and *Paspalum* spp; Meeks 1969). For example, early draw-downs (drainage completed by June) may allow perennial plants to develop rhizomes capable of producing shoots (Merendino and Smith 1991). However, early draw-downs in my study produced the greatest VFQI and diversity of plants (Table 1.3).

Mean VFQI on passive sites were similar between 2008 and 2009 (VFQI = 1.78 and 1.73, respectively; Figures 1.2 and 1.4). However, VFQI on both active management types decreased 16 - 49% between 2008 - 2009, whereas VFQI on passively managed sites only decreased 4% between years (Table 1.2). Yearly variation between active management types may be related partly to summer precipitation patterns. The National Climatic Data Center (NCDC; 2009) reported mean precipitation for Mississippi in May-October 2008 approximated the long term average ($\bar{x}$ = 72.40 cm). Mean precipitation in 2009 was reported as Mississippi's wettest summer since 1894 (May-October; $\bar{x}$ = 95.10

cm; NCDC 2009). Therefore, active-late sites may have been flooded too late into summer reducing seed germination and plant growth in 2009. Little difference in VFQI on passively managed sites may have reflected increased stability and inundation of WRP sites because hydrology is not actively managed but instead a consequence of environmental variations. Normal and high precipitation in 2008 and 2009, respectively, may have kept most of these WRP sites inundated through much of the growing season. Plant composition among the WRP wetlands in my study appears to be influenced by temporal and spatial extent and duration of growing season flooding, which is consistent with NRCS moist-soil management guidelines (Fredrickson and Taylor 1982, Howard and Wells 2009).

Species richness often is used to detect actual differences in plant composition among restored wetlands (Botta-Dukát 2005) but alone may not accurately gauge effectiveness of restoration or management efforts (Taft et al. 2006). For example, I observed no difference in plant species/genera richness among managements. Therefore, evaluating only species richness may not provide an accurate representation of plant community composition and quality of wetland habitat for wintering waterfowl. However, %GRASS and COMP were greater on active-early than passive sites in 2008 and 2009, which supports current moist-soil management guidelines for promoting availability of abundant high energy forage for migratory and wintering birds (Fredrickson and Taylor 1982, Anderson and Smith 1999, Kaminski et al. 2003, King et al. 2006, Kross et al. 2008).

Plants that establish in moist-soil wetlands play an important role in the ecological value of the wetland and meeting conservation goals (Hemesath and Dinsmore 1993).

Wetland management is complex, but components of moist-soil management guidelines may be simplified into easily understandable generalities (Hilderbrand et al. 2005). Management activities often strive to re-establish a complex wetland system and failure to recognize limitations may result in unattained conservation goals (Holling and Meffe 1996). To assume all restored wetlands will harbor native plants and function naturally because proper infrastructures were engineered and installed is tenuous (Hilderbrand et al. 2005). Wetland management should be viewed as an adaptive management strategy used by biologists and managers to obtain feedback information for structured decision making (sensu Stankey et al. 2005). For example, maximizing plant species diversity for high quality waterfowl forage is likely to increase bird use, and bird community diversity may increase with habitat complexity (i.e., COMP; Elmqvist et al. 2003, Menninger and Palmer 2006:97, O'Neal et al. 2008). However, research should continue to investigate behavioral and survival responses of waterbirds to site-specific and landscape level vegetative and wetland characteristics to guide conservation and management efforts on WRP and other wetland complexes (Kaminski et al. 2006, O'Neal et al. 2008).

Management Implications

Wetlands in my study were restored through WRP, and current NRCS moist-soil management guidelines appear to offer effective management strategies for promoting a diversity of high quality habitat and forage for wintering waterfowl. One goal of my study was to develop a method moist-soil managers could use to quantify forage quality of wetland plant communities. I evaluated VFQI and other plant community metrics and found support for current NRCS moist-soil management guidelines. My results revealed active management with early draw-down produced greatest plant community diversity, VFQI, composition, and percentage grass across years in October. The NRCS guidelines for moist-soil wetland encourage landowners to monitor and annually evaluate their plant communities to ensure desired plant responses to management. I did not detect differences in plant community diversity and VFQI until October each year. Therefore, plant community responses to management should be evaluated in October; however, monthly monitoring of moist-soil plants also is encouraged to manage emergence of any undesirable plants. Biologists and interested landowners can repeat my methods and quantify potential forage quality of WRP wetlands by using forage quality coefficients in Table 1.1.

Active management with early draw-down supported the greatest plant diversity and VFQI within and across survey years, plant diversity and VFQI on active sites decreased between 2008 and 2009. This decrease likely was a consequence of extreme (Mississippi's wettest summer since 1894) amounts of precipitation in 2009. However, actively managing with early draw-down consistently produced the greatest VFQI and plant diversity. Therefore, to achieve a diverse high quality community for waterfowl management should focus on active-early strategies. However, research should continue to investigate waterbird responses to site-specific and landscape level vegetative and wetland characteristics to guide restoration and management efforts on WRP and other wetland complexes, thus ensuring best management practices for WRP targeted wetland depended wildlife.

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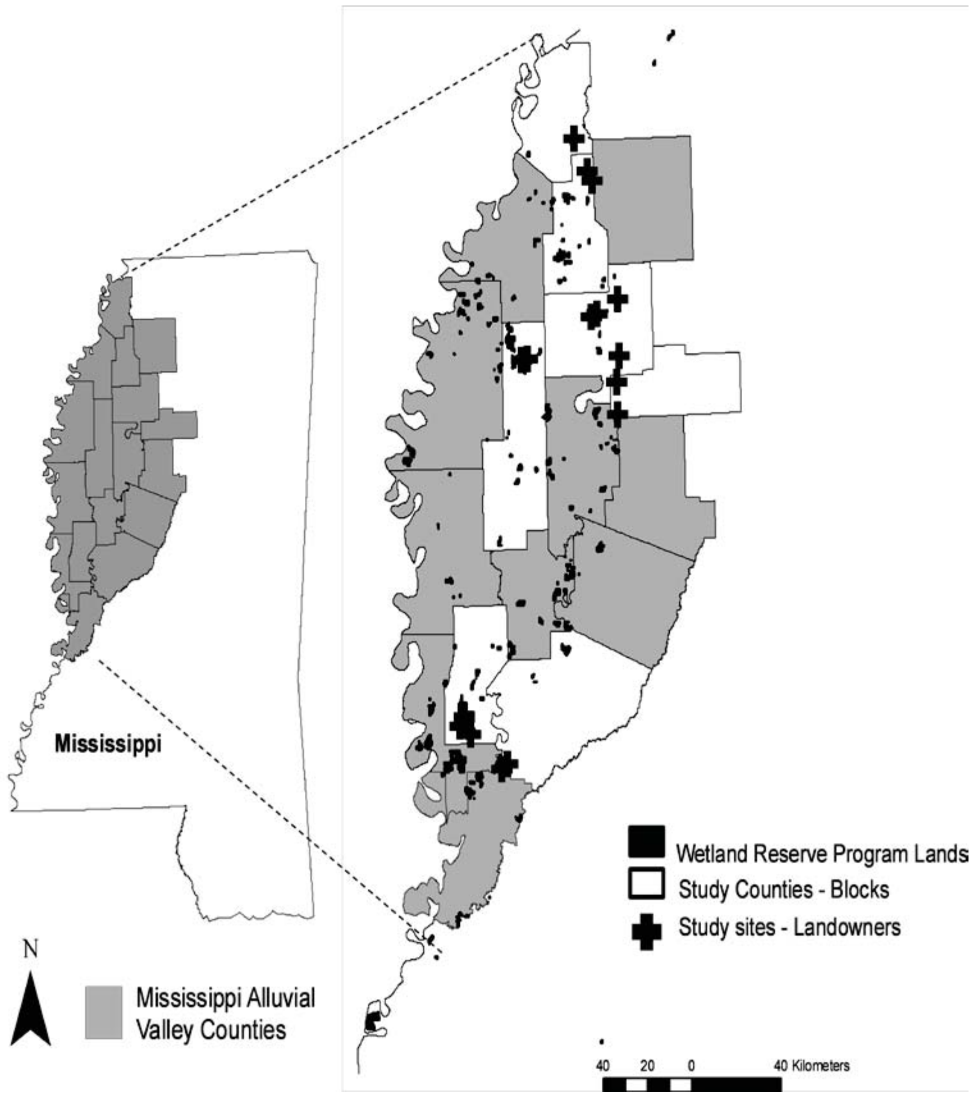

Figure 1.1. Locations of 6 county blocks (white squares) and 18 study sites (crosses) within Wetlands Reserve Program lands (black squares) where summer vegetative and winter waterfowl communities were evaluated in Mississippi, 2007-2009.

Table 1.1. Moist-soil plant species or genus observed during vegetation surveys on Mississippi Wetlands Reserve Program lands (*n* = 54 wetlands) and their mean ($\bar{x}$) waterfowl forage quality coefficient values (C), ranked by 14 waterfowl and wetland experts, 2008-2009 (Strader and Stinson 2005, Kross 2006, NRCS 2010).

Family/Scientific name	Common name	$\bar{x}$ C
Aceraceae		
Acer rubrum	Red maple	1.69
Alismataceae		
Echinodorus cordifolius	Burhead	1.78
Sagittaria spp.	Duckpotato	2.77
Amaranthaceae		
Alternanthera philoxeroides	Alligator weed	1.10
Amaranthus palmeri	Carelessweed	1.75
Amaranthus retroflexus	Pigweed	2.15
Apiaceae		
Cynosciadium digitatum	Finged dog shade	1.00
Daucus carota	Queen Ann's Lace	1.00
Eryngium prostratum	Creeping eryngo	1.29
Apocynaceae		
Apocynum cannabinum	Indianhemp	1.00
Aquifoliaceae		
Ilex decidua	Holly	1.00
Araceae		
Lemna spp.	Duckweed	1.77
Asclepiadaceae		
Asclepias spp.	Milkweed	1.00
Ambrosia artemisiifolia	Ragweed	1.77
Ambrosia trifida	Great ragweed	1.50
Aster spp.	Aster	1.08
Baccharis halimifolia	Eastern baccharis	1.00
Bidens cernua	Nodding beggartick	2.38
Boltonia spp.	Doll’s daisy	1.27
Conyza Canadensis	Horseweed	1.10
Coreopsis spp.	Tickseed	1.33
Eclipta prostrata	False daisy	1.00
Eupatorium capillifolium	Dogfennel	1.00
Eupatorium serotinum	Boneset	1.08
Gamochaeta purpurea	Purple everlast	1.00
Heliopsis helianthoides	Sweet oxeye	1.50
Iva annua	Marsh elder	1.00
Liatris spp.	Blazingstar	1.18
Mikania scandens	Hemp vine	1.18
Pluchea indica	Indian Camphorweed	1.00
Solidago gigantea	Giant golden rod	1.00

Table 1.1 (continued)

Family/Scientific name	Common name	$\bar{x}$ C
Xanthium spp.	Cocklebur	1.08
Boraginaceae		
Heliotropium spp.	Helioptrope	1.25
Cabombaceae		
Brasenia schreberi	Watershield	2.09
Callitrichaceae		
Callitriche heterophylla	Water-starwort	1.33
Caprifoliaceae		
Lonicera japonica	Honeysuckle	1.17
Ceratophyllaceae		
Ceratophyllum demersum	Coon's tail	2.07
Codiaeum		
Croton spp.	Croton	1.82
Convolvulaceae		
Ipomoea spp.	Morning glory	1.15
Cupressaceae		
Taxodium distichum	Bald cypress	1.08
Cyperaceae		
Carex spp.	Sedge	2.33
Cyperus esculentus	Yellow nutsedge	2.79
Cyperus spp.	Flat sedge	2.54
Cyperus spp.	Sedges	2.50
Eleocharis spp.	Spike rush	2.21
Rhynchospora spp.	Beak Rush	1.92
Scirpus cyperinus	Wool grass	1.46
Scirpus spp.	Bulrush	2.08
Ebenaceae		
Diospyros virginiana	Common Persimmon	1.18
Euphorbiaceae		
Chamaesyce humistrata	Spreading sandmat	1.00
Fabaceae		
Chamaecrista fasciculata	Partridge pea	1.60
Desmanthus illinoensis	Bundleflower	1.25
Lathyrus hirsutus	Caley pea	1.00
Lespedeza spp.	Lespedeza	1.50
Melilotus alba	White sweet clover	1.11
Robinia pseudoacacia	Black locust	1.08
Senna obtusifolia	Sicklepod	1.09
Sesbania macrocarpa	Coffeeweed	1.31
Quercus phellos	Willow oak	2.69
Quercus texana	Nuttall oak	2.55
Haloragaceae		
Myriophyllum aquaticum	Parrot feather	1.70
Myriophyllum spp.	Watermilfoil	2.00

Table 1.1 (continued)

Family/Scientific name	Common name	$\bar{x}$ C
Hydrocharitaceae		
Vallisneria spp.	Eelgrass	2.85
Hydrolea ovata	False fiddleleaf	1.00
Juncaceae		
Juncus spp.	Rush	1.92
Liliaceae		
Allium canadense	Meadow garlic	1.27
Lythraceae		
Ammannia coccinea	Toothcup	2.00
Lythrum alatum	Lythrum	1.27
Lythrum lanceolatum	Loosestrife	1.09
Malvaceae		
Hibiscus spp.	Rosemallow	1.08
Malvaceae		
Sida spinosa	Prickly sida	1.27
Nelumbonaceae		
Nelumbo lutea	American lotus	1.38
Oleaceae		
Forestiera acuminata	Swampprivet	1.25
Fraxinus spp.	Ash	1.62
Onagraceae		
Ludwigia spp.	Primrose/seedbox	1.54
Oenothera biennis	Evening primrose	1.17
Passifloraceae		
Passiflora incarnata	Purple passionflower	1.00
Phytolaccaceae		
Phytolacca americana	American pokeweed	1.00
Platanaceae		
Platanus occidentalis	American sycamore	1.08
Poaceae		
Agrostis spp.	Bent grass	1.20
Andropogon spp.	Bluestem	1.15
Arrhenatherum spp.	Oatgrass	1.00
Cynodon dactylon	Bermudagrass	1.23
Dichanthelium ensifolium	Cypress panic grass	1.88
Digitaria spp.	Crabgrass	2.00
Echinochloa spp.	Barnyard grass	3.00
Eragrostis spp.	Lovegrass	2.14
Erianthus giganteus	Plumegrass	1.20
Leersia oryzoides	Rice cutgrass	2.54
Leptochloa filiformis	Sprangletop	2.69
Lolium spp.	Ryegrass	1.69
Panicum spp.	Panicum	2.54
Panicum virgatum	Switchgrass	2.08
Paspalum spp.	Bull grass	2.46

Table 1.1 (continued)

Family/Scientific name	Common name	$\bar{x}$ C
Phalaris arundinacea	Reed canarygrass	1.23
Setaria spp.	Foxtail	2.46
Sorghum bicolor	Milo	2.92
Sorghum vulgare	Sudan grass	1.69
Sorgum halepense	Johnson grass	1.58
Tridens strictus	Grease grass	1.56
Urochloa platyphylla	Signalgrass	1.29
Zea spp.	Corn	2.85
Polygonaceae		
Brunnichia cirrhosa	Redvine	1.25
Polygonum pensylvanicum	Knotweed	2.43
Polygonum spp.	Annual smartweed	2.42
Polygonum spp.	Perennial smartweed	2.00
Rumex crispus	Curly dock	2.15
Pontederiaceae		
Heteranthera limosa	Mudplantain	1.85
Pontederia cordata	Pickerelweed	1.64
Potamogetonaceae		
Potamogeton crispus	Curly pondweed	2.21
Potamogeton diversifolius	Waterthread	2.36
Potamogeton spp.	Pondweed	2.62
Ranunculaceae		
Ranunculus spp.	Buttercup	1.27
Rosaceae		
Prunus spp.	Plum	1.18
Rosa palustris	Swamp rose	1.18
Rubus spp.	Blackberry	1.09
Rubiaceae		
Cephalanthus occidentalis	Common buttonbush	1.54
Diodia virginiana	Buttonweed	1.60
Salicaceae		
Populus spp.	Cottonwood	1.08
Salix spp.	Willow	1.00
Sapindaceae		
Cardiospermum halicacabum	Balloon vine	1.25
Scrophulariaceae		
Bacopa rotundifolia	Waterhyssop	1.60
Gratiola neglecta	Hedgehyssop	1.00
Lindernia dubia	False pimpernel	1.22
Solanaceae		
Atropa spp.	Belladonna	1.00
Physalis angulata	Ground cherry	1.00
Typhaceae		
Typha spp.	Cattail	1.08

