WADING BIRD FOOD AVAILABILITY IN RICE FIELDS AND CRAWFISH PONDS OF THE CHENIER PLAIN OF SOUTHWEST LOUISIANA AND SOUTHEAST TEXAS

A Thesis

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ABSTRACT

Wading birds in southwestern Louisiana and southeastern Texas rely heavily on rice fields and crawfish ponds as foraging areas; however, little information exists on food availability throughout the annual crop cycle. The objectives of this study are: 1) Develop a classification for rice and crawfish fields based upon tillage, forage crop (for crawfish fields), water depths, vegetation density, vegetation height, and other visible parameters; 2) Quantify the distribution of rice and crawfish fields in various stages across the landscape through time; 3) Determine the effects of rice and crawfish field types and landscape characteristics on wading bird use; and, 4) Evaluate the relationships among field classification, habitat characteristics, and invertebrate densities (including crawfish) in selected field types through time. To address these objectives, I used stratified-random sampling to select 50 1.6 km long road transects in 7 parishes and 3 counties of the major rice/crawfish producing parishes/counties in southwestern Louisiana and southeastern Texas. From April 2013 – April 2014 I conducted monthly surveys along the transects to assess rice/crawfish habitat conditions, as well as conduct waterbird surveys. From May 2013 until February 2014 I conducted quarterly macroinvertebrate and nekton sampling of selected fields in the region. The results of the study demonstrate the intra-annual variability in resources available to waterbirds and other wetland dependent wildlife throughout the coastal prairie region. Rice agriculture as a percentage of surveyed land use varied from 0-30%. Crawfish agriculture varied in a 12-month period from 0-15% of lands surveyed. Crop type, irrigation and tillage were the factors that contributed most to macroinvertebrate abundance and biomass. Waterbird use of fields was not randomly

distributed. Irrigation, seeding method and tillage all seemed to contribute to waterbird use of fields surveyed in the region.

CHAPTER 1
GENERAL INTRODUCTION

BACKGROUND

The coastal prairie region of Southwest Louisiana and Southeast Texas provides important habitat for many species of wading birds, waterfowl and shorebirds (Huner et al. 2002). Over 260 species of birds use these habitats to varying degrees (Huner et al. 2002). Over the last half century much of the natural wetlands in this region have been lost or drained and converted to agricultural lands but these "working wetlands" provide diverse habitat resources throughout the annual cycle for many waterbird species (Elphick and Oring 1998; Elphick et al. 2010; Ma et al. 2009; Huner et al. 2002; Manley 2004; Pickens and King 2012; Richardson and Taylor 2003; Tourneq et al. 2003).

By the year 2014, rice farming in southwestern Louisiana and southeastern Texas encompassed 125,775 ha and 21,530 ha respectively (http://www.nass.usda.gov). Although rice fields lack the structural and floristic diversity of natural wetlands they can be important for conservation, particularly in areas where natural wetlands have declined (Elphick and Oring 1998; Richardson and Taylor 2003; Tourenq et al. 2003). They provide abundant foraging opportunities at certain times of the year in the form of waste rice left in the field after harvest, as well as ratoon crops left in the field for crawfish production (Manley et al. 2004).

Both rice fields and crawfish ponds, along with the canals and ditches that make up the adjacent agricultural landscape, provide valuable nesting and brood-rearing habitat (Pickens and King 2012). Crawfish ponds provide an abundant and concentrated source of protein especially during periods of drawdown when mudflats are exposed (Ma et al. 2009). In addition, rice fields and crawfish ponds provide natural forage in the form of moist soil plant seeds and green forage (Manley et al. 2004). These working wetlands also provide the conditions necessary to support aquatic invertebrate communities essential protein sources for wading birds, waterfowl and shorebirds (Manley et al. 2004).

Globally, farming practices in rice fields and crawfish ponds influence protein sources and amounts greatly. Most notably perhaps, water distribution and irrigation methods have profound effects. The hydroperiod of rice fields is believed to contribute to the high abundance and diversity of aquatic invertebrate communities (Stenert et al. 2009). For example, the rice fields of southern Brazil that remained flooded for nearly the entire cultivation cycle had a more diverse community of aquatic invertebrates than fields with an extended dry out period (Stenert et al. 2009). Varying management practices adopted after the harvesting period, such as flooding or not flooding fields, did not seem to influence macroinvertebrate richness or density, but did influence species composition (Stenert et al. 2009).

Use of agricultural chemicals in conventional rice farming practices has also been shown to cause changes in abundance and diversity of aquatic macroinvertebrates. Stenert et al. (2010) suggested that lower richness and density in rice fields dry for short periods of time could be the result of residual effects of herbicides and pesticides on emergent invertebrates. In the rice fields of France's Rhone Delta, a study showed that a reduction of predators in insecticide-treated fields may have given rise to a trophic cascade effect leading to greater overall abundance of macroinvertebrates, but lower species diversity (Mesleard et al. 2005). In Australia, pesticide applications were also shown to influence the composition of rice field communities as the growing season progresses, retarding predator development and indirectly leading to increases in pest herbivore populations (Wilson et al. 2007).

The methods used to plant rice, in particular drilling and aerially seeding fields, may also have an effect on the density and diversity of invertebrates (Wilson et al. 2007). In Australian rice fields greater macroinvertebrate abundance in water column samples was observed at sites cultivated using drill-sowing techniques compared to aerially sown fields, possibly due to the incorporation of organic material into the soil during planting (Wilson et al. 2007).

Tillage also can affect macroinvertebrates. Macroinvertebrate richness and density changed over the rice cultivating cycle and was higher in the fallow phase than in the tillage and rice-growing phase (Stenert et al. 2009).

Individual landowners and farmers utilizing different management practices, as well as the seasonally of the crops themselves, create a spatially and temporally diverse landscape. Understanding the variability throughout the agricultural cycle is imperative to understanding when and where habitat is available to waterbirds (King et al. 2010). Previous studies conducted in the region have not considered how habitat provided by working wetlands changes throughout the year or quantified what habitat types are available at any given time (King et al. 2010). No one habitat type provided by “working wetlands” is suitable for all species of waterbirds and the habitat requirements of waterbird species vary throughout the year (Kushlan and Hafner 2000). A classification system of waterbird habitat provided by “working wetlands” in the region is needed in order to determine how much of a particular habitat type is present on the landscape at any given time.

An improved understanding of the effects of current rice and crawfish agricultural management practices on aquatic macroinvertebrate communities will aid wildlife managers and landowners who strive to provide quality waterbird habitat. In addition, an understanding of changes in the quality and quantity of habitat available throughout the year will allow wildlife professionals to make more informed management decisions about the type of habitat to provide and when the habitat should be made available.

RESEARCH OBJECTIVES

The objectives of my study are to:

1) Develop a classification for rice and crawfish fields based upon tillage, forage crop (for crawfish fields), water depths, vegetation density, vegetation structure, and other visible parameters;
2) Quantify the distribution of rice and crawfish fields in various stages across the landscape through time;
3) Determine if rice and crawfish field types and landscape characteristics are related to wading bird use; and,
4) Evaluate the relationship among field classification and habitat characteristics and invertebrate densities (including crawfish) in selected field types through time.

STUDY AREA

The study was conducted in the Gulf Coast Chenier Plain, which consists of a seven-parish region in southwestern Louisiana (Acadia, Allen, Cameron, Calcasieu, Evangeline, Jefferson Davis, and Vermillion) and a four-county region in southeastern Texas (Chambers, Jefferson, Liberty and Orange). All research was conducted on private lands where permission was granted by the landowner.

