Project Title: Water quality and other ecosystem services from wetlands managed for waterfowl in Mississippi

Co-Principal Investigators: Richard M. Kaminski, Ph.D.; Amy B. Spencer, Ph.D. student
Department of Wildlife, Fisheries, and Aquaculture
Mississippi State University, Box 9690
Mississippi State, MS 39762
Tel: (662) 325-2623 Fax: (662) 325-8726
Email: rkaminski@cfr.msstate.edu
aspencer@cfr.msstate.edu

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Technical Abstract

A successful and increasingly applied conservation practice in the Lower Mississippi Alluvial Valley (MAV) to mitigate loss of wetland wildlife habitat and improve water quality has been development and management of "moist-soil wetlands." Whereas a primary goal of moist-soil management is to provide abundant food resources for waterfowl and other waterbirds in the MAV and elsewhere on the wintering and migrational grounds, this conservation practice has the potential to provide ecosystem services critical to restoring ecosystem functions in the MAV. Within the MAV, strategic location of natural moist-soil wetlands amid farmed lands can reduce dispersal of sediments and other nutrients into surrounding watersheds. Moreover, a significant potential exists for native crayfish (*Procambarus* spp.) harvest in moist-soil wetlands in the MAV. Our current research is designed to quantify nutrient management and crayfish harvest as ecosystem services provided by moist-soil wetland management in the MAV. During spring 2009, we estimated baseline water quality parameters and average daily yield of crayfish from 9 moist-soil wetlands in Mississippi. Mean NO_3-N, NH_4-N, and PO_4-P concentrations were variable whereas total suspended solid concentrations decreased over time. Average daily yield of crayfish was 1.75 kg ha^{-1} (CV = 16%, $n = 9$). We continued our study in spring-summer 2010 in wetlands in Arkansas, Louisiana, and Mississippi. Preliminary estimates of average daily yield of crayfish in 2010 was 2.18 kg ha^{-1} (CV = 30%, $n = 15$). In July 2010, we installed water quality monitoring stations at 6 wetlands and 6 agriculture fields. We will use the data from these stations to estimate and compare monthly loads (kg ha^{-1}) of nutrients and solids from moist-soil wetlands and flooded agricultural fields. Quantifying these ancillary ecosystem services of moist-soil wetlands will encourage further establishment and management of these wetlands in the MAV and elsewhere for wildlife and associated environmental benefits.

INTRODUCTION

Loss of wetlands in the MAV has reduced surface water quality (e.g., Mitsch et al. 2005, Shields et al. 2009). To address loss of ecosystem services, ecologists and wildlife managers have encouraged best management practices (Maul and Cooper 2000, Stafford et al. 2006, Manley et al. 2009) and reestablishment of wetlands (Mitsch et al 2005, Kovacic et al. 2006, Kross et al. 2008) throughout the Mississippi River drainage. A successful management practice in the MAV to address loss of wetland wildlife habitat has been the establishment of moist-soil wetlands. Moist-soil wetlands are naturally vegetated basins, usually by herbaceous annuals (e.g., grasses, sedges), that are prolific producers of seeds and tubers. Because moist-soil wetlands can provide 4-10 times the carrying capacity of harvested agriculture fields in MAV (Kross et al. 2008), management of these habitats is encouraged to meet the goal of sustaining continental populations of waterfowl under the North American Waterfowl Management Plan (United States Fish and Wildlife Service 1986).

Additionally, within the MAV, strategic location of moist-soil wetlands amid farmed landscapes can reduce dispersal of sediments and other nutrients into surrounding watersheds. Predictions have been made regarding the environmental significance of this conservation practice relative to improving surface water quality in the MAV (Mitsch et al. 2005, Murray et al. 2009). However, to our knowledge, no effort has been made to quantify the success of this conservation practice to meet the goals of federal environmental quality mandates such as the Clean Water Act (CWA).

In addition to benefits provided by living plant material in moist-soil wetlands (e.g., carbon sequestration), seasonal flooding promotes decomposition of senescent vegetation (Magee 1993). Crayfish feed on the microbial consumers of detritus and other macroinvertebrates found in wetlands (Alcorlo et al. 2004). Thus, creating and managing moist-soil wetlands have propensity to provide significant habitat and forage for crayfish, opportunities for crayfish production and harvest, and additional economic gain for landowners (McClain et al. 1998). Harvest of crayfish for human consumption is significant, amounting to $115 million annually in the southern United States (Romaire et al. 2004). However, traditional crayfish-harvest operations incur considerable costs. Crayfish must be stocked annually into rice or other impounded fields. A sustainable crayfish-harvest from naturally occurring populations in moist-soil wetlands is a likely a cost-effective alternative.