Table 1.1 (continued)

Family/Scientific name	Common name	$\bar{x}$ C
Ulmaceae		
Celtis laevigata	Sugarberry	1.40
Ulmus rubra	Slippery elm	1.50
Ulmus americana	American elm	1.71
Verbenaceae		
Phyla lanceolata	Lanceleaf Fogfruit	1.50
Verbena spp.	Verbina	1.25
Vitaceae		
Ampelopsis arborea	Peppervine	1.00
Vitis palmata	Grape	1.08
Xyridaceae		
Xyris spp.	Yelloweyed grass	1.25

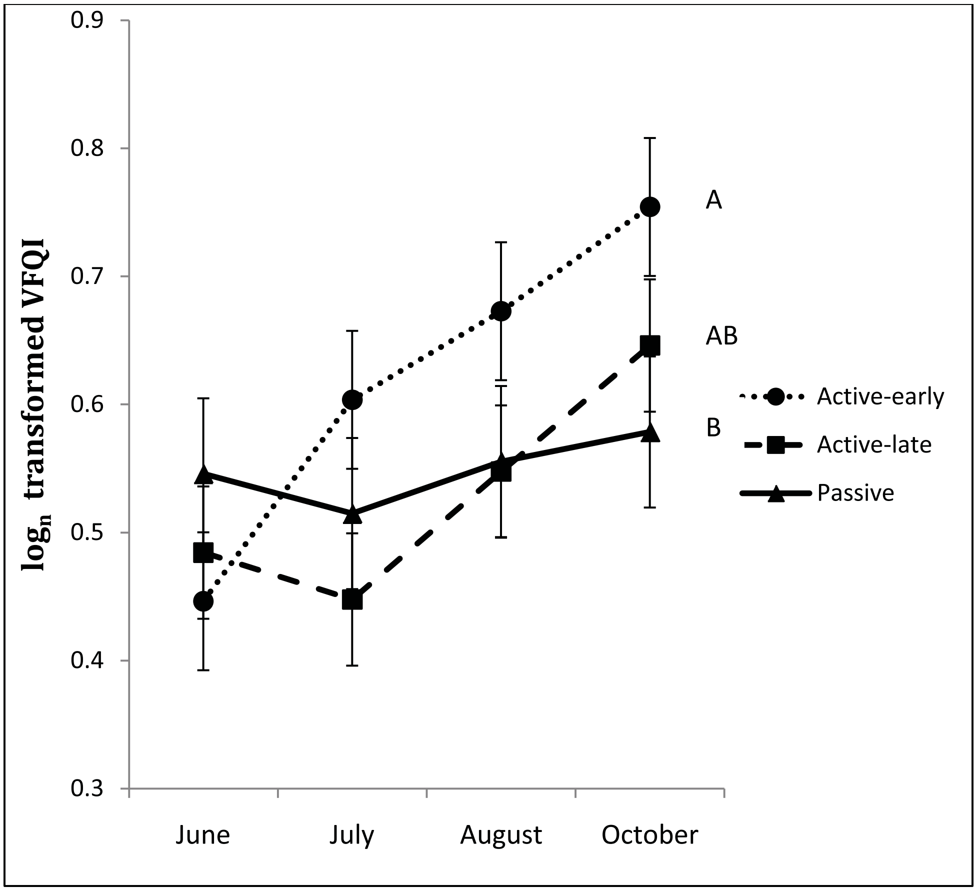

Figure 1.2. Least-squared means (± SE) of $\log_n$ transformed Vegetative Forage Quality Index (VFQI) values for 54 moist-soil wetlands on Wetlands Reserve Program lands in Mississippi, June-October 2008. Means followed by unlike letters in October 2008 differ ($P < 0.10$).

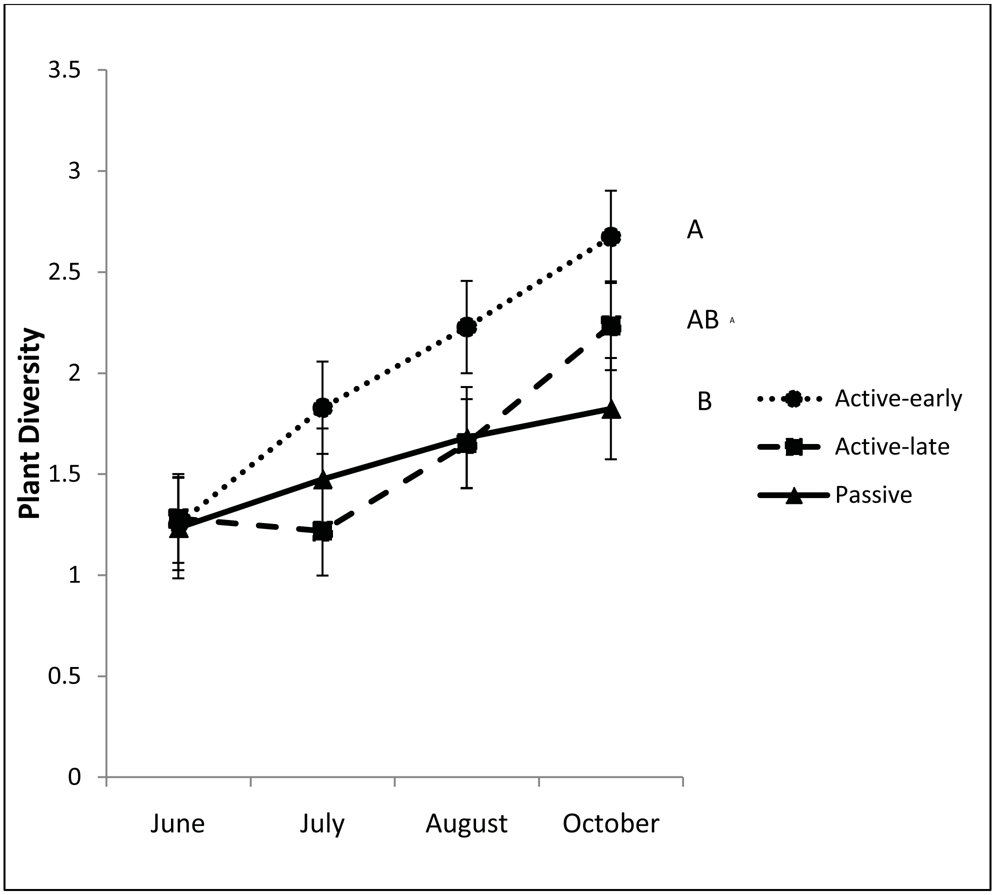

Figure 1.3. Least-squared means (± SE) for diversity values for 54 moist-soil wetland plant communities on Wetlands Reserve Program lands in Mississippi, June-October, 2008. Means followed by unlike letters in October 2008 differ ($P < 0.10$).

Table 1.2. October 2008 and 2009 plant community variables and summary statistics ($\bar{x}$ ± SE; range) among management types for 54 moist-soil wetlands on the Wetlands Reserve Program Lands, Mississippi.

Year/Variables	Management types		
	Active-early	Active-late	Passive
2008			
Vegetation Forage	1.16 ± 0.09	0.94 ± 0.07	0.78 ± 0.06
Quality Index (VFQI)	0.66-1.86	0.18-1.50	0.43-1.24
Diversity	2.67 ± 0.22	2.25 ± 0.19	1.78 ± 0.14
	0.66-4.57	0.02-3.49	0.85-2.70
Plant species/genus	18.61 ± 1.19	20.40 ± 1.38	17.40 ± 1.62
richness per wetland	8.00-29.00	2.00-31.00	6.00-27.00
$\bar{x}$ Plant growth-forms	1.70 ± 0.12	1.23 ± 0.12	1.32 ± 0.14
per sample points[a]	0.30-2.62	0.54-2.51	0.64-1.91
% grasses	50.0 ± 6.00	26.0 ±5.00	24.5 ±7.00
	10.00-100.00	0.00-78.00	0.00-92.00
% woody cover	2.00 ± 0.60	4.0 ± 1.0	5.0 ± 1.7
	0.00-8.00	18.00-85.00	0.00-18.50
n	18	21	15
2009			
Vegetation Forage	1.0 ± 0.07	0.63 ± 0.07	0.75 ± 0.09
Quality Index (VFQI)	0.40-1.64	0.12-1.34	0.28-1.38
Diversity	2.10 ± 0.14	1.58 ± 0.16	1.64 ± 0.22
	0.44-3.43	0.67-3.44	0.48-2.70
Plant species/genus	15.76 ± 1.12	14.23 ± 1.29	15.08 ± 1.63
richness per wetland	5.00-26.00	1.00-24.00	6.00-26.00
$\bar{x}$ Plant growth-forms	1.84 ± 0.13	1.62 ± 0.12	1.42 ±1.10
per sample points[b]	0.29-2.52	0.06-2.56	0.68-1.92
% grasses	43.9 ±8.0	37.9 ± 6.0	25.4 ± 6.10
	0.00-100.00	0.00-92.00	0.00-78.00
% woody cover	3.6 ± 1.7	5.0 ± 1.2	5.0 ±1.7
	0.00-25.50	0.00-22.00	0.00-18.50
n	21	21	12

[a]Plant growth-forms included grasses, sedges/rushes, aquatics, vines, woody vegetation, wildlife food crops, and broadleaves.

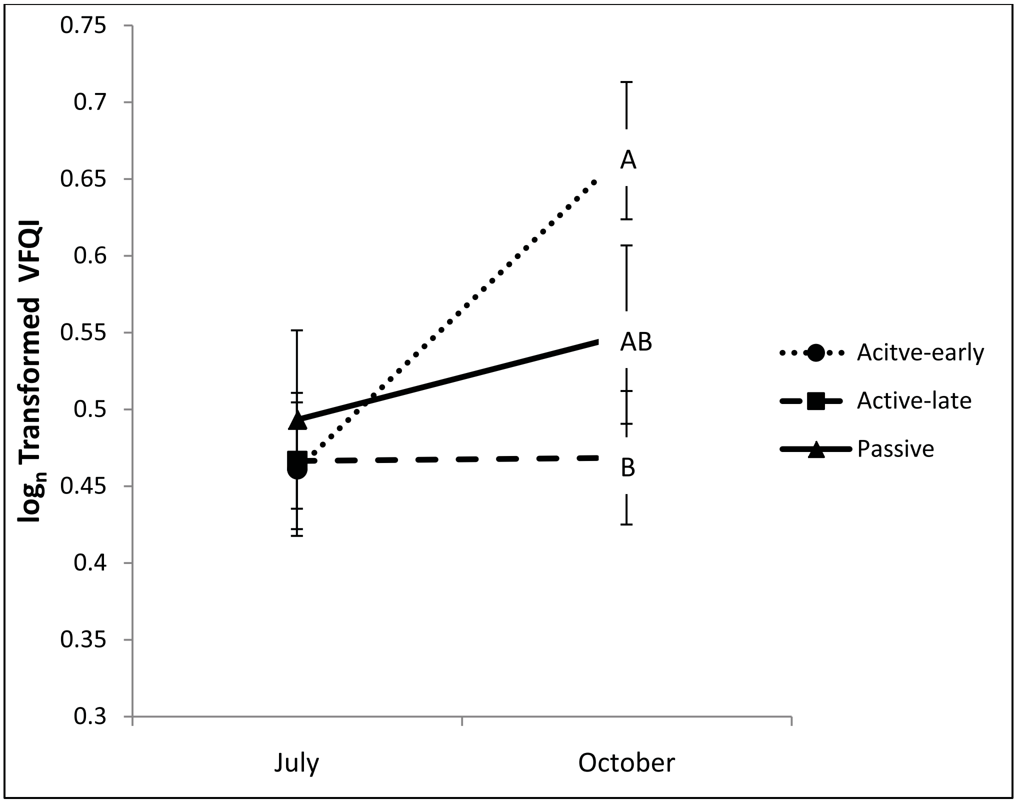

Figure 1.4. Least-squared means (± SE) of $\log_n$ transformed Vegetative Forage Quality Index (VFQI) values for 54 moist-soil wetlands on Wetlands Reserve Program lands in Mississippi, June-October 2009. Means followed by unlike letters in October 2009 differ ($P < 0.10$).

Table 1.3. Least-square means (± SE) of plant community variables among management types for 54 moist-soil wetlands on the Wetlands Reserve Program lands, Mississippi, 2008-2009. Means followed by unlike capital letters differ (*P* < 0.1).

	Management Type		
Variables	Active-early $\bar{x}$ ± SE	Active-late $\bar{x}$ ± SE	Passive $\bar{x}$ ± SE
Vegetation Forage Quality Index (VFQI)	2.04 ± 1.04A	1.74 ± 1.04B	1.74 ± 1.05B
Diversity	2.38 ± 0.18C	1.92 ± 0.18CD	1.68 ± 0.21D
Plant species/genus richness per wetland	17.09 ± 1.07	17.23 ± 1.04	16.23 ± 1.27
$\bar{x}$ Plant growth-forms per sample points[a]	1.77 ± 0.10E	1.44 ± 0.10F	1.35 ± 0.12F
% grasses	47.00 ± 6.80G	30.69 ± 6.75GH	26.09 ± 7.71H
% woody cover	3.10 ± 1.17	3.00 ± 1.15	2.84 ± 1.34

[a]Plant growth-forms included grasses, sedges/rushes, aquatics, vines, woody vegetation, wildlife food crops, and broadleaves.

CHAPTER II

SPECIES RICHNESS AND ABUNDANCE OF WINTERING DUCKS AND WATERBIRDS IN WETLANDS RESERVE PROGRAM LANDS IN MISSISSIPPI

The Mississippi Alluvial Valley (MAV) remains an internationally important region for migrating and wintering waterfowl (Reinecke et al. 1989). Annually, the MAV provides foraging and other habitats for millions of ducks and geese (Reinecke et al. 1989, Fredrickson et al. 2005). However, in the1930s, channelization, wetland drainage, construction of flood control levees, and urbanization altered significantly the natural hydrology in the MAV (Reinecke et al. 1988, King et al. 2006). Alteration of hydrological regimes in the MAV resulted in widespread conversion of emergent and forested wetlands to croplands (Rudis 1995). Loss and fragmentation of natural wintering habitat for waterfowl may have decreased carrying capacity of the MAV for waterfowl populations (Reinecke et al. 1988, Fredrickson et al. 2005, Pearse et al. 2008).

Since the 1980s, wetlands generally were protected through a variety of federal and state programs (Vottlet and Muir 1996 *in* Whigham 1999). Currently, an era of 'no-net-loss' exists, and numerous wetlands are being restored (Whigham 1999). Federal programs, such as the Wetlanda Reserve Program (WRP), provide funding to landowners to protect and restore wetlands. The WRP is administered through the Natural Resources

Conservation Service (NRCS) whereby landowners receive technical and financial assistance to protect, enhance, and restore previously farmed and other lands classified as wetlands (NRCS 2004, Haufler 2005). Increasingly, landowners in the MAV and elsewhere are taking active roles in conserving wetland habitat on their properties (Manley et al. 2004, Kaminski et al. 2006). Cooperative management of agricultural lands by federal, state, and non-governmental organizations (NGOs) and private landowners has improved wintering habitat for waterfowl and improved environmental quality (Twedt and Nelms 1999, Rewa 2005, King et al. 2006).

The North American Waterfowl Management Plan (NAWMP; 1986) serves as a framework for continental waterfowl habitat and population conservation (U.S. Fish and Wildlife Service 2004). The Lower Mississippi Valley Joint Venture (LMVJV) of NAWMP is a partnership among federal and state agencies, NGOs, and landowners who implement local and landscape-scale habitat conservation to benefit waterfowl and other wildlife in the MAV and North America. Three major waterfowl habitats were identified for conservation by the LMVJV: (1) moist-soil wetlands, (2) forested wetlands, and (3) flooded croplands (Reinecke et al. 1989, Loesch et al. 1995).

Seasonally flooded and managed moist-soil wetlands on WRP and other lands typically produce annual plant communities with abundant food and habitat for migrating and wintering waterbirds (Fredrickson and Taylor 1982, Reinecke et al. 1989, Smith et al. 1989, Nelms 2007). Wintering dabbling ducks and other waterfowl extensively use wetlands that produce high quality foods (Fredrickson and Taylor 1982). Therefore, NRCS biologists and other partners provide technical guidance to landowners enrolled in WRP and other conservation programs for maintenance of early succession moist-soil plant communities (NRCS 2007). Prescribed management of moist-soil wetlands can reduce undesirable and invasive plants which provide little nutritional value to waterfowl (Fredrickson and Taylor 1982, Strickland et al. 2009).

