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

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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." This conservation practice has the potential to provide ecosystem services critical to restoring wetland functions in the MAV such as reducing dispersal of sediments and nutrients into surrounding watersheds. Moreover, a significant potential exists for native crayfish (*Procambarus* spp.) harvest in moist-soil wetlands in the MAV. During spring 2011, we estimated average daily yield of crayfish from 18 moist-soil wetlands in Arkansas, Louisiana, Mississippi, and Missouri. Average daily yield in 2011 was 3.64 kg/ha (CV = 33%). This estimate was slightly greater and more variable than the estimated yield from Mississippi wetlands in 2009 (i.e., 1.75 kg ha^{-1}; CV = 16%, $n = 9$) and wetlands in Arkansas, Louisiana, and Mississippi in 2010 (i.e., 2.18 kg ha^{-1};CV = 30%, $n = 15$) . Our estimated daily yield of naturally occurring crayfish from moist-soil wetlands is lower than 10 kg ha^{-1} which is the average daily yield from commercially operated rice-crayfish ponds in Louisiana. However, our comparisons of operating budgets from the two harvest systems indicated that rice-crayfish systems incur $1455 in direct expenses per hectare whereas crayfish harvest operation in moist-soil wetlands incur $682 direct expenses per hectare. Although fixed expenses are lower in harvest operations from moist-soil wetlands, lower yields increased the break-even selling prices from $2.75 kg^{-1} in rice-crayfish systems to $6.38 kg^{-1} in moist-soil harvest systems. These prices, however, are still less than those observed in regions of the Southeastern United States outside of Louisiana. To determine if crayfish harvested from moist-soil wetlands are an acceptable seafood product relative to commercially harvested crayfish, we conducted a consumer acceptability panel in May 2011. We found that crayfish from both sources were well liked and did not differ significantly ($p > 0.05$) in overall consumer acceptability. In July 2010, we installed water quality monitoring stations at 5 wetlands and 5 agriculture fields. We monitored concentrations of nutrients and sediments exported from these habitats during storm events in December-March of 2010-2012. We determined that wetlands exported significantly less total suspended solids and NO_3 than agriculture fields in 2010-2011 whereas all parameters except for NH_3 were significantly lower in wetland effluent compared to agriculture fields in winter 2011-2012. We were able to calculate loads (kg ha^{-1}) from wetland habitats during the study years and determined that total annual loads of nutrients were slightly greater than currently assumed loading values of wetlands in Mississippi (i.e., 1 kg ha^{-1}). 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 and human 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 was 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 third year of our three-year study was designed to (1) estimate production of crayfish populations in moist-soil wetlands, (2) compare operating budgets of Louisiana rice-crayfish harvest systems with hypothetical budgets of moist-soil crayfish harvest systems in the MAV, (3), evaluate consumer acceptability of crayfish harvested from moist-soil wetlands, (4) quantify and compare nutrient and sediment concentrations discharged from moist-soil wetlands and adjacent agriculture fields, and (5) estimate loads of nutrients and sediments exported from moist-soil wetlands in north Mississippi.

METHODS

Study Sites

We identified 18 moist-soil wetlands on public and private lands in Arkansas, Louisiana, Mississippi, and Missouri that were appropriate for our crayfish harvest research. Locations of the wetlands were: Otter Slough Wildlife Management Area, Dexter, Missouri; Wappanocca National Wildlife Refuge, Turrell, Arkansas; 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 varied in area, were fallowed cropland or idled ponds, and had functioning water control structures and levees.

To monitor water quality of effluents from moist-soil wetlands, in July 2010 we identified 5 wetlands in the north Delta region of Mississippi. The locations of these wetlands are: Tallahatchie National Wildlife Refuge, Macel, Mississippi; Property of Dr. Ronal Roberson, Tippo, Mississippi; Charleston Farms Wetland Complex, Charleston, Mississippi; Lone Cypress Wetland Complex, Oxberry, Mississippi; and Property of Mr. Robert Brittingham, Dwiggins, Mississippi.

Field and Analytical Methods

We estimated yield of crayfish in moist-soil wetlands from April to July 2011. We set baited pyramid-style crayfish traps at a density of 25 traps ha^{-1}. 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). Average daily yield was estimated as kg ha^{-1}. Our sampling efforts were limited to no more than 6 visits per site in 2011 because flooding of the Mississippi River limited access to many sites.