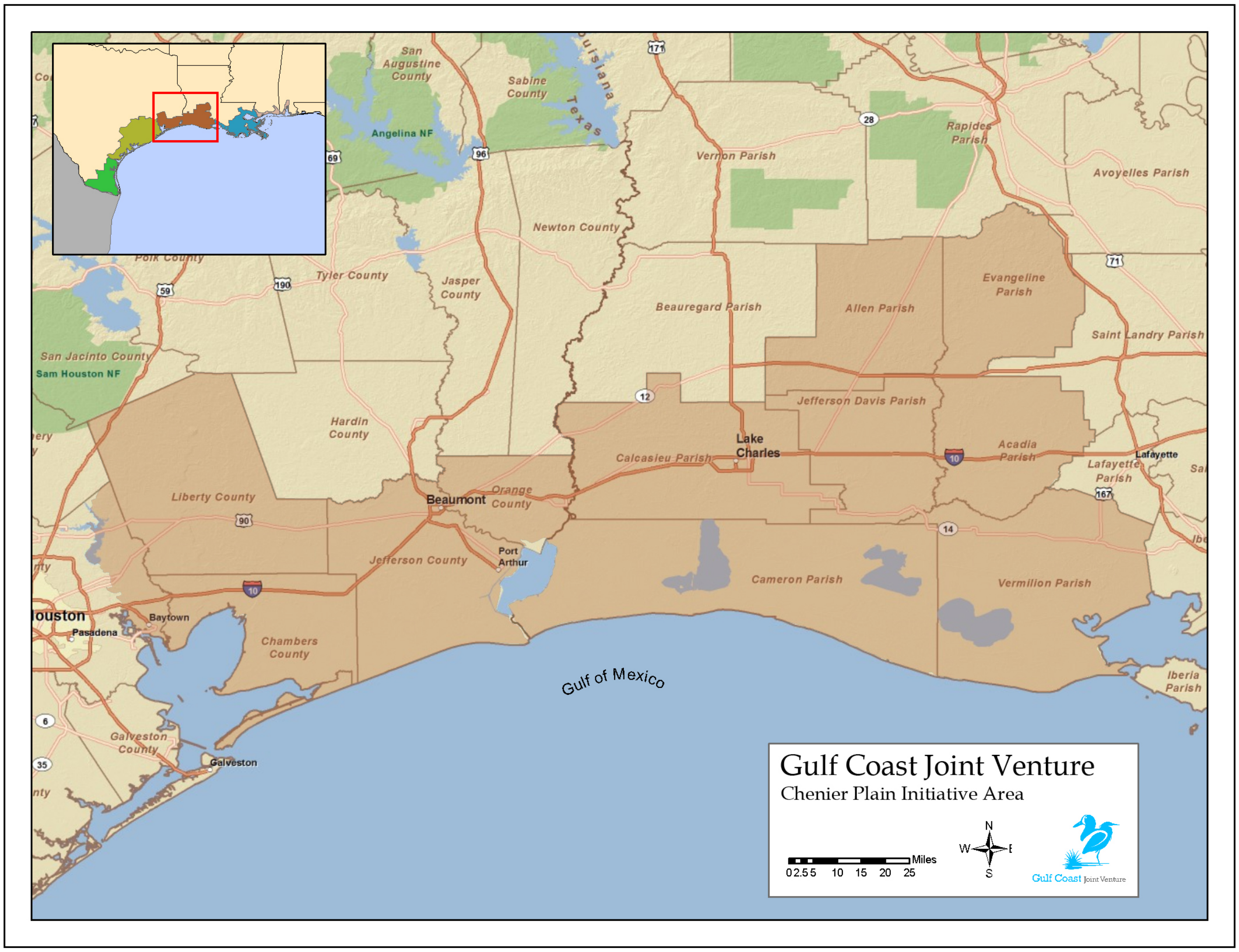

Fig. 1.1. Gulf Coast Chenier Plain

The coastal prairie region of southwestern Louisiana once spanned approximately 1.012 million hectares but now it is estimated that only about 40 hectares remain intact (Allain et al. 1999). Similarly, the coastal prairie region of southeastern Texas in the past spanned approximately 2.63 million hectares and currently only about 26,000 hectares remain (Allain et al. 1999). On the southern edge of its range, the community is composed of “islands” or “ridges” surrounded by marsh. The region has an impervious clay pan 15 to 450 cm below the surface that prevents downward percolation of water through the soil profile and inhibits upward movement of capillary water. Soils are typically circum-neutral to alkaline, saturated in winter, and often very dry in late spring and fall. Average yearly rainfall in the region is about 140 cm (http://www.nwrc.usgs.gov/factshts/019-00.pdf). Trees are confined to the more elevated and better-drained streamside ridges, forming "gallery forests", that divide the Coastal Prairie into many subunits or "coves". The soil conditions and frequent fires from lightening strikes historically prevented invasion by woody trees and shrubs and maintained the prairie vegetation. The contrast between the forest and grasslands is sharp. Coastal Prairie vegetation is extremely diverse and dominated by tall grasses (http://www.wlf.louisiana.gov/sites/default/files/pdf/document/32869-coastal-prairie/coastal_prairie.pdf).

Rice agriculture has replaced much of what was once native prairie in the region. As of 2014 rice in the seven-parish region of Louisiana totaled 125,775 ha (http://www.nass.usda.gov). In the four Texas counties, rice totaled 21,530 ha in three counties, with none recorded for Orange County (http://www.nass.usda.gov).

Rice (Oryza sativa) grown in southwest Louisiana is a commercial crop that is planted yearly in spring, with recommended planting dates between March 15th and April 20th (Saichuk et al. 2009). There are many different varieties of rice grown in this region, but variety of rice was not considered in this study.

While there are several methods of planting rice, the two most utilized planting methods in the region are aerially seeding, also known as water seeding, and drill seeding (Saichuk et al. 2009). Aerial seeding is conducted by broadcasting seed from the air onto a flooded field. In this method, fields may or may not be water leveled before planting. After the field has been seeded, the water is drawn down in order for the seeds to germinate. If the water is not drawn down, seedlings will die. Water or aerial seeding helps suppress invasive red rice, which is the primary reason for utilizing this method in southwestern Louisiana (Saichuk et al. 2009). It is also a convenient method when used in a rotation with crawfish production or when spring rains prevent fields from being dry enough to drill seed.

Drill seeding, the other most-utilized method for rice planting, involves directly sowing the rice seeds into a dry field with the use of a seed drill. Drill-sown fields may be tilled or no-tilled. No-tilled fields are usually in a rotation with another crop (such as soybeans) where the rice seed is drilled in the soil alongside soybean stubble (Saichuk et al. 2009). Tilled fields can be disked in the fall after rice harvest or in the spring directly before planting.

With both seeding methods the fields will be flushed (flooded up and drawn down) several times during the growing season. Rice is usually permanently flooded within 20-35 days after planting to a depth of 5-10cm (Saichuk et al. 2009).

There are two primary methods of irrigating rice fields in this region. The first method, and cheapest, is to irrigate fields with surface or canal water. Fields located in the southern portion of the region - primarily those fields south of Interstate 10 or those with access to river or bayou water - utilize canal water. The second method of irrigation, utilizing well water, involves pumping subterranean ground water to the surface. Well water irrigation is used when access to canal or surface water is limited or unavailable.

Crawfish is an important cash crop in the region (Huner et al. 2002). Two species make up the majority of the annual harvest: the red swamp crawfish (*Procambarus clarkii*) and the white river crawfish (*Procambarus zonangulus*) (McClain et al. 2007). Crawfish can be farmed as a monoculture (stand-alone crop) or in rotation with rice. On marginal lands that cannot support rice agriculture, crawfish is usually farmed as a monoculture (McClain et al. 2007).