Management of moist-soil wetlands by landowners in the MAV can range from active management (i.e., strategies following NRCS recommendations including annual or regular soil disturbance, hydrological management, undesirable plant control) to passive (i.e., little or no management; K. D. Nelms, NRCS, personal communication). Improving and expanding moist-soil management may enhance overall habitat suitability of WRP lands for waterfowl and other wetland wildlife (King et al. 2006). Recent evidence indicates increased wildlife use of managed moist-soil wetlands compared to wetlands with minimal management (Twedt and Nelms 1999, Bowyer et al. 2005, Kaminski et al. 2006, Pankau 2008).

Assessing plant community attributes of moist-soil wetlands is warranted because vegetation that develops after management may be critical in determining habitat value for birds (Hemesath and Dinsmore 1993). Research indicates a primary factor influencing habitat use by birds may be related to availability and quality of foraging habitat (Fredrickson and Taylor 1982, Smith et al. 1989, Buler et al. 2007). Thus, I developed a Vegetative Forage Quality Assessment Index (VFQI) to evaluate the ability of moist-soil vegetation to provide waterfowl forage (i.e., seeds and tubers) based on energy values of seeds and tubers for waterfowl (e.g., Taft et al. 1997, Andreas et al. 2004, Chapter 1). Assessing species richness and relative abundance of wintering ducks in relation to moist-soil plant community metrics (e.g., VFQI) resulting from different management regimes is useful for evaluating habitat quality of management strategies (Taft et al. 2006).

My goal was to create a rapid assessment method of moist-soil plant communities to relate to responses of winter waterfowl. Therefore, my objectives were to quantify VFQIs of seasonal plant communities and model variation in species richness and abundance of wintering dabbling and diving ducks in relation to hydrological and other management, VFQI, and other wetland vegetative metrics. I also evaluated waterbird richness and abundance responses to aforementioned response variables for waterfowl. I selected easy to quantify floristic variables that could be measured during one visit (O'Neal et al. 2008). Variables were selected if they could be seasonally managed using common moist-soil practices (Strader and Stinson 2005, Nelms 2007), allowing for development of simple, best management guidelines for greatest potential winter duck response.

Study Area

My study sites were located on private lands enrolled in WRP in the MAV of Mississippi, distributed across Grenada, Sharkey, Sunflower, Tallahatchie, and Yazoo Counties, and the boarder of Tunica/Quitman Counties (Figure 2.1). Total acreage of all WRP properties ranged among 22.7-1,448.6 ha, and each WRP property had 3-22 moist-soil wetlands from 0.4-67.8 ha. Topography, wetland characteristics, and financial resources varied among land bases and owners and influenced the intensity of management. Fifty-one (94%) of 54 study wetlands had water control structures in levees, which enabled draining or retaining water on wetlands. Wetland flooding originated from several sources including rivers, ditches, pumps, runoff, and rain. No wetlands had any interconnected hydrology and the minimum distance between wetlands was ≥ 50m. Therefore, wetlands were considered discrete, independent survey and analytical units. Common vegetation occurring in wetlands primarily consisted of species adapted to seasonal flooding and drainage (moist-soil conditions), including grasses (e.g., *Echinochloa*, *Panicum*, and *Paspalum* spp.), forbs (*Polygonum* spp., *Bidens cernua*), vines (*Brunnichia cirrhosa, Ipomoea* spp.), sedges and rushes (*Cyperus* spp., *Juncus* spp.), trees and shrubs (*Quercus spp.*, *Salix nigra*, *Cephalanthus occidentalis*), aquatics (*Ludwigia* spp., *Potamogeton* spp.), and planted food plot crops.

Methods

Study Design

In consultation with NRCS personnel, landowners, and personal field reconnaissance in fall 2007, I classified management regime of study WRP lands as either active or passive (see details below), because I did not have explicit information on management in summer 2007. Following close site monitoring, I designated management in 2008 as: (1) active management with early draw-down (i.e., active-early) when draw-down was completed by 15 June, (2) active management with late draw-down (i.e., active-late; ≥ 3 weeks after active-early draw-down dates), and (3) passive management with natural draw-down by evaporation within wetlands with or without a water-control structures. I assigned active management to moist-soil wetlands when managers followed NRCS contract guidelines, which generally included a combination of monthly inspections, annual soil disturbance (e.g., disking), control of undesirable plants (i.e., plants with little to no known value as waterfowl forage) with the primary goal of improving habitat for waterfowl (Brasher et al. 2007, Kross et al. 2008). Passively managed wetlands were not managed for waterfowl and received infrequent soil disturbance (≥ 5 years), limited or no control of undesirable plants, and minimal to no hydrological management (Brasher et al. 2007, Kross et al. 2008).

I identified the 6 aforementioned counties as blocks. These were distributed north, south, and central in the MAV of Mississippi, and each contained three replicate sites of active-early, active-late, and passive management. I used Arcview (ArcGIS 9.2) to locate and select active-early management sites from the NRCS Mississippi WRP federal database. Six active-early WRP contracts were available; therefore, I selected them for my study. I based selections and geographical matching of active-early, active-late, and passive sites based on three criteria**:** **(**1) all replicate sites were located within the same county block (i.e., multiple adjoining WRP properties occurred in each block); (2) < 20 km existed among sites within a block, because I assumed this distance would reduce variability in environmental conditions among sites (e.g., weather, flood events; Jorde et al. 1983, Cox and Afton 1996, Legagneux et al. 2009); and (3) a minimum of three moist-soil units occurred with constructed levees within each site (Kross et al. 2008). I randomly selected active-late and passive sites to pair with 6 active-early sites. After randomly selecting sites, I visited landowners to confirm preliminary classifications. If sites did not meet predetermined criteria, I randomly selected replacements within the distance criterion.

My final study design in winter 2008-2009 had unbalanced replication because one landowner changed management from passive to active-late. Therefore, five blocks contained all three management categories, and one block had passive replaced with active-late (Grenada County). I surveyed 54 WRP wetlands (i.e., sampling units; 6 blocks x 3 treatments per block x 3 replicate moist-soil wetlands per management category).

Winter Bird Surveys

I initiated winter duck surveys one week prior to opening day of the Mississippi waterfowl hunting seasons in late November 2007 and 2008 and continued counts twice monthly through mid-March 2008 and 2009. Survey periods corresponded to arrival and departure of wintering waterfowl and flooding of WRP moist-soil wetlands. I surveyed all sites in morning and afternoon (i.e., sunrise – 1000 hrs and 1400 hrs – sunset) to estimate diurnal use by waterfowl, but surveys were neither conducted at night nor in adverse weather (rain, fog, or high winds; O'Neal et al. 2008). I rotated routes among northern, southern, and central WRP locations so wetlands were not surveyed at the same relative times within morning and afternoons. With aid of binoculars, I counted birds (waterfowl and waterbirds) from vantage points and subsequently flushed birds to increase detection of birds (Twedt and Nelms 1999, Heitmeyer 2006, Kaminski et al. 2006). After counts were made from vantage points, I drove an all-terrain vehicle along levees, and an assistant and I counted flushing birds. Finally, I walked into wetlands to flush birds when vegetation obstructed our views. Birds flushed while walking accounted for < 1% of all total birds observed. Thus, I assumed detection was nearly

100%. To avoid counting birds multiple times, we visually followed flushed birds and noted their location if they alighted on areas yet to be surveyed (Kaminski and Prince 1984). During each survey, I also visually estimated and recorded on field maps the percentage of surface water in each wetland. Then, I used ArcGIS to calculate flooded area (ha) of each wetland.

Model Development

I developed an *a priori* candidate set of biologically based models hypothesized to explain variation in species richness and abundance of dabbling and diving ducks among wetland management categories and floristic and hydrological characteristics evaluated during May-October 2007-2008 prior to winter waterfowl surveys. For waterfowl survey data from winter 2008-2009, I used plant community metrics from October 2008 (Chapter 1), because these data were maximal in plant maturity, presumably seed abundance, and species richness (Chapter 1, Brasher et al. 2007). I evaluated the following variables (Table 2.1).

1) Management type (MTYPE).

Moist -soil management has been used extensively to restore and improve wetlands, and several studies indicate moist-soil management practices can enhance quality of wetlands for waterfowl (Fredrickson and Taylor 1982, Smith et al. 1989, Kaminski et al. 2006). Management intensity can directly influence plant community and wildlife responses (Fredrickson 1991, Kaminski et al. 2006, Nelms 2007). Active and passively managed sites can provide food sources for waterfowl, and birds will often concentrate on areas with such resources (Nelms and Twedt 1999, Brasher et al. 2007).

Managing annual hydrology also is critical to moist-soil plant communities, as draw-down date and flood duration affect vegetative diversity and seed production (Fredrickson 1991, Nelms 2007). As already described, I classified wetland management as: (1) active management with early draw-down, (2) active management with late draw-down, and (3) passive management with natural draw-down.

2) Vegetative Forage Quality Index (VFQI).

A VFQI can be used to assess ecological value of natural plant communities, monitor restoration success, and evaluate potential wildlife habitat quality of sites (Matthews et al. 2005, Bourdaghs et al. 2006, Chapter 1). A VFQI also can be used to evaluate moist-soil plants to provide quality forage, (e.g., seeds, tubers) based on ratings by a panel of wetlands and waterfowl experts (Chapter 1; Andreas et al. 2004, Taft et al. 2006). Therefore, I calculated VFQIs from waterfowl forage quality coefficients (C), weighted by multiplying C times the proportional occurrence (PO) of each plant species (or genus) and divided by number of species or genera (N; Chapter 1).

3) Plant species/genera richness (RICH).

Wetland management for wintering waterfowl and other wetland birds is often focused on food resources because positive relationships have been observed between food availability and bird use (Fredrickson and Taylor 1982, Champlin et al. 2009). Management of moist-soil wetlands promotes a diversity of nutrients by maintaining a complex of early succession plant species (Reinecke and Hartke 2005, Taylor and Smith 2005). Therefore, plant communities with the greatest plant species richness may provide waterfowl with a diversity of nutrients.

4) Flooded wetland area (WET).

Wetland area is a correlate of species richness, abundance, and distribution of wetland birds (Brown and Dinsmore 1986, Elmberg et al. 1994, Weller and Weller 2000, Kaminski et al. 2006, Pearse 2007). Wetland area may have a greater positive relationship on abundance of diving ducks compared to dabbling ducks (Savard et al. 1994). Therefore, to test for potential effects of waterbird and duck species richness based on variations in wetland size, I included wetland area as a covariate (Savard et al. 1994, Kaminski et al. 2006, O'Neal et al. 2008). I predicted bird abundance may vary with wetland size. Because mean wetland area was not equal within and across management types, I included wetland area as a main effect for each candidate model of waterbird, dabbling and diving duck abundance (Kaminski et al. 2006).

5) Vegetative composition (COMP).

Vegetative composition can influence distributions of waterfowl and other wildlife (Fredrickson and Reid 1986, Smith et al. 2004, Pearse 2007, Washburn and Seamans 2007). Diversity in habitat composition may influence quality of foraging habitats and escape cover (Weller and Fredrickson 1974, Smith et al. 2004). Similarly, diurnal and nocturnal use of wetlands may be linked to vegetative composition (Anderson and Smith 1999). Therefore, I calculated vegetative composition as mean number of plant growth-forms (i.e., grasses, sedges/rushes, aquatics, vines, woody vegetation, wildlife food crops, and broadleaves) per sampling point in each wetland (Johnson and Montalbano 1984, Kross et al. 2008; Chapter 1).

6) Percentage grass (% GRASS).

A goal of moist-soil management is maximizing availability of food energy for migratory and wintering birds (Fredrickson and Taylor 1982, Anderson and Smith 1999, Kaminski et al. 2003, King et al. 2006). Because seeds and tubers of grasses and sedges are high in metabolizable energy (Kaminski et al. 2003), I calculated percentage of grass species (i.e., Poaceae family) present in each wetland.

7) Percentage woody vegetation (% WOODY).

Mallards may use wetland complexes less with increased shrubs and trees (Riffell et al. 2001). Further, management recommendations for moist-soil wetlands usually discourage woody vegetation (Strader and Stinson 2005, Nelms 2007, Kross et al. 2008). Conversely, woody vegetation may increase wetland structural diversity and provide roost sites or cover for birds, such as cavity nesting species (Baldassarre and Bolen 2006). Thus, I calculated percentage woody vegetation to evaluate if waterbird and duck species richness and abundance varied with tree and shrub cover.

Statistical Analyses

I analyzed data from each year separately because I began field work in fall 2007 and was not able to determine previous hydrological management or quantify plant communities prior to flooding of sites in fall 2007. Therefore, I classified sites for winter 2007-2008 merely as either actively or passively managed, based on information from NRCS personnel and landowners. Because waterbird and waterfowl abundance may not increase linearly with wetland area (Pearse 2007), I evaluated potential linear and quadratic relationships between waterbird and duck species richness and abundance with wetland area in winters 2007-2009 (i.e., WET and WET^2), based on Akaike's Second Order Information Criteria (AIC_c; Anderson and Burnham 2002). I used linear models to evaluate if waterbird, dabbling and diving duck species richness and abundances, adjusted for WET within surveyed WRP sites, varied with MTYPE and vegetative structural and compositional metrics (VFQI, RICH, COMP, %GRASS, %WOODY) in winter 2008-2009. I used simple correlation analysis (SAS 9.2.2, Zar 1974) to determine if covariates were related and thus eliminated some to avoid possible operational and interpretive problems (Fairbairn and Dinsmore 2001, Riffell et al. 2001, SAS Institute 2009). If I detected a significant correlation ($P \leq 0.10$), I included only one variable of interrelated pairs of variables for analysis (Kaminski and Prince 1984). The VFQI was correlated positively ($P < 0.10$) with all variables except %WOODY and WET. Therefore, I included these and MTYPE in analysis.

I evaluated 3 candidate models for waterbird and duck species richness for winter 2007-2008: 1) MTYPE, 2) WET, and 3) MTYPE + WET. I only evaluated one model for waterbird, dabbling and diving duck abundance for winter 2007-2008 (i.e., MTYPE), because WET was included as a covariate of abundances to adjust for area of each surveyed wetland. For winter 2008-2009, I evaluated 11 candidate models for waterbird and duck species richness: 1) MTYPE, 2) VFQI, 3) WET, 4) COMP, 5) % WOODY, 6) % GRASS, 7) RICH, 8) VFQI*MTYPE, 9) VFQI*MTYPE + WET, 10) VFQI*MTYPE + %WOODY, and 11) VFQI*MTYPE + WET + % WOODY, and 8 models for waterbird, dabbling and diving duck abundances: 1) MTYPE, 2) VFQI, 3) COMP, 4) % WOODY, 5) % GRASS, 6) RICH, 7) VFQI*MYTPE, and 8) VFQI*MTYPE + %WOODY.

I used PROC MIXED (SAS 9.2.2) which is applicable for unbalanced replication in a block design with repeated measures for waterfowl and other birds during winter surveys (Littell et al. 2007, SAS Institute 2009). I designated predictive management and vegetative variables as fixed effects, included blocks and landowners nested within blocks as random effects, and survey periods as repeated measures. I specified compound symmetry (cs) covariate structure, based on AIC_c selection, because variances were homogenous over time. I designated $\alpha = 0.10$ *a priori* which has been used for management and observational studies without large sample sizes (i.e., $n < 26$; Tacha et al. 1982, Riffell et al. 2001, Kross et al. 2008). I examined model residuals plotted against predictor variables for clustering and uniform distribution to evaluate goodness of fit. I also examined residuals for potential outliers and evidence of unequal variances. Visual inspections of residuals for VFQI, WET, RICH, COMP, %GRASS, and %WOODY suggested equal variances. However, variances for waterbird and duck species richness and abundance were heterogeneous (SAS 9.2.2; Littell et al. 2007). Therefore, before analysis, I applied a natural log to waterbird and duck species richness and abundances data (Zar 1974:184-185).