To create operating budgets and estimate break-even selling prices of crayfish, we estimated daily yield (kg ha^{-1}) of crayfish from moist-soil wetlands as the average of daily yield estimates from all sampled wetlands from 2009-2011. We modified 2012 enterprise budgets for rice production in Mississippi in the Mississippi State Budget Generator version 6.0 (Spurlock and Laughlin 2008) to reflect costs associated with moist-soil wetland management and harvest of crayfish. These operating budgets and break-even selling prices were then compared to current enterprise budgets for production of crayfish in planted rice-fields of Louisiana (Boucher and Gillespie 2012).

We recruited 149 volunteers from the Starkville community to evaluate the acceptability of cooked crayfish tail meat at the Garrison Sensory Laboratory with cooperation for Dr. Wes Schilling of the Department of Food Science, Nutrition and Health Promotion. Panelists evaluated crayfish harvested from moist-soil wetlands and crayfish harvested from commercial rice-crayfish production fields for taste, texture, appearance, aroma, and overall acceptability based on a nine-point hedonic scale. The values for the scale were: 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; and 9 like extremely We used a randomized complete block design with panelists as blocks to evaluate differences ($\alpha = 0.05$) in overall consumer acceptability of the two crayfish tail meat samples.

We monitored nitrate (NO_3-N) nitrite (NO_2-N), ammonium (NH_3-N), soluble reactive phosphorus (SRP), particulate phosphorus (PP), total inorganic phosphorus (TP) and total suspended solid (TSS) concentrations (mg l^{-1}) within each wetland and in wetland effluent beginning July 2010. We installed storm water samplers at the water control structure of each wetland. These samplers are designed to take a effluent sample when precipitation was significant enough to produce wetland discharged. We monitored weather data and river gaging station data and retrieved storm samples within 48 hours. An agriculture field adjacent to each wetland was also sampled for effluent water quality and grab samples were taken when significant flooding occurred on the field to warrant a water sample. Within 24 hours of sampling, aliquots of each sample were filtered through a 0.45 µm cellulose filter and NO_3-N, NO_2-N, NH_3-N, and SRP concentrations were determined colorimetrically on a Hach DR 5000 spectrophotomer according to appropriate protocols (APHA 2005). We digested unfiltered aliquots of each sample and determined TP colorimetrically. We then estimated PP as the difference between TP and SRP. Beginning in December 2010, in cooperation with the Water Quality Laboratory in the Department of Wildlife, Fisheries, and Aquaculture, we also determined NO_3-N and NO_2-N concentrations with a Lachat QuickChem 8500 Flow Injection Analysis System. 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. To evaluate differences in concentrations of nutrients and sediments in runoff samples from wetlands and agriculture fields, we conducted a repeated measures analysis of variance ($\alpha = 0.05$).

We used barometric pressure referenced data loggers (In-Situ Troll 300) to estimate depth of water at water control structures at the study wetlands. We then used the logged data and standard weir equations to estimate discharge ($m^3 sec^{-1}$) from these wetlands during storm events. We created hydrographs for each sampling event, estimated total volume (L) of runoff for each peak storm event, and estimated the average wetland area (ha). We then calculated loads (kg ha^{-1}) of nutrients and sediments from the total volume of water discharged during the peak event and the measured nutrient and sediment concentrations as mentioned above.

RESULTS and DISCUSSION

Average daily yield of crayfish in 2011 was 3.64 kg ha^{-1} (n =18, CV = 32.8%). Average daily yields of crayfish from moist-soil wetlands for all three study years (2009-2011) ranged from 0.08 kg/ha to 23 kg/ha with an overall mean yield of 2.73 kg/ha (n = 42, CV = 21%). Wetlands located in Louisiana typically exhibited greater yields (Table 1).

In rice-crayfish commercial systems in Louisiana, farmers typically observe total yields of 600 kg during a 75 day season and therefore experience daily yields of 10 kg ha^{-1}. A typical harvest season in moist-soil wetlands will be shorter (i.e., 40 days) to ensure water management practices are followed that encourage optimal vegetation establishment. Our estimated average daily yield of crayfish harvested from moist-soil wetlands (2.73 kg ha^{-1}) is considerably lower than extensive culture practices in Louisiana. However, we determined that total fixed expenses associated with commercial systems (Table 2; Boucher and Gillespie 2012) were considerably higher compared to our estimates of fixed expenses associated with harvesting natural populations of crayfish from moist-soil wetlands (Table 3). Harvesting crayfish from moist-soil wetlands can potentially incur a cost of \$682 ha^{-1} (\$275 $acre^{-1}$) for a 40 season whereas commercial operations incur costs of \$1455 ha^{-1} (\$587 $acre^{-1}$) for a 75 season. Although the break-even selling price needed to recover fixed costs for harvesting crayfish from moist-soil wetlands (i.e., \$6.38 kg^{-1}) is considerably more than current break-even selling prices for Louisiana crayfish (\$2.75 kg^{-1}) these hypothetical break-even prices are still lower than those experienced by consumers in north Mississippi (e.g., >\$8 kg^{-1} at Brewski's and the Crawfish Hole, Starkville, MS; A. Alford, personal observation).