OBJECTIVES

Our project is designed to identify additional ecosystem services provided by public- and private-sector management of naturally and artificially flooded moist-soil wetlands in the Mississippi Alluvial Valley (MAV). Specifically, the first year of our study was designed to (1) provide a baseline for water quality benefits accrued by retaining winter and spring waters in managed wetlands and (2) estimate production of crayfish populations in moist-soil wetlands. We completed the first year of our field research during March-June 2009. We will expand on our efforts during March-June 2010.

METHODS

Study Sites

During the 2009 field season, we identified 9 moist-soil wetlands on public and private lands in Mississippi. Locations of moist-soil wetlands were: Yazoo National Wildlife Refuge, Hollandale, Mississippi; Panther Swamp National Wildlife Refuge, Yazoo City, Mississippi; Morgan Brake National Wildlife Refuge, Tchula, Mississippi; Coldwater National Wildlife Refuge, Charleston, Mississippi; York Woods, Charleston, Mississippi; Noxubee National Wildlife Refuge, Brooksville, Mississippi; Trim Cane Wildlife Management Area, Starkville, Mississippi; and Property of Mr. C. Clark Young, West Point, Mississippi. During the 2010 field season, we identified 15 moist-soil wetlands on public and private lands in Arkansas, Mississippi, and Louisiana. Locations of the wetlands were: Cache River National Wildlife Refuge, Brinkley, Arkansas; Wappanocca National Wildlife Refuge, Turrell, Arkansas; Coldwater National Wildlife Refuge, Charleston, Mississippi; Property of Dr. Ronal Roberson, Tippo, Mississippi; Morgan Brake National Wildlife Refuge, Tchula, Mississippi; Panther Swamp National Wildlife Refuge, Yazoo City, Mississippi; Yazoo National Wildlife Refuge, Hollandale, Mississippi, Noxubee National Wildlife Refuge, Brooksville, Mississippi; the Property of Mr. C. Clark Young, West Point, Mississippi; Tensas National Wildlife Refuge, Tallulah, Louisiana; Catahoula National Wildlife Refuge, Jena, Louisiana; and Grand Cote National Wildlife Refuge, Marksville, Louisiana. Managed moist-soil wetlands vary in area (1-8 ha), are often fallowed cropland or idled ponds, and have functioning water control structures and levees.

Field and Analytical Methods

We monitored NO_3-N, NH_4-N, PO_4-P and total suspended solid (TSS) concentrations (mg l^{-1}) within each wetland from April to June 2009. Grab samples were taken from each wetland, stored on ice, and transported to the lab. Within 24 hours of sampling, we estimated nutrient concentrations in each sample colorimetrically with a LaMotte handheld colorimeter. We estimated TSS concentrations by filtering a known volume of sample through a pre-washed and dried 1.5-µm glass fiber filter. We then dried the sample-washed filter to a constant weight at 120 C. The difference in weight between the clean filter and the sample-washed filter was used to estimate the concentration of suspended solids in the sample.

The amount of vegetation is thought to have an effect on the yield of crayfish in traditional rice-crayfish production systems (McClain 1997). We evaluated change in mean biomass of vegetation over time by collecting monthly vegetation samples (live and senescent) from ten 0.5-m^2 plots within each wetland. Samples were washed, dried at 60 C and weighed (g) to estimate dry vegetative mass.

We estimated yield of crayfish in moist-soil wetlands from April to June 2009 and April to June 2010. We set baited pyramid-style crayfish traps at a density of 25 traps ha^{-1}. We were limited by the number of traps and therefore, we set traps in each wetland every other week in 2009. Traps were baited and checked for crayfish after 48 hours. With extension of FY2009 funds, we purchased additional traps and were able to trap crayfish every week in 2010. Traps were baited and checked for crayfish after 24 hours. All crayfish in traps were taken back to the lab where individuals were sexed, identified to species, weighed (g), and measured for carapace length (mm). We estimated relative abundance as crayfish $trap^{-1}$ and yield as kg ha^{-1}. We also compared length-frequency distributions of crayfish across moist-soil wetlands with a Kruskal-Wallis test ($\alpha = 0.05$).