The two most common farming rotation systems in southwestern Louisiana are the rice-crawfish-rice and rice-crawfish-fallow/soybean (Saichuk et al. 2009). In the rice-crawfish-rice rotation, rice is grown and harvested in the summer and crawfish are raised from fall to early spring in the same field (Saichuk et al. 2009). In the rice-crawfish-rice rotation, crawfish are seeded into flooded rice fields about 4-7 weeks after rice is planted (Saichuk et al. 2009). After the rice crop is harvested, the field is usually fertilized and re-flooded in order to grow a second, called a “ratoon”, rice crop (Saichuk et al. 2009). The ratoon rice crop will serve as a forage base for crawfish in production. In the rice-crawfish-fallow/soybean rotation, three crops can be utilized in the same field every two years: rice and crawfish will be harvested in Year One, and the fields will be either left fallow, planted in a dry crop such as soybeans, or left as grazing pasture for cattle in Year Two (Saichuk et al. 2009).

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CHAPTER 2
QUANTIFYING THE DISTRIBUTION OF RICE AND CRAWFISH AGRICULTURE THROUGHOUT THE ANNUAL CROP CYCLE

INTRODUCTION

Habitat availability for waterbirds in the region exhibits high temporal and spatial variability. Numerous factors affect management decisions including diversity of crop alternatives, recreational and commercial hunting opportunities, agricultural economics, and rainfall patterns (Siachuk et al. 2009). The same field may be planted in a rice-crawfish-rice rotation one year then placed in a rice-crawfish-fallow rotation for the next two years (Siachuk et al. 2009). Production costs, such as diesel fuel, and commodity prices can greatly influence crop selection. Within-year predictions of available habitat can vary based on winter rainfall, market demands for waterfowl hunting leases, and the alterations of field borders as a result of modern leveling techniques that continue to sculpt the region (personal observation). Late cold fronts, as well as heavy spring rains, can delay planting and shift planting dates (personal conversation with farmers), thus altering the temporal availability of habitat. The crop type planned for spring planting can also determine when an individual farmer draws down crawfish ponds to plant (McClain et al. 2007; Siachuk et al. 2009). Predicting available habitat from year to year can be very complex because individual farmers make independent decisions about the best use of their farmland.

The spatial and temporal variability caused by these factors makes it challenging for wildlife managers to estimate the quantity and quality of waterbird habitat available on the landscape during any given season. Suitable nesting habitat for secretive marsh birds is not suitable habitat for a colonial wading bird rookery (King et al. 2010). Suitable foraging habitat for long legged wading birds may not be suitable habitat for short-legged shorebirds (Kushlan and Hafner 2000). A classification system for the habitat provided by "working wetlands" that will allow managers to quantify suitable habitat for many species of waterbirds that utilizes this region would be extremely valuable.

The objective of this study was to develop a classification system for rice and crawfish fields to facilitate quantification of landscape changes in the region throughout the annual crop cycle. Previous studies in the region have considered the presence of rice fields or crawfish ponds and how waterbird use varies within fields (Huner et al. 2002) but have not considered the various management practices that could contribute to variability of use within field types. Creating a standard classification system and pinpointing the structural and compositional changes in habitat characteristics among management types will help facilitate conservation planning. It will also set a standard for compilation and comparison of data from future studies.

METHODS

Sample Site Selection

Sample sites were selected by utilizing a stratified random sampling method based upon the proportion of rice planted in the parish/county in 2012 (Louisiana) and 2011 (Texas). Rice hectarage estimates were obtained from www.lsuagcenter.com for Louisiana parishes and from www.nass.usda.gov for Texas counties. A grid of township and range sections was constructed in GIS for each county. A random number generator was used to select sample sections. If a sample section chosen by the random number generator had less then 50% agriculture, the site was dropped and a new section was chosen. A total of 50 sections across the region were selected (about 50 square miles in total). Once sites were selected, all landowners within each section were identified and contacted to gain access to sample sites and to identify the person(s) responsible for agricultural management of the land. Those directly involved in the agricultural management of the land were asked to answer a survey based on the management practices currently utilized in selected fields and to identify individual field boundaries. Due to a lack of landowners willing to grant permission to the interior of their property, one side of each section was randomly chosen to serve as a 1.6 km line transect. It is from these transects that vegetation surveys were conducted. The surveys took between 3-4 days to complete depending on time of year as daylight hours varied.

The survey allowed fields to be categorized based on type of crop and management practices employed. The field categories are rice, crawfish, fallow, pasture, soybeans, sugarcane, milo or other. Additional information was collected to help explain potential variation between fields of the same category. The additional information collected was source of irrigation (ground water well or surface/canal water), seeding method (drilled or aerially seeded), tillage (till or no-till) and chemical management methods (conventional or organic). For crawfish ponds the forage crop available (natural vegetation or ratoon rice) was also determined.

Vegetation Sampling

Vegetation was sampled in each of the fields along the line transects. Sampling was conducted on a monthly basis from April 1, 2013, through April 30, 2014, to determine the temporal and spatial changes in vegetation structure and distribution between sites. One sample was taken per field per month. Sampling was conducted by visual inspection; vegetation height, density, and water depth were recorded. Vegetation height was classified as one of six possible categories: none (bare ground), very short (< 5 cm), short (5-20 cm), moderate (20-40 cm), tall (40-60 cm), and very tall (> 60 cm). Vegetation density was classified as one of four possible categories: none (bare ground), low density (< 25% coverage), moderate density (25%-50% coverage) and high density (>50% coverage). Water depth was classified as one of five possible categories: dry, mudflat (saturated soil with < 1 cm of water), shallowly flooded (1-15 cm), flooded (15-30 cm) and deeply flooded (> 30 cm).

Rice fields in a rice-crawfish rotation were classified as rice from the time the first seedling began to sprout until harvest. If the field was left dry after harvest, regardless of whether rice stubble was left in the field, it was classified as fallow. If the rice field was reflooded after harvest, it was classified as rice in expectation that a ratoon crop would be harvested or until it was drawn down again unless commercial crawfish traps were placed in the field at which time it was classified as crawfish.

RESULTS

During the 12-month study 22,483 hectares of cropland were surveyed in the region. From May through October rice occupied about 30% of the landscape before declining to about 25% in December, then none in February and March. By April as rice planting season began, roughly 20% of the landscape was back in rice production (Fig. 2.2). Land use classified as fallow peaked in February and March at 56% (Fig 2.2). June and July had the lowest proportion of fallow land with only 20% of the landscape not in production (Fig 2.2).

Rice, left in the field as a forage crop for crawfish, accounted for 69% of crawfish pond hectarage (1,165 surveyed hectares). Crawfish ponds that utilized natural vegetation as a forage base for crawfish production made up just 31% (518 surveyed hectares) of the crawfish landscape. 38% of fields (8,540 surveyed hectares) were irrigated with or had the ability to be irrigated with canal water and 62% of fields (13,943 surveyed hectares) were irrigated with well water.

Classification System

Field Classification System

Crop Type
Rice, Crawfish, Fallow, Pasture, Sugarcane, Soybeans, Milo, Other
↓
Forage Crop (Crawfish only)
Rice, Natural Vegetation
↓
Irrigation
Canal, Well
↓
Seeding Method
Drilled, Aerial
↓
Tillage
Till, No-Till
↓
Chemical Management
Conventional, Organic
↓
Water - Vegetation
See Water - Vegetation Classification

Water - Vegetation Classification

Water Depth	**Vegetation Height**	**Vegetation Density**
Dry	None	None
Mudflat (< 1 cm)	Very Short (< 5 cm)	Low (< 25%)
Shallowly Flooded (1 - 15 cm)	Short (5 - 20 cm)	Moderate (25% - 50%)
Flooded (15 - 30 cm)	Moderate (20 - 40 cm)	High (> 50%)
Deeply Flooded (> 30 cm)	Tall (40 - 60 cm)	
	Very Tall (> 60 cm)	

Fig. 2.1. Classification system of rice and crawfish in SWLA & SETX.