We did not detect a difference in mean overall acceptability of abdominal muscle samples between the two harvest practices (Table 4; $F = 0.99$, $p > 0.05$). Consumers on average rated overall acceptability of both abdominal muscle samples between 7.0-7.2 which corresponded to "like moderately" on the nine-point hedonic scale. Additionally, we did not detect differences in consumer scores for flavor ($F = 0.04$, $p > 0.05$) and texture ($F = 1.85$, $p > 0.05$) with both descriptors having scores characteristic of "like slightly" to "like moderately". We did detect statistically different mean scores for aroma ($F = 5.77$, $p = 0.016$) and appearance ($F = 5.48$, $p = 0.019$) with commercial crayfish samples receiving greater consumer scores for aroma and appearance compared to wild caught crayfish samples. However, the mean consumer scores for both descriptors across harvest practices were characteristic of 'like moderately' on the nine-point hedonic scale.

During the impounded period in fall-spring 2010-2011, we did not detect significant differences in average concentrations of total inorganic orthophosphorus (TP), soluble reactive phosphorus (SRP) and ammonia-nitrogen (NH_3) in effluent samples from the two field types ($p > 0.05$) although these nutrients exhibited a significant increase over time (Table 5). We did detect a significant difference ($p = 0.002$) in average concentrations of total suspended solids (TSS) between the field types with moist-soil wetlands exporting 80% less solids than agriculture fields. We did detect significant temporal differences ($p = 0.03$) in average concentrations of nitrate-nitrogen (NO_3) and between the two field types.

During fall-spring 2011-2012, we found concentrations of NH_3 were similar in effluent samples from the two field types and over time (Table 5). Similar to 2011, TSS concentrations were 90% greater in effluent samples from agriculture fields compared to moist-soil wetlands. Concentrations of TP, SRP, and NO_3 differed significantly between the two field types and TP and DIP also varied across the flooded period (p <0.005).

Our estimates of annual nutrient loads released by moist-soil wetlands during winter-spring (Figure 1) suggest that TP, SRP, and NO_3 loadings of >1 kg/ha/year exceed current assumed average total annual loads from wetlands in Mississippi (Shields et al. 2008).

We concluded that concentrations of most nutrients and sediments were significantly lower in runoff from moist-soil wetlands compared to runoff from agriculture fields in the surrounding landscape. 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). Agriculture fields have little crop cover after harvest and therefore little organic material is available for decomposition. Therefore, it is likely that 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. However, concentrations of TP in wetland effluent exceeded EPA recommendations of 0.128 mg/l under 303(c) of the Clean Water Act. Additionally, our estimates of nutrient loadings for TP, SRP and NO_3 exceed current assumed loading rates for wetlands in Mississippi (Shields et al. 2008). Because wetland soils have a finite capacity to store phosphorus and this nutrient is linked to environmental degradation such as the development of the hypoxic zone in the Gulf of Mexico (Rabalais et al. 2002), strategies such as periodical soil manipulations may need to be developed to increase the phosphorus storage capacity of these wetlands.

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 establishment and management of these wetlands and therefore increase habitat for waterfowl and other wetland wildlife throughout the MAV.

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Table 1. Crayfish harvest statistics from 42 moist-soil wetlands in the Mississippi Alluvial Valley and Interior Flatwoods April-June 2009 – 2011..