I evaluated all models using AIC_c statistics, where competing covariance structures were ranked according to Δ AIC_c values and selection was based on least Δ AIC_c value and biological relevancy (Burnham and Anderson 1998, Littell et al. 2007, O'Neal et al. 2008). I considered models competitive when Δ AIC_c values were ≤ 2 units of the best model with Δ $AIC_c = 0$ (Burnham and Anderson 1998, O'Neal et al. 2008). I calculated Akaike weights (*wi*) to assess relative importance of each model in explaining variation in the waterbird and duck species richness or abundance and also included a null model (intercept only) in all analyses. When evaluating models with multiple variables, often interactions of effects exist (Underwood 1997 *in* Gutzwiller and Riffell 2007). If the top model contained an interaction effect, I interpreted results by producing slopes and intercepts of the relationship between the dependent and interacting explanatory variables (Gutzwiller and Riffell 2007, SAS Institute 2009). I used predicted values (± standard errors [SE]) from top models to calculate statistics presented in tables and figures. I also used predicted values to convert relative waterbird and duck abundance to density by dividing abundance estimates by estimated wetland area for each survey (birds/flooded ha/survey ± SE). I provide means (± SE) for geese, but not statistical analyses because they occurred infrequently (see results).

Results

Waterfowl and Other Avian Species

I completed 10 surveys of 54 wetlands and counted 36,874 ducks of 15 species between December – March 2007-2009. Mean duck species richness per wetland and survey was similar between years and ranged from 0 to 7 in winter 2007-2008 ($\bar{x}$ = 1.53 ± 0.13 [SE] species) and 0 to 9 ($\bar{x}$ = 1.50 ± 0.11 species) in winter 2008-2009. Dabbling ducks accounted for 60.0% of all ducks observed during both winters. I detected 15 duck species on actively managed wetlands in winter 2007-2008 and active-late sites in winter 2008-2009 (Table 2.2). In winter 2007-2008, I observed 9 duck species on passively managed sites. I observed 12 duck species on active-early sites in winter 2008-2009, and

15 duck species on active-late and 12 species on passively manage sites in winter 2008-2009 (Table 2.2). Mallards (*Anas platyrhynchos*) comprised 37.0% of all observed ducks during winter 2007-2008; ring-necked ducks (*Aythya collaris*) were most abundant (29.0%) in winter 2008-2009. Mallards and ring-necked ducks were the most abundant dabbling and diving ducks in both years (i.e., 31.1 and 88.7%; respectively). Other common (≥ 10%) ducks observed in both years included gadwall (*A. strepera*), American green winged-teal (*A. crecca carolensis*), and northern shoveler (*A. clypeata*; Table 2.2).

I also observed 7,238 waterbirds of 13 obligate wetland species and 11,095 geese (*Branta canadensis, Anser albifrons, Chen caerulescens)* in winters 2007-2009 (Table 2.3). Geese were observed infrequently across surveys, for example, in 2007-2008 geese were observed on 4 of 18 landowner properties, and 5 of 18 landowner properties, 2008-2009 (Table 2.3). American coot (*Fulica americana*) was the most abundant waterbird observed in both winters (32.3%). I observed 12 waterbird species on actively managed and 7 species on passively managed sites in winter 2007-2008. I observed increased numbers of species on active-late sites (10) than active-early (4) and passive sites (7) in winter 2008-2009 (Table 2.4).

Waterbird and Duck Species Richness and Abundance

Evaluation of linear and quadratic effects of wetland area on waterbird and duck species richness and abundance for winters 2007-2009 indicated support for a linear relationship ($w_i \geq 0.99$; Table 2.5). Therefore, I used WET as a covariate of waterbird and dabbling and diving duck species richness and abundances in subsequent analyses.

A model, including WET, best explained variation in duck species richness in wetlands during winter 2007-2008 (w_i = 0.84, R^2 = 0.66; Table 2.6). However, a model with MTYPE best explained variation in waterbird species richness (w_i = 0.48; Table 2.6); mean number of watebird species was 32.7% greater on actively than passively managed wetlands in winter 2007-2008 ($\bar{x}$ = 6.05 ± 1.28, $\bar{x}$ = 4.56 ± 1.30; respectively). Nonetheless, the model with only WET was < 2 Δ AIC_c units from the top model and captured 33.0 % of all model weight and explained 41.0% of the variation in waterbird species richness in winter 2007-2008 (Table 2.6).

In winter 2008-2009, weight of evidence for waterbird and duck species richness was greatest for decreased %WOODY (w_i = 0.41 and w_i = 0.43, respectively). However, decreased %WOODY was < 2 Δ AIC_c units from the NULL model for both waterbirds and duck species richness, and the model with decreased %WOODY explained little variation (R^2 < 0.04; Table 2.6).

I evaluated 8 candidate models to explain variation in abundance of waterbirds and dabbling and diving ducks in winter 2008-2009. Top models for each of these avian groups included VFQI*MTYPE and decreased %WOODY (w_i = 0.79, w_i = 0.90, w_i = 0.90, respectively; Table 2.7), indicating bird responses to VFQI differed among management types. Further, percentage woody vegetation improved model fit and revealed an inverse relation between avian abundances and woody vegetation (Table 2.7). No other covariates (%GRASS, COMP, RICH) provided any weight of evidence in explaining variation in bird abundance in winter 2008-2009.

I further evaluated interaction of VFQI by management type on waterbird and dabbling and diving duck densities, because bird abundances varied with wetland area they were transformed to densities. Model predicted waterbird and dabbling and diving duck densities varied positively with VFQI for active-late draw-downs ($R^2 = 0.05$, $R^2 = 0.27$ and $R^2 = 0.10$, respectively; Figures 2.2-2.4). Based on the top model predicted values for active-late sites, waterbirds and dabbling and diving ducks reached greatest potential densities at maximum VFQI values ($\bar{x} = 2.84 \pm 2.99$, $\bar{x} = 15.80 \pm 3.77$, $\bar{x} = 3.77 \pm 3.19$ birds/ha, respectively; Figures. 2.2-2.4). Model predicted densities for waterbirds were less on passive managed sites at maximum VFQI ($\bar{x} = 0.71 \pm 0.35$, $R^2 = 0.05$). However, variation in dabbling and diving duck densities were not related to VFQI on active-early ($R^2 < 0.01$) or passive sites ($R^2 < 0.06$; Figures 2.2, 2.3). Similarly, variation in waterbird density was not related to VFQI on active-early sites ($R^2 < 0.01$; Figure 2.4). Therefore, I used top model predicted waterbird and duck densities to calculate mean density for the latter management types. Mean waterbird densities on active-early were 1.49 ± 1.65, and mean dabbling duck density was 49% greater on passive ($\bar{x} = 6.72 \pm 1.44$ ducks/ha) than active-early ($\bar{x} = 4.51 \pm 2.05$ ducks/ha) managed sites. Diving duck density was 36.2% greater on active-early sites ($\bar{x} = 1.24 \pm 1.69$ diving ducks/ha) than passive sites ($\bar{x} = 0.91 \pm 1.20$ ducks/ha).

Discussion

I evaluated winter waterfowl and other waterbird responses to different hydrological and management regimes (i.e., moist-soil management) resulting in different seasonal plant communities (Chapter 1). I evaluated models comprised of vegetative parameters that can be manipulated through standard moist-soil management techniques. My results suggested effect of management, which is often evaluated alone or sometimes with other variables (Brown and Smith 1998, Twedt and Nelms 1999, Kaminski et al. 2006), did not best explain variation in duck and waterbird use of WRP wetlands. By including floristic characteristics (i.e., VFQI, %WOODY) in models, I explained additional variation in duck and waterbird use of WRP wetlands.

Increased duck species richness in wetlands has been associated with active hydrology and substrate management (O'Neal et al. 2008), and increased dabbling duck numbers has been associated positively with wetland area at local scales (0.25 km radius; Pearse 2007). Waterbird species richness in winter 2007-2008 was supported by MTYPE wherein greater species richness was associated with active management. Additionally, waterbird and duck species richness varied positively with wetland area ($R^2 = 0.41$; $R^2 = 0.66$), which is consistent with previous studies relating avian diversity to land or habitat area (e.g., MacArthur and Wilson 1967, Kaminski et al. 2006, Pearse 2007). Results indicate that a more diverse bird community may be observed when managers ensure wetland basins are full during winter (i..e, maximizing wetland area).

Models including wetland area (WET) explained substantial variation in waterbird ($w_i = 0.33$) and duck ($w_i = 0.84$) species richness in winter 2007-2008 (Table 2.6). However, WET did not explain variation in waterbird and duck species richness in winter 2008-2009. I cannot explain inter-year difference but speculate some landowners had and used hyrological infrastructures for wetland flooding, whereas others relied predominantly on precipitation and runoff for flooding wetlands. Research indicates that variation in water levels can influence habitat availability for waterbirds (Powell 1987). The National Climatic Data Center (NCDC; 2009) reported total precipitation for December 2007 – March 2008 ($\bar{x}$ = 90.2 cm) was below the 100-year average. However, average precipitation ranking for December 2008 – March 2009 approximated the long them average ($\bar{x}$ =100.80 cm; NCDC

2009). Below average precipitation in winter 2007-2008 may have reduced available wetland habitat, concentrating ducks and other waterbirds on wetlands. Therefore, inconsistency between 2007-2008 and 2008-2009 bird species richness models may result from niche separation mediated by annual precipitation. My 2007-2008 results for waterbirds and duck species richness supports other conclusions that wetland area can be a strong determinant of richness of wetland obligate birds (Brown and Dinsmore 1986, Elmberg et al. 1994, Savard et al. 1994, Weller and Weller 2000). In 2008-2009 wetland habitats were likely less of a limiting factor, potentially allowing waterbird and duck species to segregate and specialize among wetlands (Powell 1987, Custer and Galli 2002, Green 1998). Custer and Galli (2002) reported that great blue herons (*Ardea herodias*) and great egrets (*Casmerodius albus*) partitioned feeding habitat based on wetland size. Therefore, waterbird and duck species richness may be correlated positively to wetland size, especially when wetland habitat is limited (e.g., drought conditions; Savard et al. 1994, Grover and Baldassarre 1995, Kaminski et al. 2006, Pankau 2008).

Substantial variation in duck and waterbird densities remained unexplained by models among management types ($R^2 \leq 0.31$; Figures 2.2 and 2.3). Duck and waterbird densities were similar on active and passive wetlands (Figures 2.2, 2.3 and 2.4). Further, passively managed sites were used by waterbirds and ducks in winters 2007-2009 suggesting both wetland types provided habitat for these birds (Twedt and Nelms 1999, O'Neal et al. 2008, Pankau 2008).

Typical moist-soil management involves manipulation of water-levels, soils, and vegetation to stimulate germination of natural seed banks of early succession plants that produce large quantities of seeds that are high quality forage based on TME values

(Fredrickson and Taylor 1982, Cronk and Fennessy 2001, Kaminski et al. 2003, Reinecke and Hartke 2005). Further, several authors have reported temporal management of hydrology is critical for varied vegetative responses, and growing-season draw-downs can produce more food than permanently flooded wetlands (Meeks 1969, Fredrickson and Taylor 1982, O'Neal et al. 2008, Strickland et al. 2009). Although I detected a relationship between waterbird and duck density and VFQI on active-late sites, regression analysis from the top model indicated VFQI for active-late explained only 5-27% of variation in waterbird, dabbling and diving duck densities. Likely, the October determined VFQI did not adequately approximate winter forage quality and other unmeasured metrics influenced bird use (Brasher 2010).

Estimates of VFQI were less on passive sites than active-early and active-late sites (Chapter 1). However, birds were observed on passive wetlands during all survey periods and dabbling duck densities were least at active-early sites. Active management with early draw-down supported the greatest plant diversity and VFQI within and across my survey years (Chapter 1). However, analyses of bird response to moist-soil management types do not support current moist-soil management guidelines and appear contrary to results in chapter one (i.e., recommendation of active management with early draw-down). A contradiction exists among recommended moist-soil management guidelines (i.e., active-early; Chapter 1) and bird response to management types (Chapter 2). Therefore, I offer hypotheses for paradoxical results. Preliminary analysis of 2008 moist-soil seed mass (g) from surveyed WRP wetlands, indicated there was no difference between actively and passively managed wetlands, ($\bar{x}$ = 0.44 ± 0.03 g , $\bar{x}$ = 0.51 ± 0.06 g, respectively; L. Webb, Arkansas Tech University, unpublished data). Other studies have reported active management of moist-soil areas produced greater seed densities than passively managed sites (Kross et al. 2008), but Brasher (2010) reported energetic carrying capacity did not vary among active and passively managed wetlands. Active-early sites remove water by June, allowing for a longer growing season for moist-soil plant and food crops. However, prolonged growing season and seed exposure may increase seed decomposition, germination, and wildlife granivory, thus depleting high-carbohydrate waterfowl foods prior to fall flooding (Gray et al. 2009). In contrast, seeds produced on active-late and passive sites are exposed to such conditions for a relatively short period of time prior to fall flooding. Investigations into effects of growing season management type and hydrology on fall seed availability are needed to determine seed fate.

Moist-soil draw-down methods are used to increase seed production, but response of invertebrates to moist-soil management is not well studied (Anderson and Smith 2000). Hydroperiods influence invertebrate abundance, diversity, and community structure in wetlands (Anderson and Smith 2000, Mitsch and Gosslink 2007). Therefore, I predict invertebrates, which are a primary food source for wintering waterfowl, would be more abundant in moist-soil habitats with prolonged flooding (i.e., active-late and passive sites; Baldassarre and Bolen 2006). Longer hydroperiods may provide greater opportunity for invertebrate colonization and increase survival of invertebrates that aestivate (i.e., amphipods; Thorp and Covich 1991). Prolonged wetland conditions are often correlated positively with numbers and taxa of invertebrates (Rosenzweig 1996, Anderson and Smith 2000). Active-late and passively managed sites may provide more diverse food resources during winter (i.e., greater combined seed and invertebrate community diversity) than active-early sites.

My results indicated waterbird, dabbling, and diving duck abundances were related inversely to frequency of occurrence of woody vegetation in surveyed wetlands. Managed moist-soil units generally are dominated by early succession herbaceous vegetation plants and reduced woody vegetation (Fredrickson and Heitmeyer 1988). Similarly, a primary factor influencing habitat use by waterfowl may be availability and quality of forage (Fredrickson and Taylor 1982, Smith et al. 1989, Buler et al. 2007). Many grasses and sedges produce greater seed abundances and TME values than seeds of woody vegetation (Reinecke et al. 1989, Kaminski et al. 2003). Additionally, Kross et al. (2008) reported an inverse relationship between moist-soil abundance and percentage occurrence of woody vegetation which may shade out grasses and sedges. Thus, increased abundances of waterfowl and waterbirds with decreased woody cover may be related to greater food abundance or quality in wetlands with decreased tree and scrub-shrub cover. However, I did not include seed densities in my models, and %WOODY as a univariate model did not have a strong weight of evidence for duck abundances ($w_i < 0.01$; Table 2.6). My top model included decreased %WOODY, and my overall model fit among management types was not a strong predictor of duck use ($R^2 \leq 0.27$; Figures 2.2 and 2.3). Therefore, future investigation evaluating influence of woody vegetation on bird use is required**.**

Models including plant species richness (RICH), composition (COMP), and percentage grass (%GRASS) ranked less and received minimal weights of evidence ($w_i <$ 0.01; Tables 2.6 and 2.7) for explaining variation in waterbird and duck use of wetlands compared to models that described vegetative quality, structure, and wetland area. Although moist-soil management guidelines promote growth of early-succession plants (i.e., sedges and grasses; Strader and Stinson 2005, Nelms 2007), variables related to vegetative composition in my study (i.e., RICH, COMP and %GRASS) were poor predictors of waterbirds and duck use. My results coupled with small influences of VFQI within management types suggests ducks may not be selecting habitat based solely on plant composition. Several studies have reported recently that use of wetlands by waterbirds and ducks often is a response to multiple features and not individual components (Savard et al. 1994, Smith et al. 2004, O'Neal et al. 2008, Brasher 2010).