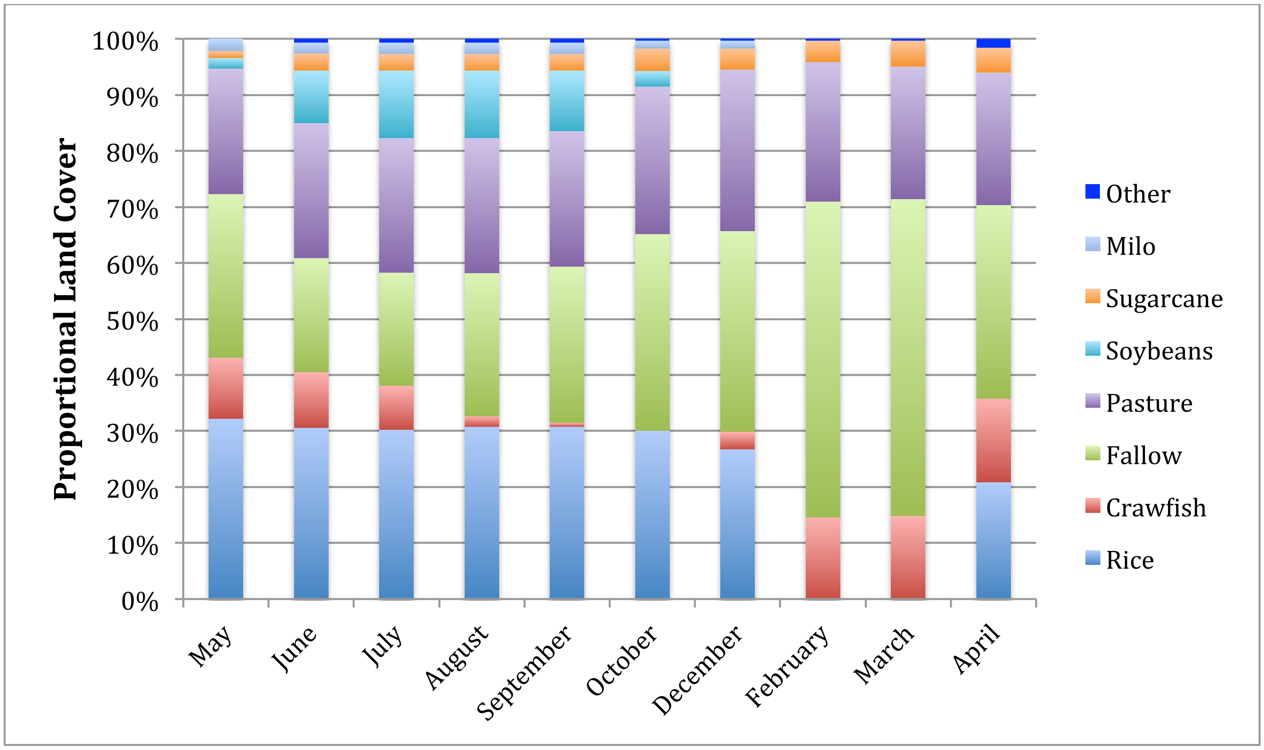

Fig 2.2. Proportional land cover by crop type in SWLA & SETX in 2013-2014.

Crawfish ponds made up about 10% of the surveyed landscape in May and began declining in June before reaching zero or near zero in September and October (Fig 2.2). Crawfish ponds began increasing again in December and peaked around 15% in the months of February through April (Fig 2.2).

Water Depth

Water present on the landscape varied throughout the survey period. Water was present in about 25% of the fields surveyed by area in the month of May (Fig 2.3). It increased to about 37% in June and July before declining to only about 12% in August (Fig 2.3). September and October saw steady increases in water present on the landscape until peaking in December at almost 60% (Fig 2.3). The presence of water on the landscape changed dramatically from December to February, when only 26% of land surveyed had water present before increasing again to 51% in March (Fig 2.3).

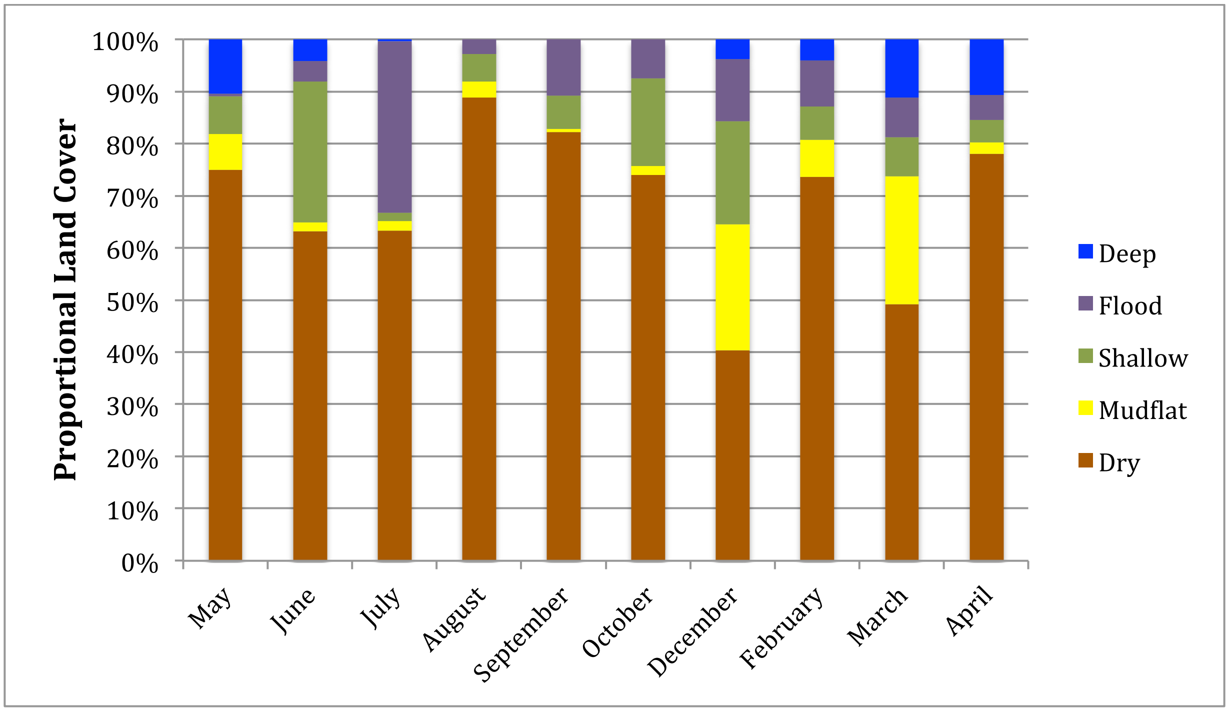

Fig 2.3. Proportional land cover by water depth in SWLA & SETX in 2013-2014.

Vegetation

Vegetation height peaked in October with 56% of vegetative cover categorized as very tall (see Fig. 2.4). The month of April had the lowest level of vegetative cover with 25% of wet or dry fields classified as having no cover at all. December-March and May had slightly more vegetation present with only 20% classified as having no vegetation (Fig 2.4).

Vegetation density peaked in July with 75% of the landscape surveyed categorized as having high vegetation densities (Fig 2.5). February and March had the highest proportion of fields categorized as having low vegetation densities at 47% and 45% respectively (Fig 2.5).

Proportional land cover by crop type was not only temporally variable but also spatially variable, however, rice, crawfish, and fallow accounted for at least 58% of hectarage surveyed in each month (Fig 2.6). Rice and crawfish land use saw less variation among transects than did other land use types, including fields classified as fallow.