Year	Site	State	kg ha^{-1}
2009	Coldwater NWR	MS	1.23
2009	York Woods #1	MS	3.62
2009	York Woods #2	MS	1.45
2009	Trim Cane WMA	MS	1.22
2009	Property of C. Clark Young	MS	1.13
2009	Noxubee NWR	MS	0.88
2009	Morgan Brake NWR	MS	2.69
2009	Yazoo NWR	MS	3.65
2009	Panther Swamp NWR	MS	2.20
2010	Cache River NWR #1	AR	0.26
2010	Cache River NWR #2	AR	0.85
2010	Wapanocca NWR #1	AR	0.05
2010	Wapanocca NWR #2	AR	7.28
2010	Coldwater NWR	MS	0.70
2010	Property of Ronal Roberson	MS	9.13
2010	Property of C. Clark Young	MS	2.00
2010	Noxubee NWR	MS	1.05
2010	Morgan Brake NWR	MS	0.47
2010	Yazoo NWR	MS	1.40
2010	Panther Swamp NWR	MS	1.22
2010	Tensas NWR	LA	2.30
2010	Catahoula NWR #1	LA	1.68
2010	Catahoula NWR #2	LA	1.95
2010	Grand Cote NWR	LA	2.36
2011	Otter Slough WMA #1	MO	7.17
2011	Otter Slough WMA #2	MO	0.68
2011	Wapanocca NWR #3	AR	0.65
2011	Wapanocca NWR #1	AR	3.40
2011	Wapanocca #2	AR	5.87
2011	Noxubee NWR #1	MS	0.45
2011	Noxubee NWR #2	MS	1.50
2011	Property of C. Clark Young #1	MS	0.63
2011	Property of C. Clark Young #2	MS	1.03
2011	Morgan Brake NWR #1	MS	4.21
2011	Morgan Brake NWR #2	MS	5.10
2011	Yazoo NWR #1	MS	0.33
2011	Yazoo NWR #2	MS	0.34
2011	Panther Swamp NWR	MS	0.49
2011	Tensas NWR	LA	1.38
2011	Catahoula NWR #2	LA	6.60
2011	Catahoula NWR #1	LA	23.02
2011	Grand Cote NWR	LA	2.68

Table 2. Estimated fixed costs associated with rice-crayfish commercial harvest systems in Louisiana. From Boucher and Gillespie 2012.

Table 3.A Estimated Costs and Returns per Acre, Single Crop Crawfish, Owner-Operator, Southwest Louisiana, 2012.

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		dollars		dollars
INCOME				
Crawfish (Dec - May)	lbs		600.0000	

TOTAL INCOME				
DIRECT EXPENSES				
CUSTOM				
Airplane seed	cwt	5.60	1.4000	7.84
Global pos. system	acre	0.35	2.0000	0.70
Airplane fert	cwt	6.25	0.7500	4.68
BAIT				
Crawfish bait (fish)	lbs	0.40	175.0000	70.00
Manuf. crawfish bait	lbs	0.26	180.0000	46.80
FERTILIZER				
Urea (45%)	lbs	0.19	75.0000	14.25
HIRED LABOR				
Irrigation labor	hour	9.60	1.8500	17.76
OTHER				
Hip boots	pair	74.95	0.0083	0.62
Sacks	each	0.40	18.1824	7.27
SEED				
Rice seed	lbs	0.45	120.0000	54.00
OPERATOR LABOR				
Tractors	hour	9.60	0.3491	3.35
Self-Propelled Eq.	hour	9.60	6.2605	60.10
IRRIGATION LABOR				
Crawf irrig single	hour	9.60	0.3960	3.80
DIESEL FUEL				
Tractors	gal	3.50	1.7397	6.08
Self-Propelled Eq.	gal	3.50	1.0075	3.52
Crawf irrig single	gal	3.50	71.2224	249.27
GASOLINE				
Self-Propelled Eq.	gal	3.50	1.5975	5.59
REPAIR & MAINTENANCE				
Implements	acre	1.71	1.0000	1.71
Tractors	acre	0.72	1.0000	0.72
Self-Propelled Eq.	acre	3.17	1.0000	3.17
Crawf irrig single	acin	0.15	33.0000	4.95
Crawf pond&eq single	acre	7.18	1.0000	7.18
INTEREST ON OP. CAP.	acre	14.46	1.0000	14.46

TOTAL DIRECT EXPENSES				587.87

Table 3. Estimated fixed costs associated with harvesting crayfish from moist-soil wetlands in the Mississippi Alluvial Valley and Interior Flatwoods.