Although I examined site-specific physical and floral wetland components to explain bird use, I did not evaluate wetland landscape or anthropogenic disturbance. Bird species richness and densities can be a function of landscape structure and wetland complexes (Atauri and Lucio 2001, Fairbairn and Dinsmore 2001, Pearse 2007). Similarly, waterbird richness often increases with total wetland habitat within a 3 km surrounding area because birds may be attracted to areas with more wetland habitats (Fairbairn and Dinsmore 2001, Brasher 2010). Landscapes that support more wetland habitat within a greater area may reduce risky movement among different habitats by reducing home range size (i.e., home range for wintering mallards and northern pintails ranges between 2.2-48.0 km; Baldassarre and Bolen 2006, Legagneux et al. 2009). I did not measure degree of isolation of wetland complexes nor landscape structure and relate these to potential bird use. Nonetheless, I recognize NRCS encourages enrollment of WRP lands as continuous connecting blocks; thus, some of my properties may have a greater number of connecting wetland complexes (NRCS 2004). Future research should examine combination of site-specific and landscape-scale wetland characteristics on waterfowl and waterbird use. Similarly, landowners of WRP lands often use land for recreational purposes (i.e., hunting, fishing) a potential source of disturbance to birds (Evans and Day 2002). Repeated human intrusion can cause declines in avian richness and abundance (Madsen 1995, Riffell et al. 1996, Madsen 1998). Therefore, areas with greater disturbance could have forced birds to other locations with fewer disturbances and may explain why birds used active and passive sites.

My models explained a small portion (< 27%) of variation in waterbird and duck use of moist-soil wetlands at WRP lands in the MAV, Mississippi. Although VFQI explained some variation in waterbird and duck use of active–late sites and waterbird use of passive sites, VFQI was not a strong predictor of bird use in active-early sites. Other study results confirmed my observations of no detectable difference in waterfowl densities between active and passive management (Kaminski et al. 2006) and potential energetic carrying capacities (Brasher et al. 2007), although waterbirds and ducks densities were usually greater on actively managed areas. Nonetheless, my results support the conclusion that wintering waterbirds and ducks may not be using moist-soil wetlands based solely on forage quality (i.e., VFQI). Ducks may not require abundant high quality foraging resources during winter compared to other life stages that are more energetically costly (i.e., migration, breeding; Baldassarre and Bolen 2006). Wintering birds may be using moist-soil wetland complexes, which include both active and passively managed sites, because of a diversity of habitat types that meet various life cycle needs occurring during winter (e.g., forage, pair bonds, molt, and roosts; Richardson and Kaminski 1992, Custer and Galli 2002, Baldassarre and Bolen 2006). Research should investigate behavioral responses of waterbirds and ducks to site-specific and landscape level vegetative and wetland characteristics to facilitate effective conservation and management guidelines to maximize winter habitat requirements (e.g., ecological fitness of birds; Kaminski et al. 2006, O’Neal et al. 2008).

Management Implications

Wetlands used in my study were restored through the Wetlands Reserve Program in Mississippi and provided habitat for a variety of waterbirds, with management objectives often directed towards wintering waterfowl. I used models based on quality, structural, and compositional components of fall vegetative communities, as well as broad management categories to evaluate waterbird and duck use. I was only able to describe a small amount of variation in waterbird and duck use of moist-soil wetlands enrolled in WRP in the Mississippi Alluvial Valley, Mississippi, based on metrics derived from currently accepted management recommendations for waterfowl (Strader and Stinson 2005, Nelms 2007, Strickland et al. 2009). However, I found strong weight of evidence for a difference in bird response to increasing VFQI among management types ($w_i > 0.79$) with late draw-down and reduced woody vegetation producing the best potential waterbird and duck response. Similarly, wetland area influenced waterbird and duck species richness. Therefore, maximizing wetland area may provide greatest bird species richness, and actively managing moist-soil wetlands may also increase waterbird species richness and winter bird (waterbirds and ducks) abundances. I recommend continued investigation of influence of management techniques (active and passive) on wetlands (i.e., soil, vegetation, water quality) and subsequent bird response. My results support that waterbirds and ducks used passively managed wetlands. Thus, I submit that landscape level modeling exercises that include a cost-benefit analysis of management operations (sensu Pankau 2008) and landscape level features (sensu Pearse et al. 2007) is appropriate. Current WRP management provides a mosaic of wetland types (i.e., permanent, seasonal, passive, and actively management) on the landscape and appears to provide waterbirds and ducks with a diversity of habitat through the winter. To facilitate effective management and conservation of wetlands, guidelines should focus on restoring hydrology to develop and sustain a diversity of wetland habitat conditions and complexes which should support important habitat components required by wintering birds (Kaminski et al. 2006, O'Neal et al. 2008). Site-specific evaluation and recommendations will ensure optimal management of current WRP wetlands and allow landowners to manage to the best of their ability.

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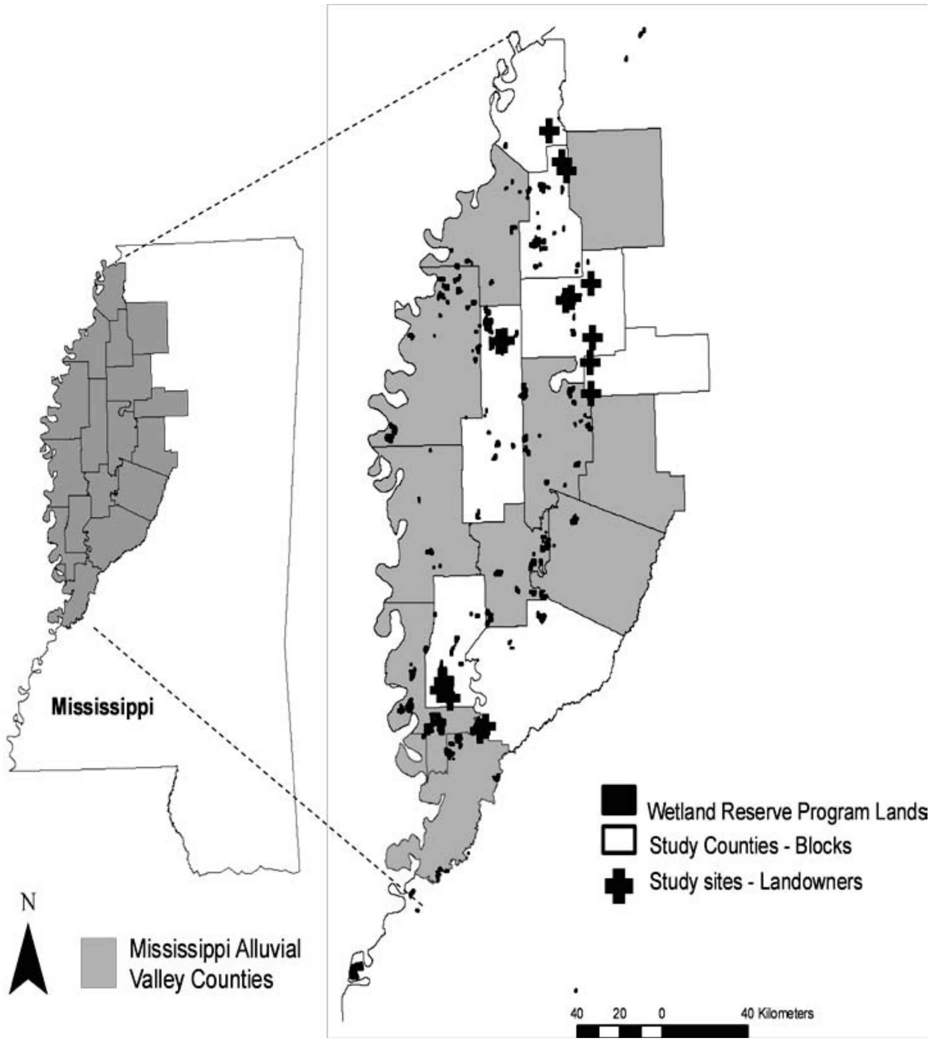

Figure 2.1. Locations of 6 county blocks (white squares) and 18 study sites (crosses) within Wetlands Reserve Program lands (black squares) where summer vegetative and winter waterfowl communities were evaluated in Mississippi, 2007-2009.

Table 2.1. Variables and their summary statistics for 54 moist-soil wetlands on Mississippi Wetlands Reserve Program lands, winters 2007-2009.

Winter/variables	Acronym	$\bar{x}$ ± SE	Range
2007-2008			
Management type	MTYPE	[a]	[a]
Wetland area (ha)	WET	7.83 ± 0.57	0.12 - 31.27
2008-2009			
Management type	MTYPE	[a]	[a]
Wetland area (ha)	WET	6.48 ± 0.44	0.00 - 31.27
Vegetation Forage Quality Index (VFQI)	VFQI	1.00 ± 0.02	0.18 - 1.86
Percentage woody cover (%)	%WOODY	4.00 ± 0.40	0.00 - 25.50
Percentage grasses (%)	%GRASS	36.65 ± 2.00	0.00 - 100.00
$\bar{x}$ Plant growth-forms per sample points[b]	COMP	1.66 ± 0.03	0.06 - 2.56
Plant species/genus richness per wetland	RICH	19.23 ± 0.37	2.00 - 31.00

[a]Blank denotes a category for which a mean cannot be calculated.

[b]Plant growth-forms included grasses, sedges/rushes, aquatics, vines, woody vegetation, wildlife food crops, and broadleaves.

Table 2.2. Duck species occurrences (X) among management types in 54 Mississippi Wetlands Reserve Program moist-soil wetlands, winters 2007-2009.

Common name	Scientific name	2007-2008		2008-2009		
		Active *n* = 36	Passive *n* = 18	Active -early *n* = 18	Active -late *n* = 21	Passive *n* = 15
Dabbling ducks						
Wood duck	*Aix sponsa*	X	X	X	X	X
Northern pintail	*Anas acuta*	X		X	X	X
American wigeon	*A. americana*	X		X	X	X
American green-winged teal	*A. crecca carolensis*	X	X	X	X	X
Blue-winged teal	*A. discors*	X	X	X	X	X
Mallard	*A. platyrhynchos*	X	X	X	X	X
American black duck	*A. rubripes*	X		X	X	X
Gadwall	*A. strepera*	X	X	X	X	X
Northern shoveler	*A. clypeata*	X	X	X	X	X
Diving Ducks						
Lesser scaup	*Aythya affinis*	X			X	
Ring-necked duck	*A. collaris*	X	X	X	X	X
Canvasback	*A. valisineria*	X			X	
Bufflehead	*Bucephala albeola*	X	X	X	X	X
Hooded merganser	*Lophodytes cucullatus*	X	X	X	X	X
Ruddy duck	*Oxyura jamaicensis*	X			X	
	Total	15	9	12	15	12

Table 2.3. Summary statistics (mean ± SE; range) for goose densities on 54 moist-soil wetlands on Mississippi Wetlands Reserve Program lands, 2007-2009.

Winter/Management type	Sample size (*n*)	$\bar{x}$ ± SE	Range
2007-2008			
Active	36	2.06 ± 1.87	0.00-220.10
Passive	18	0.02 ± 0.02	0.00-0.88
2008-2009			
Active-early	18	1.11 ± 0.92	0.00-77.14
Active-late	21	8.60 ± 7.29	0.00-751.88
Passive	15	0.38 ± 0.27	0.00-15.26

Table 2.4. Occurrence (X) of waterbird species (excluding dabbling and diving ducks) among management types in 54 Mississippi Wetlands Reserve Program moist-soil wetlands, winters 2007-2009.

Guild/Common name	Scientific name	2007-2008		2008-2009		
		Active *n* = 36	Passive *n* = 18	Active-early *n* = 18	Active-late *n* = 21	Passive *n* = 15
Geese						
White-fronted goose	*Anser albifrons*	X		X	X	X
Canada goose	*Branta canadensis*	X	X	X	X	X
Snow goose	*Chen caerulescens*	X		X	X	
	Total	3	1	3	3	1
Waterbirds						
Roseate spoonbill	*Ajaia ajaja*				X	
Great egret	*Ardea alba*	X	X	X		X
Great blue heron	*A. herodias*	X	X	X	X	X
American bittern	*Botaurus lentiginosus*	X				
Killdeer	*Charadrius vociferous*	X	X		X	X
Snowy egret	*Egretta thula*	X	X		X	
White ibis	*Eudocimus albus*	X			X	
American coot	*Fulica americana*	X	X	X	X	X
Common snipe	*Gallinago gallinago*	X	X		X	X
Wood stork	*Mycteria americana*	X				
Double-crested cormorant	*Phalacrocorax auritus*	X			X	
Pie-billed grebe	*Podilymbus podiceps*	X	X	X	X	X
Greater yellowlegs	*Tringa melanoleuca*	X			X	X
	Total	12	7	4	10	7

Table 2.5. Candidate models for linear and quadratic effects of wetland area (WET) on duck and waterbird species richness and abundance observed on Wetlands Reserve Program moist-soil wetlands in Mississippi. For each model, Akaike's Second Order Information Criteria (AIC_c, ΔAIC_c), model estimated parameters (K), and model weights (w_i) are presented.

Winter/models	Model	K	AIC_c	ΔAIC_c	w_i
2007-2008					
Duck species richness	WET	6	322.8	0.0	0.99
	WET^2	7	333.4	10.6	0.01
Dabbling duck abundance	WET	6	716.6	0.0	0.99
	WET^2	7	726.2	9.4	0.01
Diving duck abundance	WET	6	527.5	0.0	1.00
	WET^2	7	538.4	10.9	0.00
Waterbird species richness	WET	6	484.7	0.0	0.99
	WET^2	7	494.6	9.9	0.01
Waterbird abundance	WET	6	695.4	0.0	0.99
	WET^2	7	705.6	10.2	0.01
2008-2009					
Duck species richness	WET	7	488.9	0.0	0.99
	WET^2	8	499.2	10.3	0.01
Dabbling duck abundance	WET	7	1,006.2	0.0	0.99
	WET^2	8	1,015.8	9.6	0.01
Diving duck abundance	WET	7	889.2	0.0	0.99
	WET^2	8	899.6	10.4	0.01
Waterbird species richness	WET	7	257.5	0.0	1.00
	WET^2	8	269.1	11.6	0.00
Waterbird abundance	WET	7	748.4	0.0	0.99
	WET^2	8	758.8	10.4	0.01

Table 2.6. Models explaining variation in winter duck and waterbird species richness on Mississippi Wetlands Reserve Program moist-soil wetlands in relationship to management type (MTYPE), wetland area (WET; ha), vegetative forage quality index (VFQI), plant community richness (RICH), plant community growth-forms (COMP), percentage woody vegetation (%WOODY), percentage grass (%GRASS), and the null model (NULL). For each model, model estimated parameters (K), Akaike's Second Order Information Criteria (AIC_c, ΔAIC_c), and model weights (w_i) are presented.

Guild/winter/model	K	AIC_c	ΔAIC_c	w_i
Duck Species 2007-2008				
WET	6	322.8	0.0	0.84
MTYPE	7	328.0	5.2	0.06
WET*MTYPE	10	328.2	5.4	0.06
NULL	5	329.1	6.3	0.04
Duck species 2008-2009				
-%WOODY	7	480.9	0.0	0.41
NULL	5	482.6	1.7	0.18
VFQI*MTYPE - %WOODY	14	483.9	3.0	0.09
%GRASS	7	484.1	3.2	0.08
VFQI	7	484.3	3.4	0.08
COMP	7	484.8	3.9	0.06
MTYPE	9	485.4	4.5	0.04
VFQI*MTYPE	13	485.7	4.8	0.04
WET	7	488.9	8.0	0.01
-RICH	7	489.1	8.2	0.01
VFQI*MTYPE+WET - %WOODY	15	489.9	9.0	0.00
VFQI*MTYPE+WET				
Waterbird species, 2007-2008				
MTYPE	6	483.9	0.0	0.48
WET	7	484.7	0.8	0.33
NULL	5	486.8	2.9	0.11
WET*MTYPE	10	487.8	3.9	0.07
Waterbird species, 2008-2009				
-%WOODY	7	252.2	0.0	0.43
NULL	5	254.0	1.8	0.17
VFQI*MTYPE - %WOODY	14	255.7	3.5	0.07
%GRASS	7	256.1	3.9	0.06
COMP	7	256.1	3.9	0.06
VFQI	7	256.3	4.1	0.06
MTYPE	9	256.6	4.4	0.05
WET	7	257.5	5.3	0.03
VFQI*MTYPE	13	257.7	5.5	0.03

Table 2.6 (continued)

Guild/winter/model	K	AIC$_c$	ΔAIC$_c$	w_i
VFQI*MTYPE+WET-%WOODY	15	259.0	6.8	0.01
VFQI*MTYPE+WET	14	260.4	8.2	0.00
-RICH	7	261.3	9.1	0.00

Table 2.7. Models explaining variation in dabbling and diving duck and waterbird abundances, winter 2008-2009 on Mississippi Wetlands Reserve Program moist-soil wetlands in relationship to management type (MTYPE), wetland area (WET; ha), vegetative forage quality index (VFQI), plant community richness (RICH), plant community growth-forms (COMP), percentage woody vegetation (%WOODY), percentage grass (%GRASS), and the null model (NULL). For each model, model estimated parameters (K), Akaike's Second Order Information Criteria (AIC_c, ΔAIC_c), and model weights (w_i) are presented.