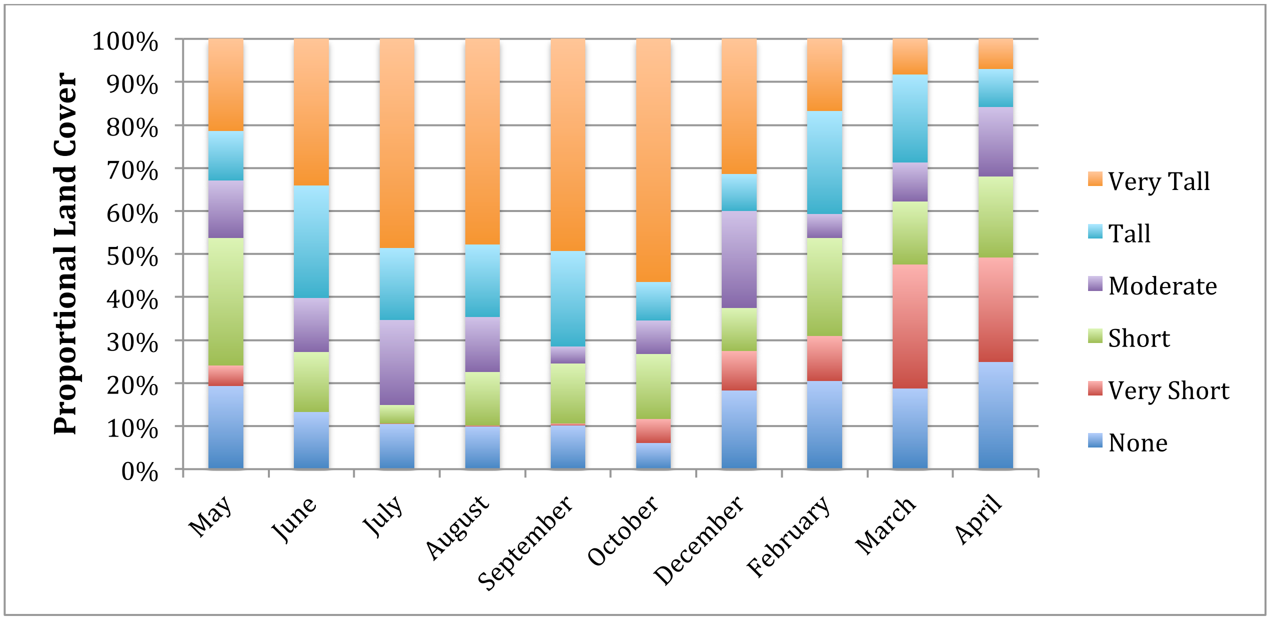

Fig 2.4. Proportional land cover by vegetation height in SWLA & SETX in 2013-2014.

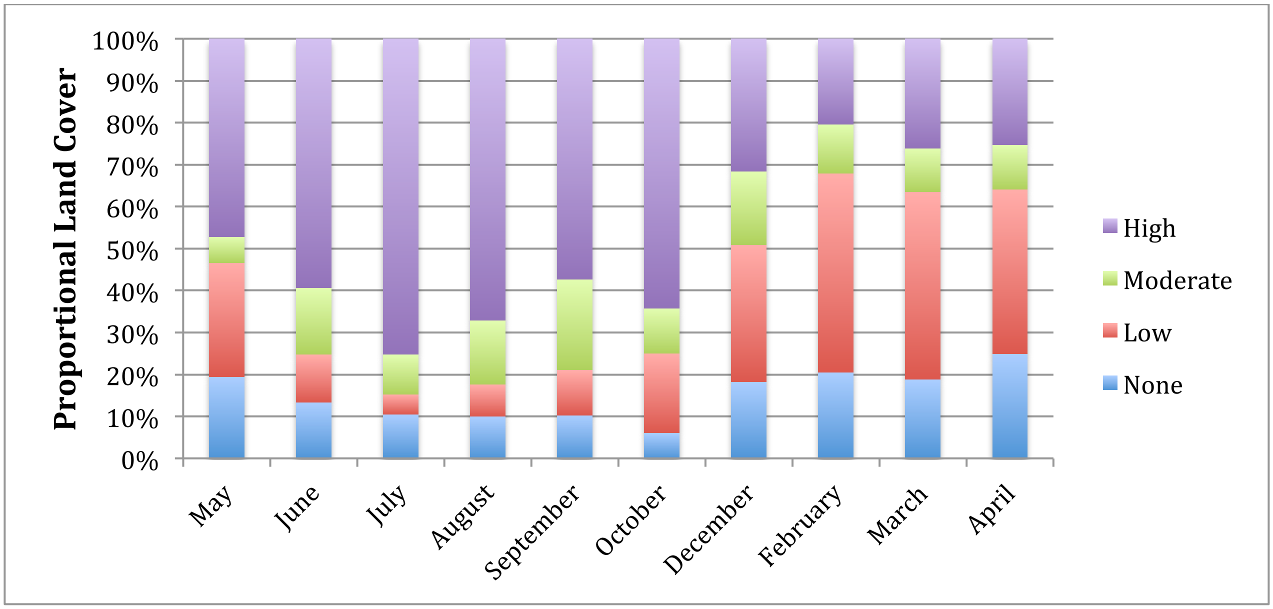

Fig 2.5. Proportional land cover by vegetation density in SWLA & SETX in 2013-2014.

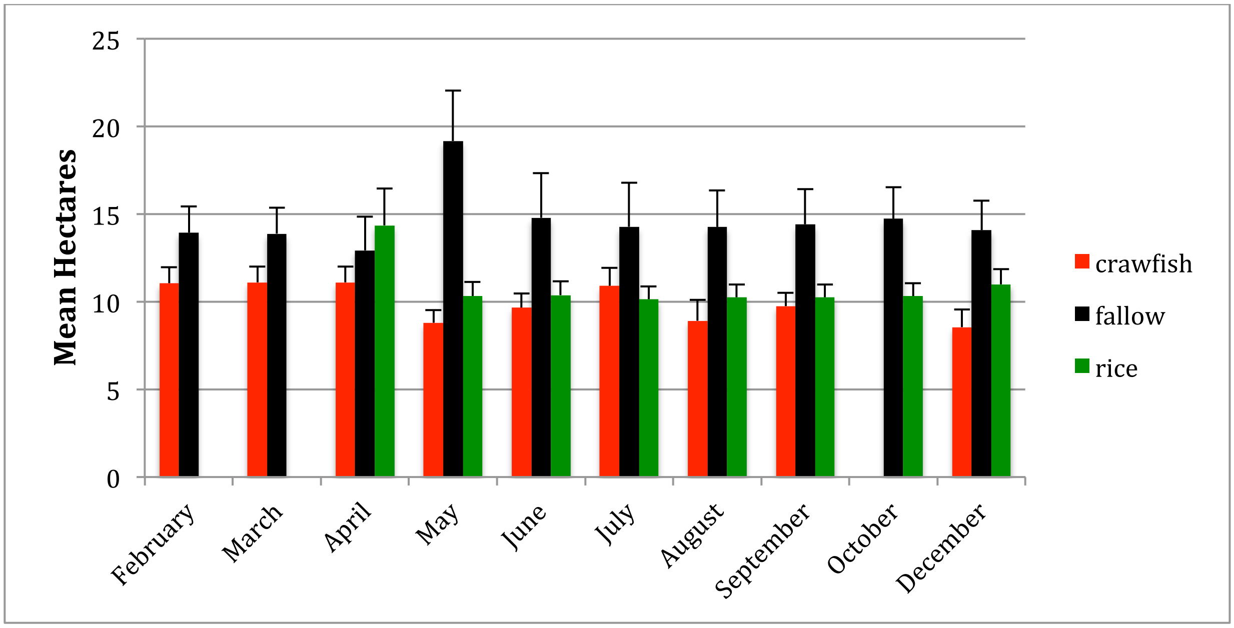

Fig 2.6. Spatial variation (mean # of ha/crop type (+ SE)) between crop types among line transects in SWLA & SETX in 2013-2014.