RESULTS

The average concentration of TSS across all wetlands was 17.5 mg l^{-1} (CV = 5%). A general decline in TSS concentrations was apparent across the study period (Table 1). The change in TSS concentrations across the study period for individual wetlands ranged from a decline of 84% to an increase in 29% (Table 2). The average concentration of NH_3-N across all wetlands was 0.58 mg l^{-1} (CV = 10%). Concentrations of NH_3-N did not exhibit a change over the study period (Table 1). The average concentration of NO_3-N across all wetlands was 0.07 mg l^{-1} (CV = 66%). Concentrations of NO_3-N were variable and did not exhibit a discernable temporal trend (Table 1). The average concentration of PO_4-P across wetlands was 0.49 mg l^{-1} (CV = 4%). As with NH_3-N, concentrations of PO_4-P did not exhibit a temporal trend (Table 1). Average vegetative biomass in moist-soil wetlands from April to June 2009 was 29.2 g m^{-2} (CV = 27%). Vegetation in some wetlands decreased over time, while others exhibited increases in vegetation (Table 3).

We harvested a total of 91 kg of crayfish from 1,298 trap sets in 2009. The pooled mean relative abundance was 2.6 crayfish $trap^{-1}$ (CV = 17%) and the mean daily yield was 1.75 kg ha^{-1} (CV = 16%). Average yield in wetlands in East Mississippi were lower than from wetlands in the Delta region (Figure 1). We encountered two species of crayfish in the sampled moist-soil wetlands: *Procambarus clarkii*, the Red Swamp Crayfish; and *Procambarus acutus*, the White River Crayfish. Both species are the primary species cultured in rice-crayfish production systems. We only encountered the Red Swamp crayfish in wetlands located in the Delta region. The length-frequency distributions of the Red Swamp crayfish were significantly different across wetlands with wetlands in the south Delta region producing larger individuals (K-W $p < 0.0001$; Figure 2). We harvested the White River crayfish from all wetlands except for one wetland in the south Delta region. The length-frequency distributions of the White River crayfish differed significantly across wetlands and wetlands in East Mississippi produced significantly smaller individuals (K-W $p < 0.0001$; Figure 3).

In 2010 we harvested a total of 94 kg of crayfish from 2,005 trap sets in wetlands located in Arkansas, Mississippi, and Louisiana. Preliminary estimates of the pooled mean relative abundance is 2 crayfish $trap^{-1}$ (CV = 16%) and the mean daily yield is 2.18 kg ha^{-1} (CV = 16%). We are currently analyzing harvest data from 2010. Full results will be reported in FY2010 final report.

DISCUSSION

Seasonally flooded plant communities concentrate nutrients and sediments from agricultural and other non-point sources of run-off (Maul and Cooper 2000, Manley et al. 2009). Whereas site-specific investigations of the environmental significance are key to understanding functional capabilities of these wetlands (King et al. 2009), a landscape- or ecosystem-scale (Mitsch and Day 2004) approach is necessary to predict the capability of this practice to improve ecosystem quality. In 2009, we demonstrated that moist-soil wetlands exhibit declines in total suspended solid concentrations during spring while nutrient concentrations did not exhibit discernable reductions over time. Nonetheless, estimates of nutrient concentration from moist-soil wetlands in 2009 were lower than those estimated from agriculture fields in Mississippi (Maul and Cooper 2000). For example, water in flooded agriculture fields exhibit average concentrations of suspended solids of 283 mg l^{-1} (Maul and Cooper 2000). Whereas estimates of concentrations within wetlands provide information regarding within-wetland water quality, current estimates of the benefit of these wetlands to landscape environmental quality are unknown. Therefore, in 2010, we installed water sampling stations at the outflow of six wetlands and six agriculture fields. We will use the data from these stations to estimate and compare monthly loads (kg ha^{-1}) of nutrients and solids from moist-soil wetlands and flooded agricultural fields.