Guild/winter/model	K	AIC_c	ΔAIC_c	w_i
Dabbling ducks				
VFQI*MTYPE - %WOODY	15	990.9	0.0	0.90
VFQI*MTYPE	14	995.6	4.7	0.09
- %WOODY	8	1,001.2	10.3	0.00
MTYPE	10	1,005.1	14.2	0.00
%GRASS	8	1,005.5	14.6	0.00
VFQI	8	1,005.6	14.7	0.00
NULL	7	1,006.2	15.3	0.00
COMP	8	1,006.6	15.7	0.00
- RICH	8	1,011.5	20.6	0.00
Diving ducks				
VFQI*MTYPE - %WOODY	15	875.3	0.0	0.90
VFQI*MTYPE	14	880.5	5.2	0.07
- %WOODY	8	883.6	8.3	0.01
MTYPE	10	888.0	12.7	0.00
%GRASS	8	889.2	13.9	0.00
NULL	7	889.2	13.9	0.00
VFQI	8	889.3	14.0	0.00
COMP	8	890.0	14.7	0.00
Waterbirds				
VFQI*MTYPE - %WOODY	15	736.9	0.0	0.79
VFQI*MTYPE	14	739.9	3.0	0.17
- %WOODY	8	745.4	8.5	0.01
MTYPE	10	745.8	8.9	0.01
%GRASS	8	747.7	10.8	0.00
VFQI	8	747.8	10.9	0.00
NULL	7	748.4	11.5	0.00
COMP	8	748.7	11.8	0.00
- RICH	8	748.7	11.8	0.00
- RICH	8	753.0	16.1	0.00

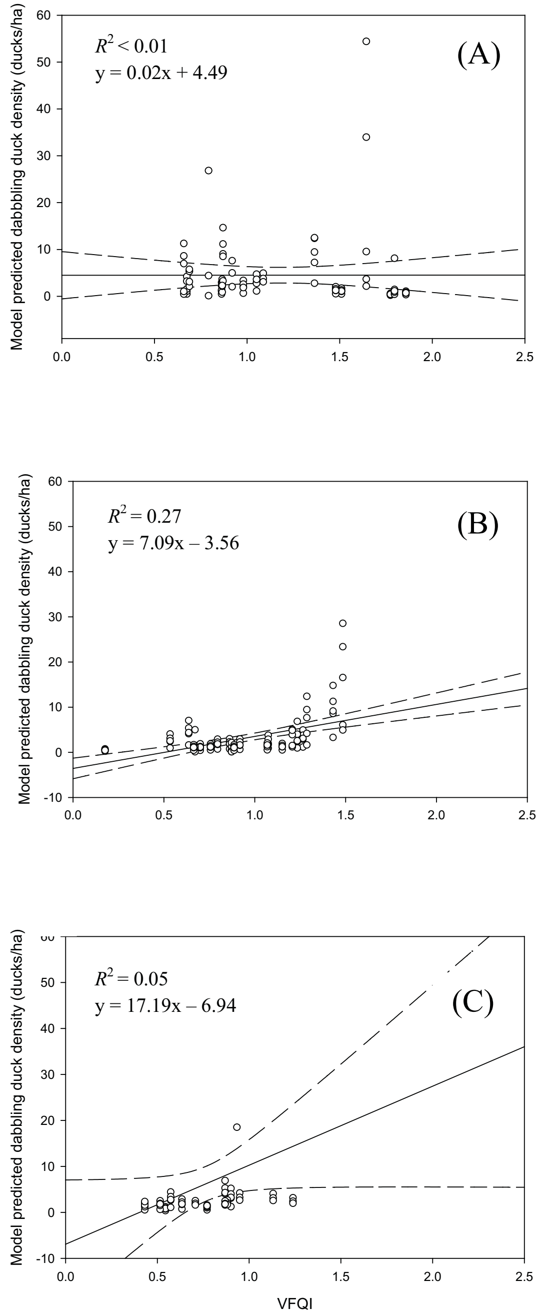

Figure 2.2. Model predicted dabbling duck densities by VFQI for each management types, (A) active-early, (B) active-late, and (C) passive, on Mississippi Wetlands Reserve Program lands, winters 2008-2009. Open circles denote duck density by VFQI, solid line represents the linear regression, and dashed line is ± 95 confidence bands.

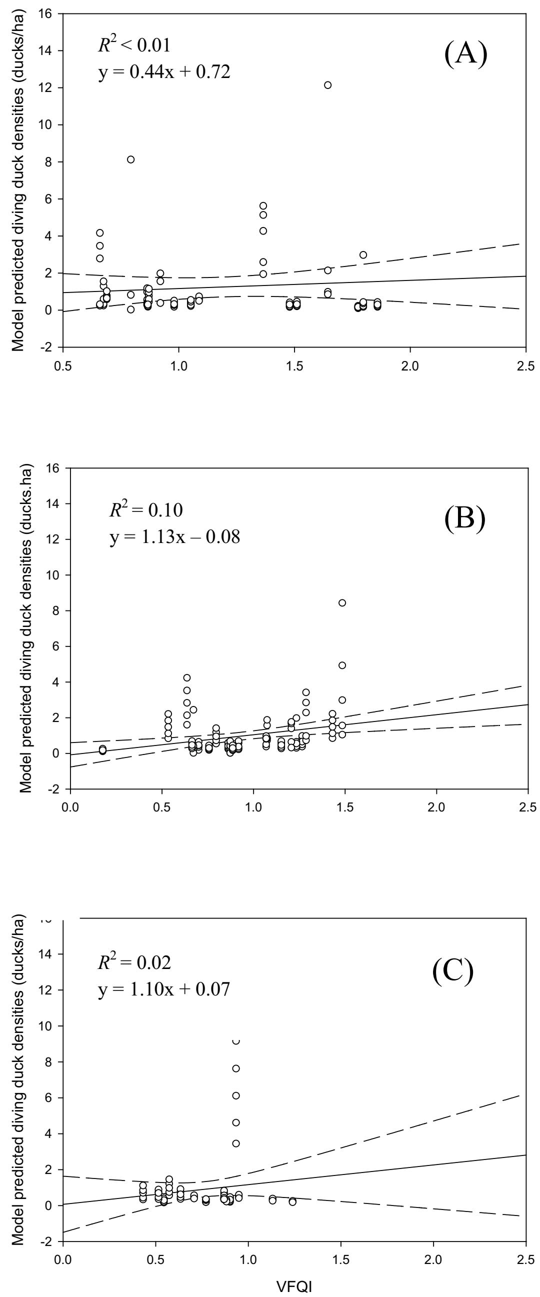

Figure 2.3. Model predicted diving duck densities by VFQI for each management types, (A) active-early, (B) active-late, and (C) passive, on Mississippi Wetland Reserve Program lands, winters 2008-2009. Open circles denote duck density by VFQI, solid line represents the linear regression, and dashed line is ± 95 confidence bands.

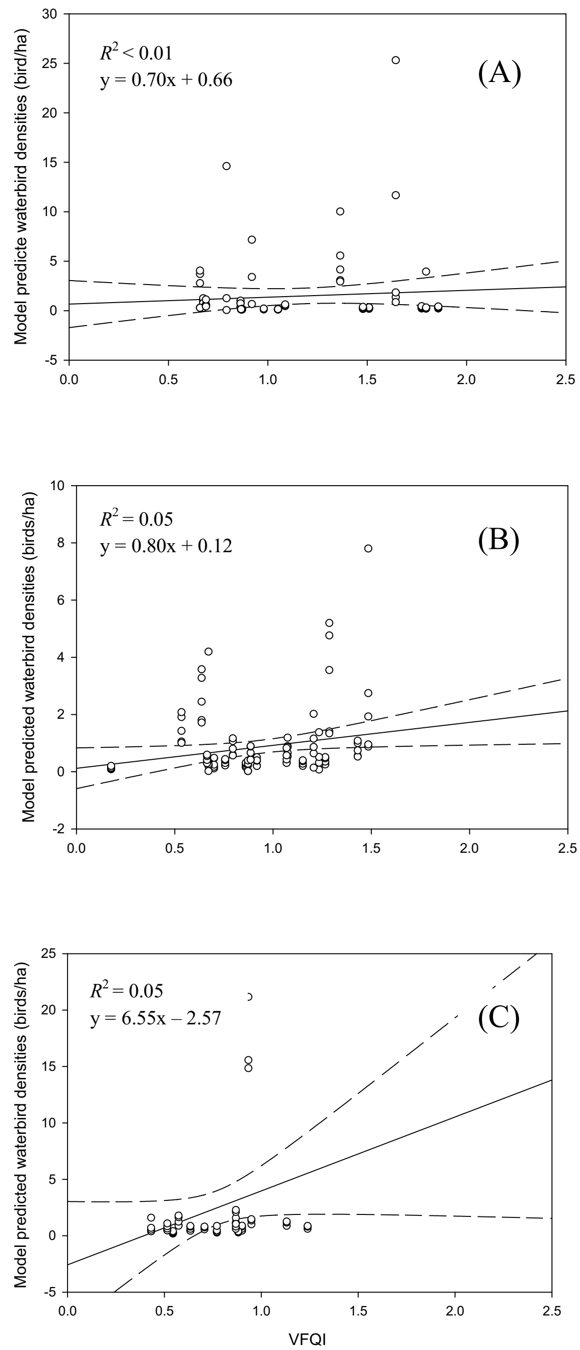

Figure 2.4. Model predicted waterbird densities by VFQI for each management types, (A) active-early, (B) active-late, and (C) passive, on Mississippi Wetland Reserve Program lands, winters 2008-2009. Open circles denote bird density by VFQI, solid line represents the linear regression, and dashed line is ± 95 confidence bands.

CHAPTER III

SYNTHESIS

Wetlands Reserve Program (WRP) lands in the Mississippi Alluvial Valley (MAV) often contain seasonally flooded moist-soil wetlands (i.e., natural lowlands dominated by early succession vegetation) used by a diversity of wetland-dependent and other wildlife species (Fredrickson and Taylor 1982, Reinecke et al. 1989). Managed moist-soil wetlands promote existence of vegetative communities with abundant plant and animal foods and other habitat resources (Reinecke et al. 1989, Smith et al. 1989, Nelms 2007). Migrating and wintering waterfowl often concentrate on these wetlands and glean foods high in energy and protein (Fredrickson and Taylor 1982, Reinecke et al. 1989). Planning and implementation of wetland conservation for waterfowl in the MAV and other regions usually are based on estimated availability of energy from foods in natural wetlands, including moist-soil wetlands, and croplands (Reinecke et al. 1989, Smith et al. 1989, Loesch et al. 1995).

Birds foraging in moist-soil wetlands acquire energy mainly by ingesting seeds and tubers (e.g., *Cyperus* spp., *Echinochloa* spp.) that have potential to provide metabolizable energy (ME) similar to agricultural seeds (Kaminski et al. 2003). Kross et al. (2008) reported managed moist-soil wetlands in the MAV provide about 555 kg (dry mass)/ha of seeds and tubers, which equates to nearly 1.4 million kcal/ha of potential ME. Therefore, expanding moist-soil management on WRP lands can enhance overall availability and quality of foraging habitat for waterfowl and other wetland wildlife

(Kaminski et al. 2006, King et al. 2006, Kross et al. 2008, O'Neal et al. 2008).

Guidelines for development and management of moist-soil and other wetlands in the MAV are available (e.g., Reinecke et al. 1989, Strader and Stinson 2005, Nelms 2007, Strickland et al. 2009). However, few environmental monitoring techniques exist to evaluate wetland conservation programs in North America. Therefore, my goal was to evaluate plant, waterfowl, and other waterbird responses to management intensity and growing-season hydrology in moist-soil wetlands on WRP lands in the MAV in Mississippi. Additionally, management intensity and hydrological manipulations of WRP wetlands may directly and indirectly influence water quality. Therefore, comparison of water quality metrics among wetlands with different management regimes should provide insight into the effect of management on water contained within and released from moist-soil wetlands. Results from my study will provide landowners with a current set of potential "best" management practices for enhancing waterfowl habitat and water quality in moist-soil wetlands on WRP lands in the MAV.

In Chapter I, I evaluated plant community metrics in moist-soil wetlands subjected to different management intensities (i.e., active and passive) and relative date of draw-down (i.e., early and late season). An important goal of WRP in the MAV is to provide quality foraging habitat for migrating and wintering waterfowl. Thus, I developed a Vegetative Forage Quality Index (VFQI) to evaluate moist-soil plant communities as foraging habitats for waterfowl based on potential availability of energy from seeds and tubers in the wetlands (Taft et al. 1997, Kaminski et al. 2003, Andreas et al. 2004). The VFQI provided a simple efficient method to assess WRP plant communities as potential waterfowl foraging habitat. Additionally, I found active management with early draw-down produced the greatest plant community diversity, VFQI, vegetative structural composition, and percentage occurrence of grass species. Therefore, I concluded current NRCS guidelines that recommend active management and annual dewatering of moist-soil wetlands are valid for sustaining diverse early succession plant communities dominated by grass and sedge species that typically provide high energy foods for waterfowl.

In Chapter II, I modeled variation in species richness and abundance of wintering ducks and other waterbirds in relation to early and late season draw-down, active and passive management, VFQI, and other wetland vegetative metrics. Density of wintering ducks and waterbirds increased with increasing autumn VFQI, active management with late draw-down, and decreased occurrence of woody vegetation. Additionally, duck and total waterbird species richness was positively related to wetland area. Therefore, results from my study support active management to promote greatest VFQI in autumn, annual late draw-downs by July, and maximum winter flooding of wetlands to attract greatest species richness and abundance of wintering ducks and other waterbirds.

In the Appendix, I present results from a preliminary evaluation of water quality in managed WRP moist-soil wetlands and associated drainage ditches. I measured 5 water quality metrics including (1) water temperature (°C), (2) pH, (3) dissolved oxygen (mg/L), (4) specific conductance (µS/cm), and (5) total suspended solids (mg/L). Water quality parameters measured on WRP wetlands were variable with no clear differences detected between wetland management regimes and associated drainage ditches ($P > 0.10$). I recommend continued investigation of the effects of moist-soil management on surface water quality and its contribution to the MAV aquifer.

Wetland conservation should focus on actively restoring and managing hydrology and wetland areas to develop and sustain habitat complexes for waterfowl and other wetland obligate species (Kaminski et al. 2006, O'Neal et al. 2008). Researchers should investigate behavior of waterbirds using WRP wetlands to site-specific and landscape level vegetative and wetland characteristics to understand their functional use, thus facilitating effective conservation and management guidelines to maximize NRCS conservation goals (Gray et al. 1996, Kaminski et al. 2006, O'Neal et al. 2008). Similarly, rigorous analyses of seasonal water quality (e.g., APHA 2005) should be conducted to determine environmental and economic values of water retained within and released from moist-soil wetlands.

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APPENDIX A:

EVALUATION OF MANAGEMENT AND HYDROLOGY ON WATER QUALITY IN WETLANDS RESERVE PROGRAM LANDS, MISSISSIPPI: A PILOT STUDY

Introduction

The Wetland Reserve Program (WRP) was authorized under the Food, Agriculture, Conservation, and Trade Act of 1990 (Farm Bill) and established throughout the United States by 1996 (Natural Resources Conservation Service [NRCS] 2007). The WRP is a voluntary program administered through NRCS under which landowners receive technical and financial assistance to protect, enhance, and restore previously or currently farmed wetlands (Haufler 2005, NRCS 2007). Wetlands provide habitat for wildlife and fish, improve water quality, reduce flooding, and enhance ground water recharge (Mitsch and Gosselink 2007). Presently, there are over 9,900 WRP projects on nearly 728,434 hectares in the United States (Kaminski et al. 2006, NRCS 2007). Most lands enrolled in WRP are in the Lower Mississippi Valley in the states of Arkansas, Illinois, Kentucky, Louisiana, Mississippi, Missouri, and Tennessee. The largest amount of restoration of WRP lands occurs in the Mississippi Alluvial Valley (MAV) of Arkansas, Louisiana and Mississippi, where > 161,000 hectares of farm land have been restored (Ducks Unlimited 2006, King et al. 2006).