DISCUSSION

The results of this study demonstrate the intra-annual variability in resources available to waterbirds and other wetland dependent wildlife throughout the coastal prairie region of Southwest Louisiana and Southeast Texas. In previous research, the use of mudflats, mature rice, and crawfish ponds by waterbirds has been noted (Pierluissi 2006; Pickens 2012; Villani 2010; Huner et al. 2002; Manley et al. 2004), but this is the first study, in the region, that has evaluated the actual distribution of these resources across the landscape and how they vary through time.

Fields that were placed in rice production started to exhibit the rice crop in April, and either continued in production or had stubble remaining until December. Around December the fields were usually tilled or were in a fallow status until around March of the following spring. Winter fields were flooded either for crawfish production, weed control or waterfowl hunting. For this study, a rice field was classified as rice as long as it was reflooded after harvest. This was done because it was unknown whether a field was flooded for waterfowl hunting, weed control or crawfish production until commercial crawfish traps were placed in the field. Crawfish production began in December, increased until February, stabilized around April, then declined in May through July. Fields planted in soybeans started exhibiting crop in May and increased until July then stabilized for a couple of months before decreased in September and October. The total hectarage allocated to pasture was consistent throughout the annual cycle. Fallow field hectarage reached its highest levels in February and March when fields were being prepared for the spring planting.

The months with the most standing water or moist soil are the months in the peak of the rice growing season (May through July) and the wet winter months of December through March. The data from December and March could be a bit deceiving as a large portion of the fields classified as wet were mudflats and are probably attributed to rainfall during those months rather than intentional flooding or drawing down of fields. August and September appear to be the driest months of the year when fields are intentionally drawn down for rice harvest and have not yet been reflooded for a ratoon crop, as well as during April when rice is being planted or rice planted in March has not yet reached a sufficient height to accommodate flooding.

The volume of water present on the landscape varies throughout the year as well. Mudflat conditions (moist fields with a water depth of less than 1 cm) were usually brought on by an intentional drawdown of water from the field or by heavy local rains, and were most prominent during December and March. Fields that were deeply flooded (having a water depth greater than 30 cm) were most prominent in March, April and May. This coincides with the peak of crawfish harvest and crawfish ponds tended to have much greater water depths, on average twice the depth of rice fields. Flooded fields with water depths of between 15-30 cm were most prominent in the month of July, the peak of rice growing season. Shallowly flooded fields, those with water depths of between 1 cm and 15 cm, were more common in the month of June. The increase of flooded fields and increase in flood depth was expected as rice plants mature and increase in height, the water depth in those fields can safely increase without damaging the crop, allowing for increased efficiency in weed control (Saichuk et al. 2009).

July through October showed the most hectarage in the survey designated as very tall (having a height of greater than 60 cm) with October being the most prominent month. This was an unexpected finding and was probably due to the fact that many cut rice fields had stubble remaining in the fields in excess of 60 cm. Fields in the months of May through October had the greatest levels of high-density vegetation, that is fields with at least 50% vegetative ground cover. July was the month that had the most hectarage classified at a high-density level. July was about the peak of rice growth in the region when rice fields peaked in height and density as well as area of flooded fields. By August many fields and been drawn down and harvested. The graphs of vegetation height do not clearly illustrate this as rice crops in July reached heights in excess of 1 m and even after being cut still had stubble remaining in the field in excess of 60 cm. Future studies would be wise to consider adding another level or two of vegetation height (60cm – 1m and >1m) in order to distinguish between cut rice and standing crop at time of analysis. Vegetation density in rice fields also did not decrease much as the only disruption in density of remaining stubble were from combine tires rolling vegetation flat. Even after the combine damage to stubble many fields still fell into the high-density category as having greater than 50% coverage. The months of December through May had the most hectarage with no vegetative cover.

These data are valuable, however, an integration of this type of habitat data with average waterbird densities within the various habitat types could lead to more effective conservation planning for a wide-variety of waterbird species in the region. The approach, however, is not without issues.

More frequent sampling may have developed a more robust model, but this is also labor intensive with each set of road transects requiring 3-4 days to survey. Other studies have quantified habitat availability in rice fields with remote sensing (Pickens and King 2012). Although this has potential for some aspects, no measurements of water depth, vegetation density, and vegetation height can be attained remotely. Furthermore, multiple scenes would need to be analyzed to account for the effect of the rapid changes in management that are common to this landscape. A drone equipped with videography or high resolution photography is a possible sampling tool in the future, but it would also be very labor intensive, would not be able to measure water depths, and may create animosity with private landowners. Thus, there is no single sampling method that can provide a comprehensive survey.

I believe the classification system for rice and crawfish agriculture created in this study will be beneficial for use in future studies but is not without flaws. Adding another vegetation height category to quantify rice greater then 60 cm but less than 1m and a category greater than 1 m will aid in distinguishing between a harvested rice crop that has been reflooded for a ratoon crop and those that have not yet been harvested. It will also be helpful to determine if a dry field has stubble or a standing crop to be harvested at the time of survey. The other modification I recommend is a Rice-Fallow category to distinguish between a dry field that contains cut rice stubble and a fallow rice field that contains no rice stubble but perhaps natural vegetation. Distinguishing between these two types of fallow fields will also add greater clarity to the landscape classification model.

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CHAPTER 3
THE EFFECTS OF RICE AND CRAWFISH FIELD TYPES AND LANDSCAPE CHARACTERISTICS ON NEKTON COMMUNITIES

INTRODUCTION

Crawfish ponds provide an abundant and concentrated source of protein for waterbirds, especially during periods of drawdown when mudflats are exposed (Ma et al. 2009). In addition, rice fields and crawfish ponds provide natural forage in the form of moist soil plant seeds and green forage (Manley et al. 2004). These working wetlands also provide the conditions necessary to support aquatic invertebrate communities essential protein sources for wading birds, waterfowl and shorebirds (Manley et al. 2004).

Many aspects of how rice farming benefits global waterbird populations are understood (Kushlan and Hafner 2000; Elphick and Oring 1998; King et al. 2010; Tourenq et al. 2003; Manley et al. 2004; Ma et al. 2010). The hydroperiod of rice fields is believed to contribute to the high abundance and diversity of aquatic invertebrate communities (Stenert et al. 2009). In rice fields of southern Brazil, fields that remained flooded for nearly the entire cultivation cycle had a more diverse community of aquatic invertebrates than fields with an extended dry out period (Stenert et al. 2009). Varying management practices adopted after the harvesting period, such as flooding or not flooding fields, did not seem to influence macroinvertebrate richness or density, but did influence species composition (Stenert et al. 2009). The seasonal abundance of many aquatic invertebrates in California rice fields was correlated with water temperature and plant stand (Zalom 1981).

Rice field sediments can support viable resting stages of aquatic invertebrates during fallow phases with drying for two years without compromising aquatic invertebrate emergence (Stenert et al. 2010). Invertebrate taxon richness in rice fields of southern

Brazil was lower in sediments dry for 20 days and two years compared to sediments dry for one year (Stenert et al. 2010). When a field is flooded after a dry period of several days, a rapid colonization of collectors and grazers took place (Leitao et al. 2007). A study of Spanish rice fields showed that aquatic snails disperse readily by direct water connections and can be carried by waterbirds flying between rice fields (Van Leeuwen et al. 2013). Although not directly an invertebrate study, Katano et al (2003) investigated fish diets and concluded fish that accessed rice fields and irrigation ditches predominantly preyed on aquatic insects such as Ephemeroptera, Chironomidae and Trichoptera, but aerial insects and benthic algae were also fed upon by a few species.