Table 3.F Estimated costs per acre
Moist-soil Average yield owner operator labor
, Mississippi, 2012

ITEM	UNIT	PRICE	QUANTITY	AMOUNT
		dollars		dollars
DIRECT EXPENSES				
HARVEST AIDS				
TRAPS	each	8.25	12.0000	99.00
OTHER				
Waders	pair	69.99	0.2800	19.60
Ice Chest 48qt	each	22.88	0.0300	0.69
Sacks	each	0.30	2.0000	0.60
BAIT				
Manuf. crawfish bait	lbs	0.24	120.0000	28.80
OPERATOR LABOR				
Self-Propelled	hour	9.60	10.0875	96.84
GASOLINE				
Self-Propelled	gal	3.50	5.0437	17.64
REPAIR & MAINTENANCE				
Self-Propelled	acre	10.22	1.0000	10.22
INTEREST ON OP. CAP.	acre	2.20	1.0000	2.20

TOTAL DIRECT EXPENSES				275.59

Table 4. Mean scores (N=149) for consumer acceptability of cooked abdominal meat from commercially harvested crayfish and wild crayfish captured from moist-soil wetlands.

	Source	
	Commercial	Wild
Appearance	7.4[a*]	7.1[b]
Aroma	7.3[a]	7.0[b]
Flavor	6.9	6.8
Texture	7.5	7.3
Overall	7.2	7.0

[*] Means within rows followed by different letters are significantly different ($p < 0.05$).

Table 5. Mean (95% confidence interval) concentrations (mg/l) of nutrients and sediments in agriculture and wetland runoff samples for December-May 2011 and 2012. Estimates are untransformed $\log_e$ values for field types computed from least-squared means in a repeated measures model.

	Agriculture Fields	Moist-soil Wetlands
Variable[a]	2011	
TP*	0.30 (0.08, 0.43)	0.25 (0.07, 0.34)
SRP*	0.05 (0.02, 0.09)	0.06 (0.02, 0.11)
NO_3***	0.53 (0.27, 1.09)	0.08 (0.04, 0.17)
NH_3*	0.06 (0.02, 0.10)	0.06 (0.02, 0.09)
TSS**	78.2 (35.6, 143.6)	15.4(6.39, 26.35)
	2012	
TP***	0.46 (0.27, 0.77)	0.25 (0.16, 0.39)
SRP***	0.06 (0.03, 0.14)	0.06 (0.03, 0.13)
NO_3**	0.53 (0.34, 0.83)	0.17 (0.11, 0.27)
NH_3	0.09 (0.05, 0.15)	0.05 (0.03, 0.10)
TSS**	129 (66.1, 252)	12.3 (6.46, 23.3)

[a] * = Significant ($p<0.05$) across time, ** = significant between habitats, *** = significant across time and between habitats.

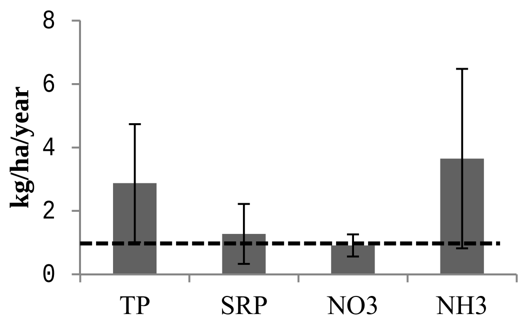

Figure 1. Average total annual loads (kg/ha/year ± SE) delivered by moist-soil wetlands in Mississippi during December 2010- May 2011. The dashed line represents 1 kg/ha/year, the current assumed total annual loads of TP and NO_3 delivered to the lower Mississippi River by wetlands in Mississippi.

SIGNIFICANT RESEARCH FINDINGS

During spring 2011, we estimated average daily yield of crayfish from 18 moist-soil wetlands in Arkansas, Louisiana, Mississippi, and Missouri. Average daily yield in 2011 was 3.64 kg/ha (CV = 33%). This estimate was slightly greater and more variable than the estimated yield from Mississippi wetlands in 2009 (i.e., 1.75 kg ha^{-1}; CV = 16%, n = 9) and wetlands in Arkansas, Louisiana, and Mississippi in 2010 (i.e., 2.18 kg ha^{-1};CV = 30%, n = 15) .

Our comparisons of operating budgets from the two harvest systems indicated that rice-crayfish systems incur $1455 in direct expenses per hectare whereas crayfish harvest operation in moist-soil wetlands incur $682 direct expenses per hectare. Although fixed expenses are lower in harvest operations from moist-soil wetlands, lower yields increased the break-even selling prices from $2.75 kg^{-1} in rice-crayfish systems to $6.38 kg^{-1} in moist-soil harvest systems. These prices, however, are still less than those observed in regions of the Southeastern United States outside of Louisiana.