Stated goals of the WRP are to protect, restore, and enhance functional and ecological values of recovered wetland ecosystems (NRCS 2007). Wetlands are recognized for their role in flood control and protection and improvement of water quality, recharging ground water, and providing wildlife habitat (Mitsch and Gosselink 2007). Moist-soil wetlands are seasonally flooded wetlands which produce early successional plant communities dominated by grasses (e.g., *Panicum* spp., *Paspalum* spp.), sedges (*Cyperus* spp., *Carex* spp.) and other herbaceous plants (Fredrickson and Taylor 1982, Smith et al. 1989, Nelms 2007, Kross et al. 2008). Moist-soil wetlands enrolled in the WRP program provide an opportunity to evaluate the quality of water associated with these managed, restored wetlands. Management guidelines provided to landowners by NRCS state a primary goal for moist-soil management on WRP sites is to maintain a diversity of early succession plant communities (NRCS 2007). Moist-soil management also has potential to maintain or improve water quality in agricultural systems, because water passing through wetlands is cleansed by plant, animal, and microbial communities (Shutes 2001, Bruland et al. 2003, Bossio et al. 2006). However, this is also the potential to reduce water quality through erosion of the tilled soils.

Wetland restoration efforts focus on renewing ecosystem services such as improving biodiversity, enhancing water quality, and restoring hydrological function (Whigham 1999, Zedler and Kercher 2005, Mitsch and Gosselink 2007). Improving and increasing total area enrolled in WRP moist-soil management should enhance ecosystem services (NRCS 2007). However, actual levels of management of moist-soil wetlands by landowners can range from active management (i.e., implementation of practices recommended by NRCS including regular soil disturbance, water level management, and control of undesirable plants) to passive (i.e., few or no management activities implemented; Chapters 1 and 2). Research has revealed that management intensities (i.e., active vs. passive) in moist-soil wetland can influence wetland community parameters such as seed abundance (Kross et al. 2008), plant diversity and abundance (Fredrickson and Taylor 1982, O'Neal et al. 2008), invertebrate diversity and abundance (Anderson and Smith 1999), and use by wetland obligate birds (Kaminski et al. 2006, O'Neal et al. 2008). However, there has been no research on effects of moist-soil management intensity on water quality parameters. Therefore, I evaluated water quality in moist-soil wetlands managed at different levels of intensity and in nearby drainage ditches. Knowledge and comparison of water quality metrics (i.e., nutrients, sediments, and chemistry) of moist-soil wetlands under different management intensities are important because water retained in these sites during winter eventually will be released into streams. Therefore, comparisons of water quality parameters among moist-soil wetlands with different levels of management to nearby agricultural ditches should provide insight into effectiveness of moist-soil management in improving water quality. Thus, my objectives were to (1) measure and document water quality parameters of flooded moist-soil wetlands under active and passive management intensities, and (2) compare values of water quality metrics from moist-soil wetlands with the same from nearby agricultural ditches.

Project Description

Study Area and Design

Study sites were located on private lands enrolled in WRP in the Mississippi region of the Lower MAV distributed across Grenada, Quitman/Tunica, Sharkey, Sunflower, Tallahatchie, and Yazoo counties (Figure 1.1). The WRP properties ranged from 22.7-1,448.6 ha and each WRP property had 3-22 moist-soil wetlands from 0.4-67.8 ha.

Management intensity and hydrologic manipulations of WRP wetlands may directly and indirectly influence water quality (Mitsch and Gosselink 2007, Nelms 2007, NRCS 2007). I categorized WRP properties based on management type and timing of hydrological manipulations. I was not able to determine hydrological management prior to flooding of study sites in fall 2007; thus, I classified study sites for winter 2007-2008 merely as either actively or passively managed, as reported by NRCS personnel and landowners (Chapter 1). Following extensive site monitoring in summer 2008, landowner management techniques and hydrologic manipulations were designated as (1) active management with early draw-down (i.e., active-early) when draw-down was completed by 15 June, (2) active management with late draw-down (i.e., active-late) when draw-down was $\geq$ 3 weeks after active-early dates (i.e., early to mid-July), or (3) passive management with unregulated hydrology whereby addition and losses of water were governed by precipitation, run-off, evapotranspiration, and loss from seepage through levees. To be included in the active management category some combination of monthly inspections, annual soil disturbance (e.g., disking), and control of undesirable plants (i.e., plants with little to no known value as waterfowl forage; Brasher et al. 2007, Kross et al. 2008, Strickland et al. 2009) had to be used by the landowner. Wetlands with infrequent soil disturbance, limited control of undesirable plants, and minimal hydrological management were classified as having passive management (Brasher et al. 2007; Chapters 1 and 2).

The 6 counties were designated as blocks and within each there were three replicated study sites each of active-early, active-late, and passive management strategies (i.e., 6 blocks x 3 management types per block x 3 replicate moist-soil wetlands per management category = 54 wetlands). Water sampling also was conducted in agricultural ditches within or < 100 m of each landowner's property (*n* = 18). These non-WRP samples were classified according to nearest management type as (1) active-ditch, (2) active-early-ditch, (3) active-late-ditch, or (4) passive-ditch. Hereafter, the combined water quality sampling locations (3 landowner management techniques [i.e., active, active-early, active-late, and passive] and paired ditches [i.e., active-ditch, active-early-ditch, active-late-ditch, and passive-ditch]) are referred to as water management types.

Water Sampling Design and Statistical Analyses

I collected water samples 13-16 March during 2008 and 2009. Water samples were collected within 15 m of water control structures inside the moist-soil wetlands to characterize quality of water entering drainage ditches from wetland outlets (Maul and Cooper 2000). Water quality parameters providing basic biological, chemical, and physical information about the systems were measured to gauge the conditions in the wetlands and associated waterbodies. Additionally, as wetland managers also may need to obtain field measurements of water quality to aid with assessment of management practices (Hemond and Benoit 1988), metrics were selected if they could be easily and inexpensively quantified by landowners. I selected five metrics for evaluation: (1) temperature (°C): useful as a measure of conditions for invertebrates, plants, and microbes; (2) pH: influences water chemistry and the metabolism of microorganisms; (3)

dissolved oxygen (mg/L): numerous chemical and biological reactions in water systems are impacted positively and negatively by availability of oxygen; (4) specific conductance (µS/cm): provides an indirect gauge of total dissolved solids and salinity which can be used to assess groundwater interactions and salt loading; and (5) total suspended solids(mg/L): greater concentrations can inhibit light penetration and directly affect aquatic life at all trophic levels. Total suspended solids also can suggest greater concentrations of bacteria, nutrients, metals, and pesticides as they are often derived from similar sources (Wilde 2008).

I used a portable YSI model 3800 to measure temperature pH, dissolved oxygen concentrations, and specific conductance in the field (Maul and Cooper 2000, American Public Health Association [APHA] 2005), and calibration followed protocols in the calibration checklist logbook. I collected water samples and stored them in 0.25 L sterilized Nasco Whirl-PAK bags, kept on ice during transportation, and stored frozen at Mississippi State University (MSU) until analyses. Water samples were analyzed at MSU, College of Forestry Resources hydrology laboratory. Total suspended solids were analyzed following standard methods of filtration and gravimetric measurements per protocols (APHA 2005).

My data represent an initial attempt to evaluate effects of management and hydrology on water quality in moist-soil wetlands. I performed an ANOVA to test null hypotheses of no difference in water quality metrics (i.e., temperature, pH, dissolved oxygen, specific conductance, and total suspended solids) among water management types (i.e., 2008 active, active-ditch, passive and passive-ditch, and 2009 active-early, active-early-ditch, active-late, active-late-ditch, passive, and passive-ditch; PROC

MIXED, SAS 9.2.2). Years were analyzed separately because of the different water management type classification criteria described above. I designated water management types as fixed effects, and blocks and private properties nested within blocks as random effects. To evaluate homogeneity of variances of water quality parameters, I plotted the residuals of the water quality data against predictor variables and examined residuals for clustering and uniform distribution. Variances for all water quality parameters appeared unequal based on examinations; therefore, I natural log transformed the data sets before analyses (Zar 1974). Transformations resulted in homogeneity of variances.

Results

Overall mean water temperatures (ºC) were similar between 2008 and 2009 ($\bar{x}$ = 16.09 ± 1.41 [SE], $\bar{x}$ = 17.89 ± 1.07, respectively). Greatest mean temperature was observed in passive sites during 2009 ($\bar{x}$ = 18.94 ± 1.07). Least mean temperature was observed in passive-ditch sites in 2008 ($\bar{x}$ = 15.43 ± 2.43). Minimum and maximum temperatures were 10.44 (i.e., passive-ditch 2009) and 23.78°C (i.e., active-late-ditch 2009). There were no significant differences among 2008 water management types ($F_{3, 54.5}$ = 1.21, P = 0.32) and among 2009 water management types ($F_{5, 50.2}$ = 1.77, P = 0.14; Figure A.1).

Overall mean pH values were similar between 2008 and 2009 ($\bar{x}$ = 7.34 ± 1.03, $\bar{x}$ = 8.06 ± 1.04, respectively). Greatest mean pH value was observed in passive sites during 2009 ($\bar{x}$ = 8.49 ± 1.03) where as the least mean pH values were observed in passive-ditch sites in 2009 ($\bar{x}$ = 7.75 ± 1.04). There were no significant differences among 2008 water management types ($F_{3, 14.2}$ = 2.55, P = 0.10) and among 2009 water management types ($F_{5,\,50.5}$ = 1.77, P = 0.14; Figure A.2). All pH values were circumneutral tending towards slightly basic conditions.

Overall mean dissolved oxygen (mg/L) concentrations across water management types were slightly greater in 2009 ($\bar{x}$ = 9.13 ± 1.11) than in 2008 ($\bar{x}$ = 8.88 ± 1.09). Greatest mean dissolved oxygen was observed in active-early-ditch sites during 2009 ($\bar{x}$ = 9.86 ± 1.12). The least mean dissolved oxygen concentration was observed in active-ditch sites during 2008 ($\bar{x}$ = 6.92 ± 1.09). There were no differences among 2009 water management types ($F_{5,\,50.5}$ = 0.35, P = 0.88). However, there was a difference among 2008 water management types ($F_{3,\,54.7}$ = 6.31, P < 0.01; Figure A.3), where active-ditch sites were less than active, passive, and passive-ditch sites ($P \leq 0.03$; Figure A.3).

Overall mean specific conductivity (µS/cm) was greater in 2009 ($\bar{x}$ = 73.73 ± 1.23) than 2008 ($\bar{x}$ = 46.56 ± 1.25), though levels during both years would be classified as low. Greatest mean specific conductivity was in active-late-ditch sites during 2009 ($\bar{x}$ = 91.19 ± 1.23). The least mean specific conductivity was in passive-ditch sites during 2008 ($\bar{x}$ = 31.68 ± 1.33). Active management sites were ≥ 11% greater than passive management sites during 2008 and 2009. However, there were no significant differences among 2008 water management types ($F_{3,\,16.7}$ = 1.32, P = 0.30) and among 2009 water management types ($F_{5,\,23.6}$ = 0.64, P = 0.67; Figure A.4).

Overall mean total suspended solids (mg/L) concentrations were less in 2008 ($\bar{x}$ = 26.97 ± 1.54) than 2009 ($\bar{x}$ = 35.90 ± 1.62). Greatest mean total suspended solid concentrations were observed in active-early-ditch sites during 2009 ($\bar{x}$ = 53.38 ± 1.76) and least mean total suspended solid values were observed in 2009 active-early sites ($\bar{x}$ = 8.44 ± 1.87). Mean total suspended solids concentrations had greatest variability among water quality metrics, but there was no significant difference among 2008 water management types ($F_{3, 60.0} = 1.58$, $P = 0.20$) and among 2009 water management types ($F_{5, 55.8} = 1.15$, $P = 0.35$; Figure A.5).

Discussion

Results from this pilot study provide baseline data for future evaluations of water quality in WRP wetlands. There were no significant differences in temperature, pH, specific conductance, and total suspended solids among water management types ($P > 0.10$). Total dissolved oxygen was the only water quality parameter where I detected a difference among active-ditch sites and other water management types. Dissolved oxygen in 2008 active-ditch sites was less than other 2008 water management types ($P \leq 0.03$; Figure A.3). Dissolved oxygen can be influenced by a variety of factors, such as aquatic vegetation, whose respiration and photosynthesis can affect oxygen concentrations (Rose and Crumpton 1996). Similarly, prolonged wetland flooding can influence the microbial communities increasing anaerobic conditions and decreasing decomposition (Bossio et al. 2006). Wetlands can have low dissolved oxygen if decomposition processes dominate; however, managed wetlands should accumulate less organic matter, thus decomposition and associated oxygen consumption is reduced (Bossio et al. 2006).

Mississippi Department of Environmental Quality (MDEQ) has set broad water quality standards for the MAV (MDEQ 2007). The MDEQ has adopted a policy where guidelines and standards for pH, temperature, and dissolved oxygen shall apply to all waterbodies in Mississippi. The MDEQ water quality standards also include minimal standards for bacteria, specific conductance and dissolved solids for fish and wildlife. Because moist-soil management on WRP lands is directed at improving wetland habitat for wildlife, moist-soil wetlands should meet aforementioned general water body standards and fish and wildlife water quality criteria. Results from all water quality evaluations for temperature, pH, dissolved oxygen, and specific conductance were within the suggested Mississippi water quality standards for dissolved oxygen, and specific conductivity (i.e., ≤ 32.2ºC, 6.0-9.0, > 5 mg/L, and < 1000 µS/cm, respectively; see MDEQ 2007).

The MDEQ did not have standards for total suspended solids for comparison with my water management types. However, values from my water management types were similar to those measured in impounded wetlands on the Yazoo National Wildlife Refuge, Mississippi ($\bar{x}$ = 79.5 ± 25.3[SE]; Maul and Cooper 2000) and stubble rice fields, Mississippi MAV (35.2 ± 7.9[SE]; Manley et al. 2009). I did not measure bacteria or dissolved solids to compare with fish and wildlife water quality criteria.

Temperature is influenced strongly by outside conditions especially in shallow systems with little thermal mass where the range in temperatures was probably a result of diurnal variation and differences in water depth and flow. My pH values tended toward slightly basic conditions which are driven by the alkalinity common in MAV soils (Richardson and Vepraskas 2001). Similarly, active biological process in wetland soils can influence pH values where organic soils often tend toward basic conditions (Mitsch and Gosselink 2007). Specific conductance is driven by solubility of the ionic constituents in the soils which are low in the MAV as the data confirmed.

Moist-soil management encourages growth of a diverse community of early succession plants such as grasses and sedges (Fredrickson and Taylor 1982, Nelms 2007) and these types of vegetation can be effective at trapping suspended sediment. Studies have shown wetland management that encourages the growth of dense grass communities can decrease sediment loading (Barling and Moore 1994, Meyer et al. 1995). A lack of stabilizing vegetation can result in greater concentrations of total suspended soils as reduced vegetation maintains high water flow and suspended particles are flushed through the system (i.e., passive sites; Maul and Cooper 2000, Stanley et al. 2000), conditions of which are of particular concern in regions like the MAV with highly erodible soils (Nett et al 2004, Manley et al. 2009). I did not detect differences in total suspended solids among my water management types, but variance in this metric was relatively large within and among my water management types. Therefore, larger sample sizes appear necessary to reduce variation (i.e., coefficient of variation) to determine precisely mean total suspended solids of individual moist-soil wetlands and effects of management regimes.

Studies have reported greater variability of total suspended solids and no difference in temperature, pH, dissolved oxygen concentrations, and specific conductance in flooded agricultural fields (Maul and Cooper 2000) and urban stormwaters (Birch et al. 2004). Most water quality parameters measured on my WRP wetlands were highly variable with no clear differences among water management types (Figures A.1-A.5). However, my data support that WRP moist-soil wetlands had similar water quality parameters, at the time of sampling, as nearby ditches.

Conclusions

I conducted an initial evaluation of water quality in moist-soil wetlands and associated nearby ditches. However, my single sampling event in March 2008 and 2009 did not detect any consistent differences in basic water quality metrics among my water management types. Therefore, water management types may not influence water quality based on a single sampling event. Future research should provide detailed evaluations and analyses of soil and nutrient cycling and retention, accumulation and retention of organic compounds. Further, researchers should examine a broader range of temporal and spatial variations within individual wetlands to identify the factors and process (i.e., sediment retention and transformation of nutrients) that influence water quality (Smith et al. 1997). Similarly, a detailed evaluation of indicator biotic communities (i.e., invertebrates, periphyton) could provide integrated information on water quality (Mitsch and Gosselink 2007). Developing an *a priori* definitions of 'water quality' would ensure that proper metrics were evaluated (e.g., nutrient loading, contaminant levels, total suspended solids) to address more focused questions. My study suggested that our single sampling event did not detect differences in water quality among water management types in WRP restored moist-soil wetlands. However, rigorous analyses need to be performed on focused water quality parameters over time (sensu APHA 2005) to ensure conservation goals and objectives are being met.