The use of agricultural chemicals in conventional rice farming practices has been shown to cause changes in abundance and diversity of aquatic macroinvertebrates. Stenert et al. (2010) suggested that lower richness and density in rice fields dry for short periods of time could be the result of residual effects of herbicides and pesticides on emergent invertebrates. In the rice fields of France's Rhone Delta, the proportion of predators in organic rice fields are comparable to those observed in macroinvertebrate communities of natural temporary ponds (Mesleard et al. 2005). The same study showed that a reduction of predators in insecticide-treated fields may have given rise to a trophic cascade effect leading to greater overall abundance of macroinvertebrates, but lower species diversity (Mesleard et al. 2005). Pesticide applications can continue to influence the composition of rice field communities as the growing season progresses, retarding predator development and indirectly leading to increases in pest herbivore populations (Wilson et al. 2007). A study of Costa Rican rice fields showed more macroinvertebrates resistant to pollution were found in the conventional fields compared to the organic fields, possibly showing that aquatic macroinvertebrates respond to the type of management products that are applied to the rice field (Rizo-Patron V et al. 2013).

The methods used to plant rice, including drilling and aerially seeding fields, may also have an effect on the density and diversity of invertebrates (Wilson et al. 2007). Greater macroinvertebrate abundance was observed at sites cultivated using drill-sowing techniques compared to aerially sown fields, possibly due to the incorporation of organic material into the soil during planting (Wilson et al. 2007). Macroinvertebrate richness and density changed over the rice cultivating cycle and was higher in the fallow phase than in the tillage and rice-growing phase (Stenert et al. 2009). However, some management effects on aquatic invertebrates may be temporary. Aquatic rice fields developing under varying management regimes were substantially different from each other early in the rice-growing season, but became more similar as the season progressed (Mesleard et al. 2005; Wilson et al. 2007).

The objective of this study is to evaluate the relationship between field classification and habitat characteristics and invertebrate densities in selected field types through time. The study will also attempt to determine how agricultural management practices affect potential caloric values for waterbirds foraging in rice fields and crawfish ponds in this region. I predict that rice fields and crawfish ponds irrigated with well water have a greater macroinvertebrate abundance and biomass than fields irrigated with canal water. I also predict that rice fields and crawfish ponds irrigated with canal water will have greater fish, amphibian and invertebrate predator abundance and biomass reducing the number of macroinvertebrates present but providing greater caloric value for foraging wading birds. By providing a caloric value for fields based on the classification system defined in chapter

2 wildlife managers will be able to determine when waterbird food resources in the region are abundant and when waterbird food resources are scarce.

METHODS

Sample Site Selection

Sample sites were selected by utilizing a stratified random sampling method based upon the proportion of rice planted in the parish/county in 2012 (Louisiana) and 2011 (Texas). Rice hectarage estimates were obtained from www.lsuagcenter.com for Louisiana parishes and from www.nass.usda.gov for Texas counties. A grid of township and range sections was constructed in GIS for each county. A random number generator was used to select sample sections. If a sample section chosen by the random number generator had less then 50% agriculture, the site was dropped and a new section was chosen. A total of 50 sections across the region were selected (about 50 square miles in total). Once sites were selected, all landowners within each section were identified and contacted to gain access to sample sites and to identify the person(s) responsible for agricultural management of the land. Those directly involved in the agricultural management of the land were asked to answer a survey based on the management practices currently utilized in selected fields and to identify individual field boundaries. The survey allowed fields to be categorized based on type of crop and rotation. The field categories are rice, crawfish, or other (soybeans, wheat, corn, fallow, etc.). Additional information was collected to help explain potential variation between fields of the same category. The additional information collected was tillage (till or no-till), planting method (drilled or aerially seeded), use of pesticides and herbicides (conventional or organic), and source of irrigation (ground water well or surface/canal water). For crawfish ponds the forage crop available (natural vegetation or ratoon rice) was also determined.

Aquatic Macroinvertebrate Sampling

Aquatic macroinvertebrate samples were collected during periods of inundation from May 1, 2013, until February 22, 2014. Samples were collected on a monthly basis for May, June and July of 2013 and quarterly samples were taken in fields that were inundated during October 2013 and February 2014. A total of 90 fields were sampled during the study.

Based on the results of the landowner survey (Chapter 1), fields within sample sites were chosen for intensive study. If the selected field was not inundated at the time the nearest field with similar attributes was sampled. Macroinvertebrates were collected with a D-frame net (0.3 m X 0.3 m; 500 µ nytex screen) at a random location within each selected field. I conducted a total of 10 sweeps of 2 meters per sweep (surface covered 6 m^2; Bolduc and Afton 2003). Vegetation collected in the net was retained so as not to discard invertebrates trapped in vegetation. Samples collected were immediately stored in a 95% ethanol solution and frozen for storage until they could be processed in the lab. Each sample was sorted carefully, separating invertebrates from vegetation and sediment. Each sample was processed until a through scan of the material no longer produced an invertebrate, fish or reptile. Organisms collected were stored in vials containing a 95% ethanol solution. Organisms were then sorted, counted and identified to family. Samples were dried at 60°C for 24 hours then weighed in order to determine dry biomass.

Fish and Amphibian Sampling

Fish and amphibian samples were collected during periods of inundation from May 1, 2013, until February 22, 2014. Samples were collected on a monthly basis for May, June and July of 2013, and quarterly samples were taken in fields that were inundated during October 2013 and February 2014. Sample sites were paired with invertebrate sample sites. Three Gee style minnow traps were placed in each field sampled for a period of 24 hours. Samples collected were immediately euthanized by being placed in an ice chest containing an ice water slurry for a period of at least five minutes per LDWF sampling permit #2004. Samples where then stored in Ziploc bags and placed on ice for storage during transportation. Samples were frozen until processed. Samples were identified to species and wet weights and lengths were measured for each individual. Samples were then refrozen for storage until bombing could take place.

Caloric Value Determination

Invertebrate samples after being sorted, identified, dried at 60°C for 24 hours and weighed were then processed in order to determine a caloric value for each family. Invertebrate samples were ground to a fine powder with the use of mortar and pestle. The powder was mixed with water to create a paste and the paste was pelletized and placed in an oven at 60 °C for 24 hours. The pellets were weighed to make sure they were between 0.8 and 1.2 grams then loaded into the Parr 6200 Calorimeter. For the invertebrate families that had enough dry mass available, three bombs were conducted. The families that did not have enough for three samples were bombed as many times as dry material allowed. Families that did not have enough dry material for one sample were all combined into a single sample and three bombs were conducted.

Fish, reptiles and amphibians were identified to species, wet weights and lengths were obtained and they were processed to determine a caloric value. Wet samples were placed into a blender and the blended material was pelletized and placed in the oven at 60 °C for 24 hours. The pellets were weighed to verify that their weight was between 0.8 and 1.2 grams then they were loaded into the Parr 6200 Calorimeter. Three bombs were conducted for each species. The caloric value determination is based on total energy available not digestible energy as no digestibility coefficients were calculated.

Data Analysis

Analyses of the relationship between macroinvertebrate count, biomass, and caloric value with field type and field management methods were restricted to the 14 (biomass and caloric content) or 10 (count) most numerous macroinvertebrates. Subsequent analyses were separated by collection method, trap or D-net. For each of macroinvertebrates, nested generalized linear mixed models were constructed and evaluated following the procedure outlined in Bolker et al. (2008) and Zuur et al. (2009). Candidate models with one of six probability distributions (normal, log-normal, Poisson, negative binomial, zero-inflated Poisson, and zero-inflated negative binomial) and the corresponding canonical link function were compared by AICc. Estimation of maximum likelihood was by Laplace approximation. All models included field size and sample date as random variables, and crop type, seeding method nested within crop type, tillage method nested within crop type, and irrigation method nested within crop type were the fixed explanatory variables. The model with the probability distribution and link combination with lowest AICc was selected for inference. Statistical significance for inference was set at 0.05. All analyses were performed in SAS, vers. 9.4 (SAS Institute, Inc., Cary, NC). To assess temporal effects, family-level dissimilarity among sampling months was estimated by the Bray-Curtis index (1957). Following construction of the dissimilarity matrix, non-metric multidimensional scaling produced 2 dimensions for subsequent fitting of environmental vectors to the ordination by permutation test (999 permutations; Oksanen et al. 2015).