Vegetative biomass decreased in some wetlands whereas it increased in others during spring-summer 2009. Increases in vegetative biomass in these wetlands were caused by growth of submerged and emergent aquatic macrophytes (e.g., *Ludwigia leptocarpa*). Because of predictions made from rice-crayfish production systems, we expected that decreases in vegetative biomass in wetlands would result in lower yields of crayfish. We did not see an apparent relationship in the change in vegetation and crayfish yield (Table 3). We collected vegetation samples from wetlands in 2010. Therefore, a larger sample sizes will enable us to evaluate the relationship between vegetative biomass and crayfish yields in 2011.

In high yield rice-crayfish production systems in Louisiana, producers can expect daily yields of 10.5 kg ha^{-1}. Our yields from 2009 and 2010 were substantially lower in moist-soil wetlands. Whereas yields are greater in traditional production fields, these systems also have greater associated fixed and variable costs compared to moist-soil wetlands (Avery et al. 1998). For example, a producer with a 16-ha rice field can expect to spend $1,000 to $2,000 annually on planting a forage base in fields. Whereas in moist-soil wetlands this variable cost is nonexistent or minimal because the forage base is natural vegetation. Additionally, a crayfish producer in Louisiana must produce high yields to profit. A preliminary estimate of the expected direct costs associated with rice-crayfish operations is \$750 ha^{-1}. Direct costs associated with harvesting crayfish from moist-soil wetlands is likely only to include costs for bait and traps and is estimated to be \$485 ha^{-1}. Therefore, producers of crayfish in rice-crayfish operations must either sell more crayfish or demand higher prices to cover direct costs. We will use estimated yields from 2009 and 2010 to refine our estimates of the economic potential of crayfish harvest from moist-soil wetlands.

Strategic location of moist-soil wetlands amid farmed lands can reduce transport of sediments and other nutrients into surrounding watersheds and thus enhance water and environmental qualities. A major environmental, ecological, and economic consequence of loss of wetlands throughout the Mississippi River Basin has been the development of the hypoxic zone in the Gulf of Mexico (Rabalais et al. 2002). Moist-soil wetlands may reduce nitrogen inputs to the Gulf of Mexico. Subsequently, quantifying ecosystem services provided by moist-soil management will facilitate fulfillment of proposed surface water quality regulations (i.e., total maximum daily loads). Finally, understanding the economic benefits of crayfish harvests from moist-soil wetlands will likely encourage the establishment of these wetlands and therefore increase habitat for waterfowl and other wetland wildlife throughout the MAV.

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Spencer, A.B., H.M. Hagy, R.M. Kaminski. 2009. Crayfish-harvest potential in wetlands managed for waterfowl in Mississippi. Poster Presentation presented at the 139th meeting of the American Fisheries Society, Nashville, TN. August 31-September 3, 2009.

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TRAINING POTENTIAL

The proposed project provided necessary field work for Amy Spencer, a PhD student in Department of Wildlife and Fisheries at Mississippi State University. Ms. Spencer's field of interest is in wetland ecology and aquatic ecosystem management. She also holds a Master's degree in fisheries from the department and her extensive aquatic ecology and population modeling background will aid in the successful implementation of the proposed research. We hired Christian Singleton, a Starkville High School senior who learned valuable field experience and knowledge about wetland and waterfowl conservation. We also hired Mason Conley, an undergraduate student in the Department of Wildlife, Fisheries, and Aquaculture at Mississippi State University. Numerous graduate students in the Department of Wildlife, Fisheries, and Aquaculture also volunteered invaluable time. We also encouraged landowners and land managers to observe water quality and crayfish sampling activities. We received field assistance from one landowner as well. We also involved high school students in crayfish harvest activities during a College of Forest Resources' sponsored summer camp. We believe that continuing our model of a combination of formal and informal training will increase the population of individuals aware of wetland conservation principles.

Student Training

Name	Level	Major
Amy B. Spencer (Co-PI)	Ph.D.	Forest Resources
Christian Singleton (Wage)	High School	Starkville (MS) High
Mason Conley (Wage)	B.S.	Wildlife and Fisheries
Alan Leach (Volunteer)	M.S.	Wildlife and Fisheries
Matt Palumbo (Volunteer)	M.S.	Wildlife and Fisheries
James Callicutt (Volunteer)	M.S.	Wildlife and Fisheries
Jacob Straub (Volunteer)	Ph.D.	Forest Resources
Justyn Foth (Volunteer)	M.S.	Wildlife and Fisheries
Heath Hagy (Volunteer)	Ph.D.	Forest Resources

Table 1. Average (± S.E.) total suspended solid and nutrient concentrations (mg l^{-1}) in moist-soil wetlands in Mississippi for each sampling event in 2009.