To determine if crayfish harvested from moist-soil wetlands are an acceptable seafood product relative to commercially harvested crayfish, we conducted a consumer acceptability panel in May 2011. We found that crayfish from both sources were well liked and did not differ significantly ($p > 0.05$) in overall consumer acceptability.

In July 2010, we installed water quality monitoring stations at 5 wetlands and 5 agriculture fields. We monitored concentrations of nutrients and sediments exported from these habitats during storm events in December-March of 2010-2012. We determined that wetlands exported significantly less total suspended solids and NO_3 than agriculture fields in 2010-2011 whereas all parameters except for NH_3 were significantly lower in wetland effluent compared to agriculture fields in winter 2011-2012. We were able to calculate loads (kg ha^{-1}) from wetland habitats during the study years and determined that total annual loads of nutrients were slightly greater than currently assumed loading values of wetlands in Mississippi (i.e., 1 kg ha^{-1}).

PUBLICATIONS, PRESENTATIONS, and OUTREACH

Alford, A.B., R. Kaminski, J.L. Avery, L.R. D'Abramo. 2011. Characteristics of harvestable crayfish populations in managed wetlands of the Lower Mississippi Alluvial Valley. American Fisheries Society. Seattle, WA.

Alford, A.B. Paddling and Canoe Landowner Workshop. Louisiana State University AgCenter and Mississippi State University Natural Resources Enterprises. Monroe, LA. 2011.

Alford, A.B., R.M. Kaminski, R. Kroger, L.R. D'Abramo, and J. Avery. 2011. Ecosystem services derived from moist-soil management. Poster presentation. Mississippi Chapter of the Wildlife Society. Louisville, MS, October 4-5, 2011.

Alford, A.B. R. Kroger, and R.M. Kaminski. 2012. Nutrient characteristics of moist-soil wetlands in agricultural landscapes. Oral presentation. Mississippi Water Resources Conference. April 3-4, 2012. Jackson, MS.

Alford, A.B., R. Kaminski. 2012. Duck hole 'dads' (dat's crawdads). Mossy Oak Gamekeeper: Farming for Wildlife. Spring 2012.

Alford, A.B., S. Grado, and R. Kaminski. 2012. Crawfish: Another incentive to practice wetland conservation. Mississippi Ducks Unlimited Annual Convention. July 27, 2012. Natchez, MS.

AWARDS

Alford, A.B. John F. Skinner Memorial Award. 2011. American Fisheries Society.

Alford, A.B. James Kennedy Endowed Fellowship in Waterfowl and Wetlands Conservation. 2011. Mississippi State University.

TRAINING POTENTIAL AND INFORMATION TRANSFER

The proposed project provided necessary field and laboratory research for Amy Alford, a Ph.D. student in Department of Wildlife, Fisheries and Aquaculture (WFA), Mississippi State University. Mrs. Alford's field of interest is wetland ecology and aquatic ecosystem management. She also holds a M.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. The experience that Mrs. Alford gained through this research project has earned her a Research and Extension Associate appointment with the Louisiana Sea Grant College Program in Baton Rouge, LA.

We also encouraged landowners and land managers to observe water quality and crayfish sampling activities. We received field assistance from three landowners. We also involved high school students in crayfish harvest activities during the College of Forest Resources' sponsored summer camp. Mrs. Alford in a Natural Resources Enterprises sponsored workshop in Monroe, LA where she met with area landowners to discuss the potential for crayfish harvest from wetlands managed for wildlife habitat. We produced a popular article regarding crayfish harvests in moist-soil wetalnds for the Mossy Oak Gamekeeper monthly magazine. Mrs. Alford presented the economic analysis of crayfish harvest in moist-soil wetlands to members of the Mississippi Chapter of Ducks Unlimited at the annual convention in Natchez, MS. 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. Alford (Co-PI)	Ph.D.	Forest Resources
John Perron (Wage)	B.S.	WFA
Kelsey Brock (Wage)	B.S.	Speech Pathology
Candice Bogen	B.S.	WFA

FUTURE RESEARCH

This report summarizes the results of our three-year research project. Amy Alford, the PhD candidate and Co-PI on the project is currently preparing the dissertation from this research and plans on defending in spring 2013. We hope that through the extension and outreach activities that we have participated in and the future peer-reviewed manuscripts that will be produced from this research that innovative approaches similar to ours will be made to quantify additional ecosystem services from specific habitat management practices.