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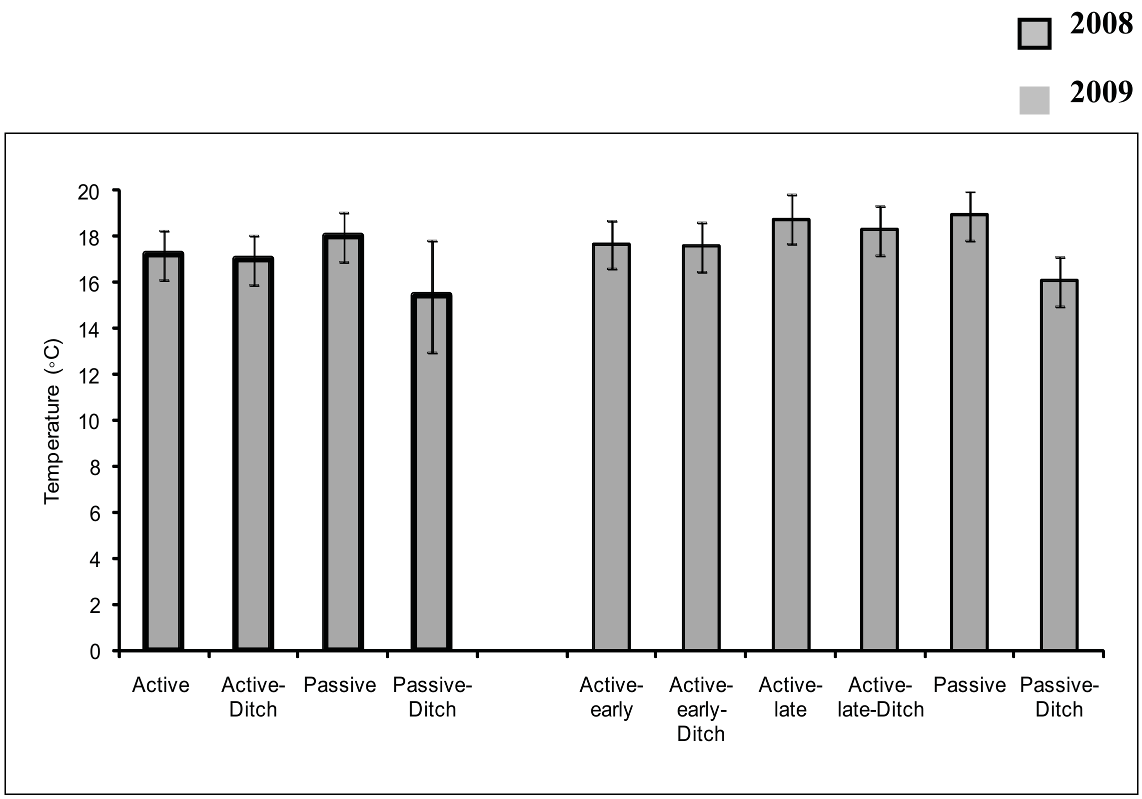

Figure A.1. Mean temperature ± SE (°C) in 54 moist-soil wetlands and 18 paired drainage ditches among management types on Wetland Reserve Program Lands, Mississippi, 2008-2009.

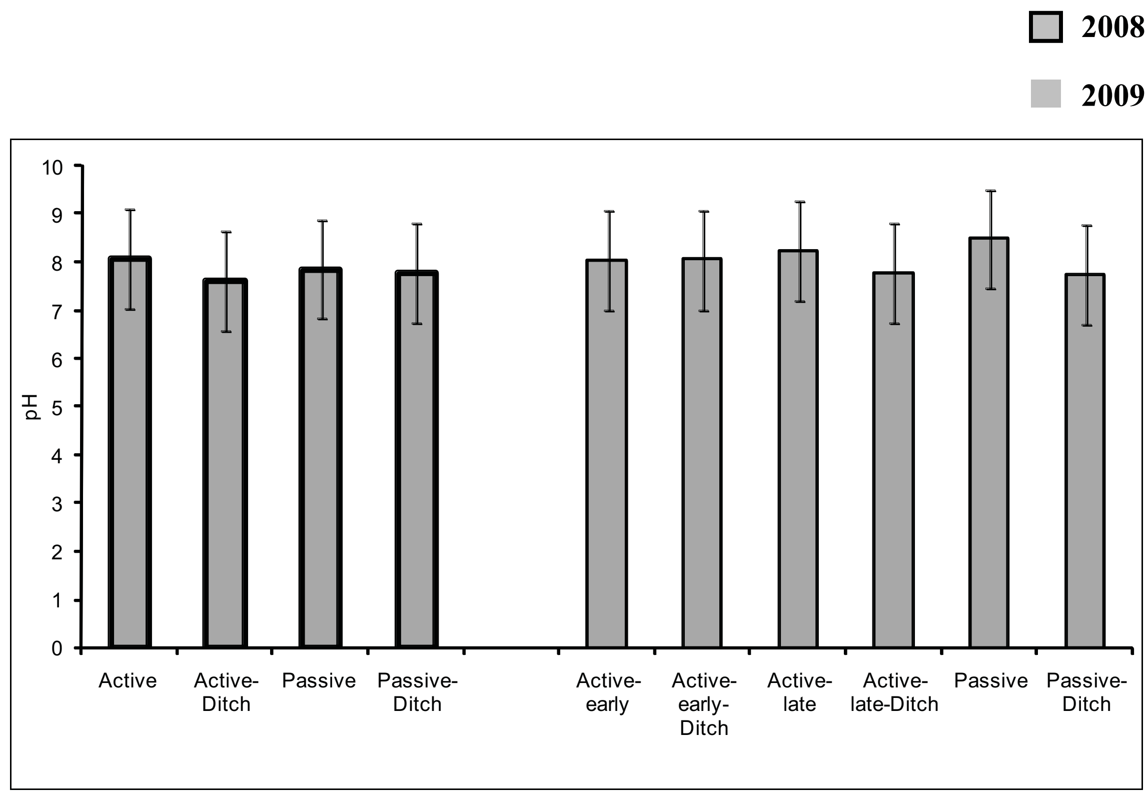

Figure A.2. Mean pH ± SE in 54 moist-soil wetlands and 18 paired drainage ditches among management types on Wetland Reserve Program Lands, Mississippi, 2008-2009.

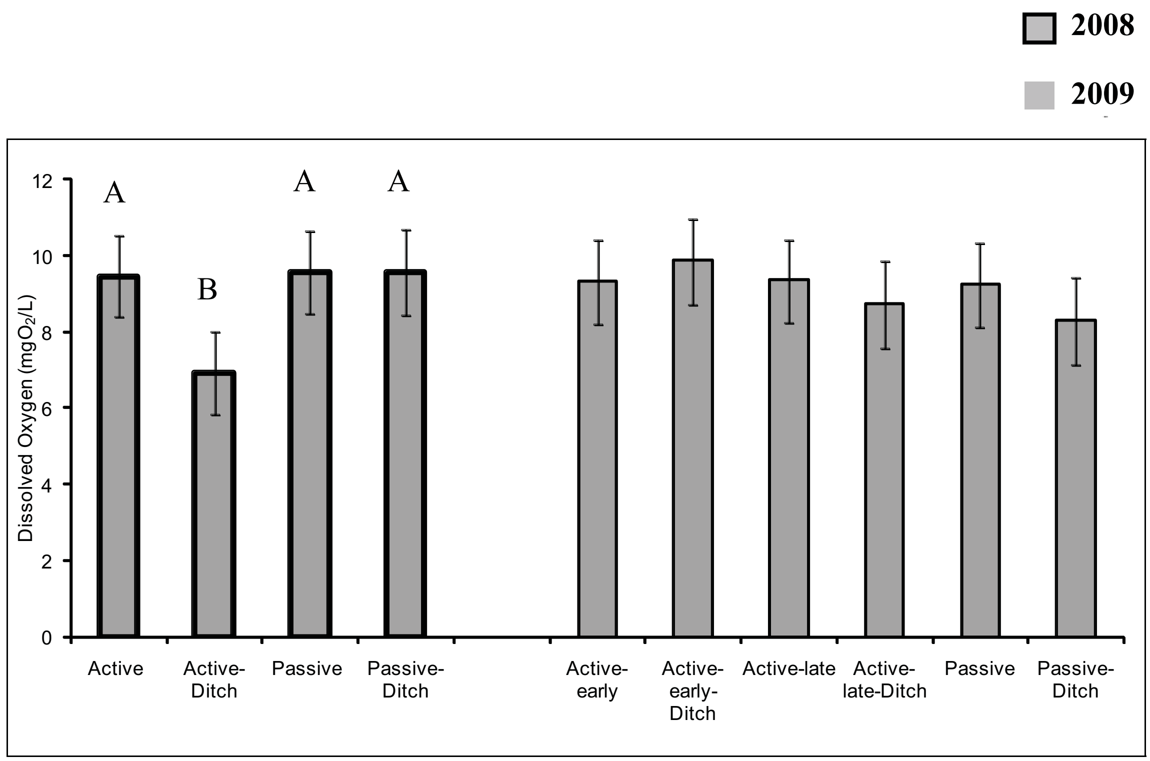

Figure A.3. Mean dissolved oxygen ± SE (mgO_2/L) in 54 moist-soil wetlands and 18 paired drainage ditches among management types on Wetland Reserve Program Lands, Mississippi, 2008-2009. Means followed by unlike letters in 2008 differ ($P < 0.10$).

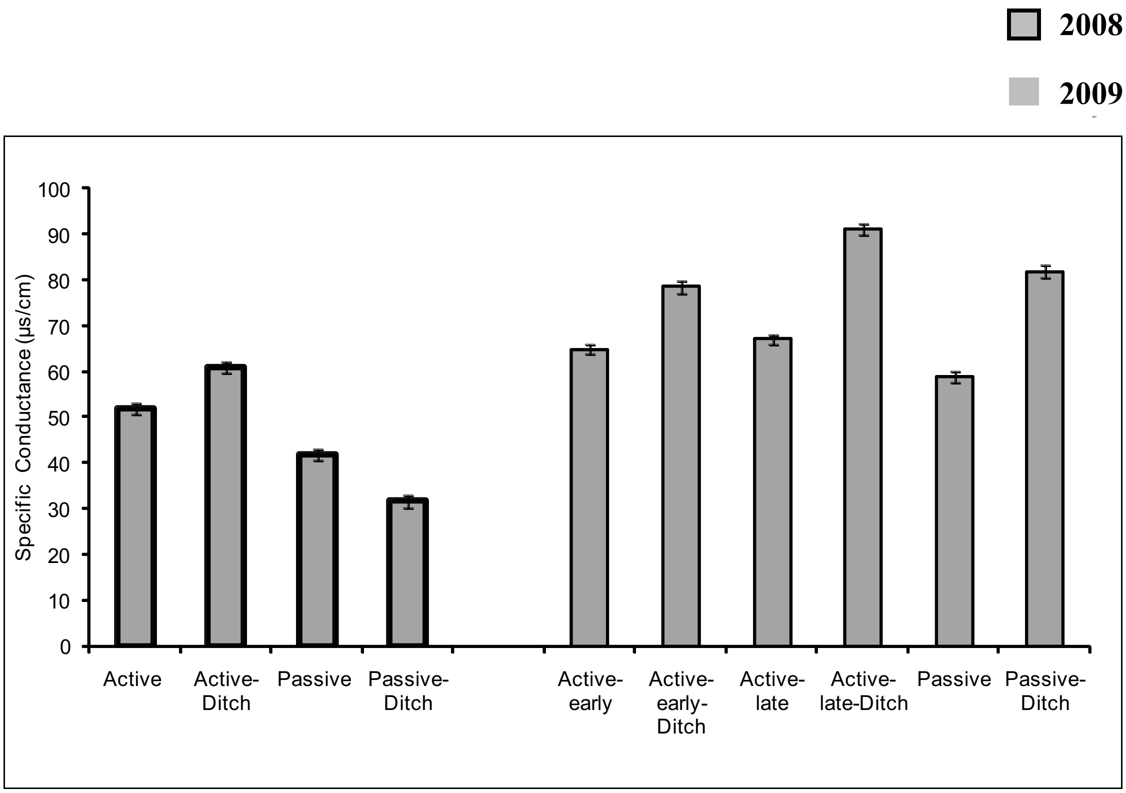

Figure A.4. Mean Specific Conductance ± SE (µS/cm) in 54 moist-soil wetlands and 18 paired drainage ditches among management types on Wetland Reserve Program Lands, Mississippi, 2008-2009.

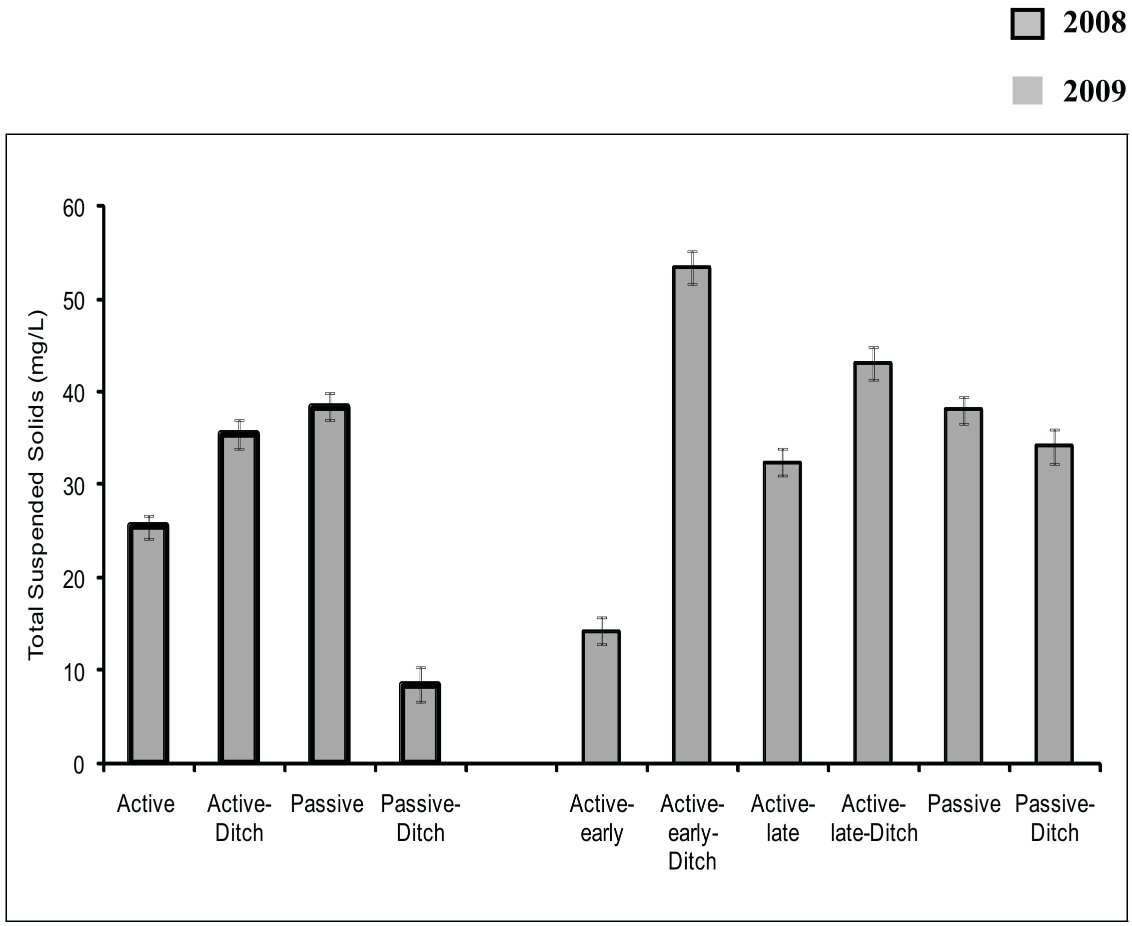

Figure A.5. Mean total suspended solids ± SE (mg/L) in 54 moist-soil wetlands and 18 paired drainage ditches among management types on Wetland Reserve Program Lands, Mississippi, 2008-2009.