	Period				
Variable	1	2	3	4	5
TSS	20.2±4.73	18.5±4.46	17.7±4.00	16.3±3.60	14.8±3.36
NH_3-N	0.80±0.24	0.55±0.03	0.51±0.05	0.50±0.1	0.52±0.05
NO_3-N	0.03±0.02	0.004±0.003	0.01±0.01	0.24±0.06	0.05±0.02
PO_4-P	0.46±0.05	0.56±0.14	0.49±0.13	0.52±0.13	0.44±0.08

Table 2. Percent change in total suspended solid concentrations in moist-soil wetlands in Mississippi during April to June 2009. ND = North Delta; EMS = East Mississippi; SD = South Delta.

Site	% change in total suspended solids
ND1	-84.3
ND2	-59.6
ND3	-64.2
EMS1	-50.0
EMS2	-34.4
EMS3	+29.49
SD1	-2.6
SD2	-7.7
SD3	-8.2

Table 3. Average (± S.E.) daily yield of crayfish and percent change in vegetative biomass in moist-soil wetlands from April to June 2009.

Site	Average [a] yield (kg/ha)	% change in vegetation dry mass
ND1	1.0 ± 0.4	-35.0
ND2	3.6 ± 0.2	-65.0
ND3	2.1 ± 0.4	+35.0
EMS1	1.1 ± 0.4	-43.9
EMS2	1.2 ± 0.3	+41.6
EMS3	0.9 ± 0.2	+40.1
SD1	2.6 ± 1.2	+82.7
SD2	3.6 ± 1.4	+36.4
SD3	2.2 ± 0.5	+92.2

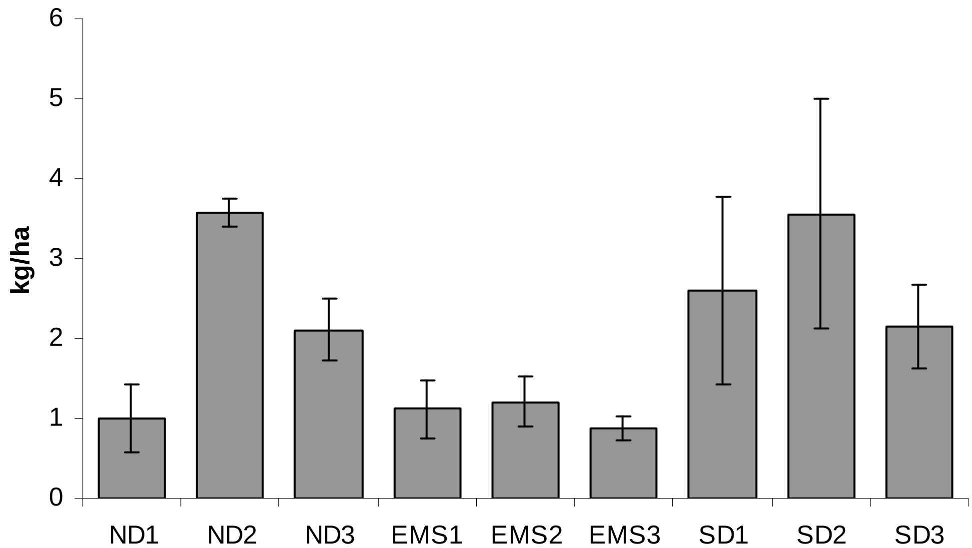

Figure 1. Average daily yield of crayfish from moist-soil wetlands in Mississippi during April to June 2009.

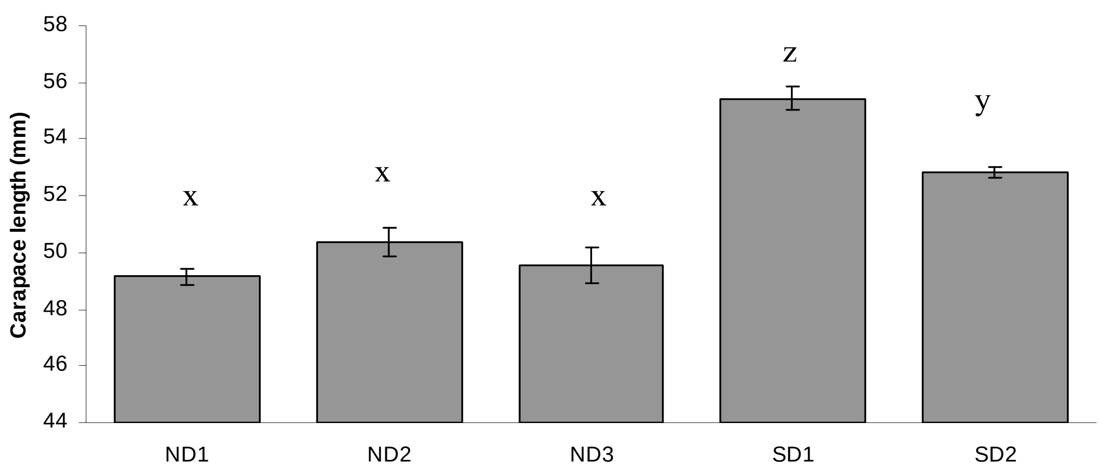

Figure 2. Average carapace length of Red Swamp crayfish harvested from moist-soil wetlands during April to June 2009. Letters designate significant ($p < 0.0001$) least-squared differences in length-frequency distributions.

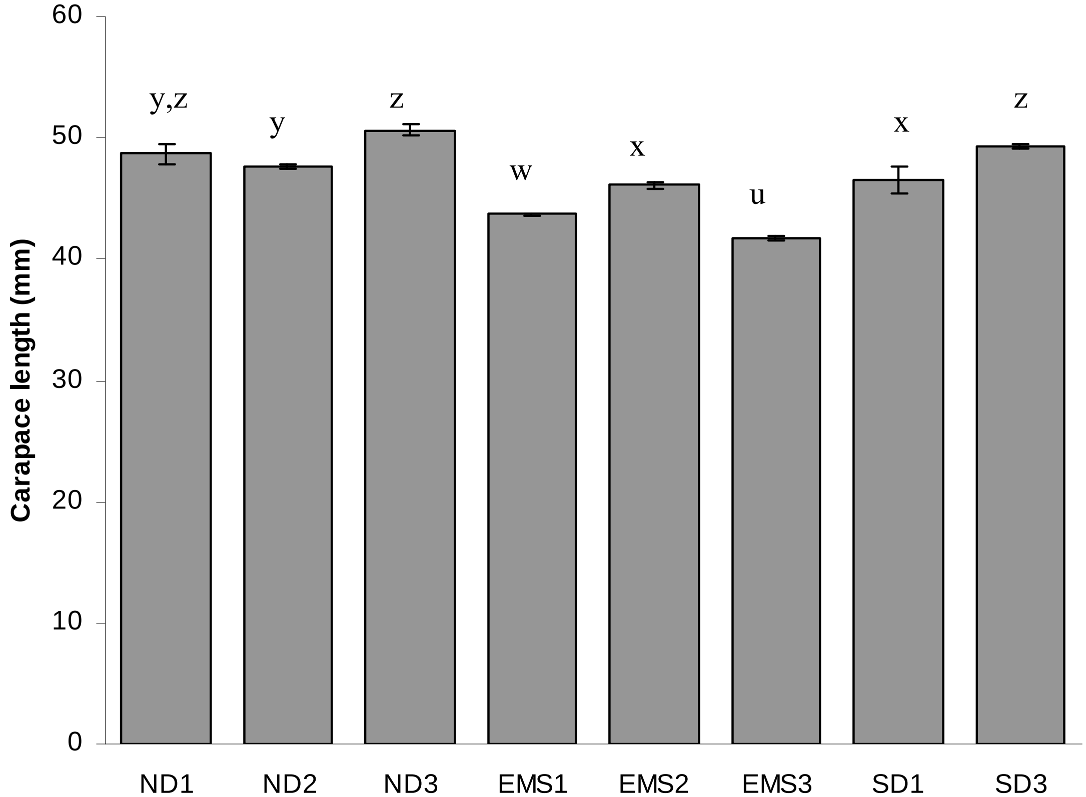

Figure 3. Average carapace length of White River crayfish harvested from moist-soil wetlands during April to June 2009. Letters designate significant ($p < 0.0001$) least-squared differences in length-frequency distributions.