RESULTS

We identified 36,169 individuals from 27 orders which were made up of 78 families: 68 arthropod families, 4 families of leaches, 2 amphibian families, one reptile family and 3 fish families. Fourteen families made up 95.5% of total biomass collected in the sweep net samples with the ten most abundant families comprising 92.8% of the total individuals collected and identified from sweep net sampling (Table 3.1). Due to the large number of rare families, the analysis focused the most abundant families and those families that contributed the most to total biomass. Due to only sampling two organic fields no statistical analysis based on chemical management was possible.

Table 3.1. Proportion by family of invertebrate biomass and density.

95.5%	**Biomass (14)**	**92.8%**	**Individuals (10)**
27.7%	Cambaridae	38.6%	Baetidae
23.0%	Planorbidae	23.1%	Corixidae
11.1%	Baetidae	9.1%	Chironomidae
7.0%	Physidae	6.6%	Notonectidae
5.2%	Aeshnidae	3.9%	Hydrophilidae
4.4%	Corixidae	3.3%	Annelida
3.6%	Notonectidae	2.9%	Physidae
3.2%	Hydrophilidae	2.6%	Coenagrionidae
2.4%	Ranidae	1.7%	Dytiscidae
1.9%	Belostomatidae	1.1%	Planorbidae
1.8%	Poecillidae		
1.5%	Dytiscidae		
1.3%	Libellulidae		
1.2%	Coenagrionidae		

Table 3.2. D-Net Invertebrate Data – mean density (CPUE) of macroinvertebrates and standard error by date, field class, irrigation type and tillage method.

Invert D-Net Data

	May	Sites	May (μ)	(SE)	June	Sites	June (μ)	(SE)
Density	9,743	26	374.73	(74.75)	11,713	26	450.50	(68.90)
# of Families	52				52			
Biomass (g)	16.6085	26	0.6388	(0.2172)	19.5454	26	0.7517	(0.1364)

	July	Sites	July (μ)	(SE)	October	Sites	October (μ)	(SE)
Density	2,719	15	181.27	(36.63)	6,006	11	546.00	(161.94)
# of Families	51				39			
Biomass (g)	9.5798	15	0.6387	(0.1103)	14.1532	11	1.2867	(0.4038)

	February	Sites	February (μ)	(SE)
Density	3,631	11	330.09	(69.89)
# of Families	35			
Biomass (g)	28.0209	11	2.5474	(0.6455)

	Crawfish	Sites	Crawfish (μ)	(SE)	Rice	Sites	Rice (μ)	(SE)
Density	16,656	38	438.32	(64.05)	17,156	51	336.39	(46.36)
# of Families	54				79			
Biomass (g)	55.3043	38	1.4554	(0.2633)	32.6035	51	0.6393	(0.1107)

	Canal	Sites	Canal (μ)	(SE)	Well	Sites	Well (μ)	(SE)
Density	4,333	19	228.05	(40.44)	29,479	70	421.13	(46.31)
# of Families	61				74			
Biomass (g)	17.5991	19	0.9263	(0.2571)	70.3087	70	1.0044	(0.1558)

	Till	Sites	Till (μ)	(SE)	No Till	Sites	No-Till (μ)	(SE)
Density	21,430	54	396.85	(53.13)	12,382	35	353.77	(53.10)
# of Families	79				62			
Biomass (g)	44.0861	54	0.8164	(0.1356)	43.8217	35	1.2520	(0.2697)

Table 3.3. Mean density (#/m^2 (SE)) of aquatic macroinvertebrates by field class and irrigation type.

		Crawfish		Rice	
Order	Family	Canal	Well	Canal	Well
Collembola					
	Poduridae			0.01 (N/A)	0.01 (N/A)
	Isotomidae			0.02 (0.02)	
	Sminthuridae				>.01 (N/A)
Ephemeroptera					
	Baetidae	2.04 (1.19)	38.21 (9.67)	6.31 (2.63)	21.44 (4.33)
	Caenidae		0.04 (0.03)	0.08 (0.06)	0.11 (0.04)
	Polymitarcyidae				0.02 (N/A)
Odonata				0.01 (N/A)	
	Petaluridae	0.04 (N/A)	0.20 (0.10)		0.02 (N/A)
	Gomphidae		>.01 (N/A)		>.01 (N/A)
	Aeshnidae	0.21 (0.16)	0.76 (0.27)	0.03 (0.02)	0.06 (0.03)
	Corduliidae		0.09 (0.05)	0.04 (N/A)	0.05 (0.02)
	Libellulidae	0.04 (N/A)	0.30 (0.11)	0.76 (0.22)	0.65 (0.18)
	Lestidae		0.02 (N/A)		
	Coenagrionidae	0.04 (N/A)	0.75 (0.28)	2.41 (1.48)	2.31 (0.80)
Orthoptera					
	Tettigoniidae			0.01 (N/A)	
Hemiptera			0.01 (N/A)		
	Mesoveliidae			0.01 (N/A)	0.02 (0.01)
	Hebridae				0.01 (N/A)
	Macroveliidae		0.05 (0.03)	0.01 (N/A)	
	Hydrometridae				>.01 (N/A)
	Gerridae			0.01 (N/A)	
	Saldidae				>.01 (N/A)
	Nepidae			0.03 (0.02)	
	Belostomatidae		0.18 (0.08)	0.16 (0.07)	0.06 (0.02)
	Corixidae	1.21 (0.83)	23.04 (7.74)	2.56 (1.00)	13.26 (5.60)
	Naucoridae				>.01 (N/A)
	Notonectidae	0.71 (0.55)	2.84 (1.09)	1.39 (0.78)	6.98 (1.78)
Homoptera					
	Cicadellidae		0.27 (0.13)	0.12 (0.06)	0.08 (0.02)
Trichoptera					0.01 (N/A)
	Hydroptilidae			0.02 (N/A)	
	Leptoceridae		0.01 (N/A)	0.01 (N/A)	

Table 3.3. Continued

		Crawfish		Rice	
Order	Family	Canal	Well	Canal	Well
Lepidoptera					
	Crambidae			0.01 (N/A)	
Coleoptera					
	Gyrinidae				0.01 (N/A)
	Curculionidae	0.08 (0.05)	0.02 (0.01)	0.98 (0.33)	0.32 (0.11)
	Carabidae			0.02 (N/A)	
	Haliplidae			0.03 (0.02)	0.03 (0.02)
	Dytiscidae		0.21 (0.10)	1.86 (0.58)	1.61 (0.60)
	Noteridae			0.01 (N/A)	
	Hydrophilidae	0.67 (0.34)	2.08 (1.00)	2.91 (0.83)	2.89 (0.69)
	Lampyridae		>.01 (N/A)		>.01 (N/A)
	Staphylinidae			0.09 (0.05)	
	Scirtidae			0.01 (N/A)	
	Elmidae				0.01 (N/A)
	Ptilodactylidae			0.01 (N/A)	
	Chrysomelidae			0.02 (0.02)	0.01 (N/A)
Hymenoptera					
	Braconidae			0.04 (N/A)	
Diptera			0.01 (N/A)	0.02 (N/A)	0.01 (N/A)
	Ceratopogonidae		0.01 (N/A)	0.62 (0.30)	0.13 (0.04)
	Chaboridae		0.04 (0.03)	0.01 (N/A)	
	Chironomidae	0.08 (0.05)	4.54 (1.70)	6.73 (3.15)	7.15 (2.64)
	Culicidae	0.08 (0.05)	0.29 (0.12)	0.21 (0.10)	0.28 (0.08)
	Simuliidae			0.01 (N/A)	
	Tanyderidae		0.01 (N/A)		
	Tipulidae	0.04 (N/A)	0.12 (0.05)	0.03 (N/A)	0.01 (N/A)
	Dolichopodidae			0.02 (N/A)	
	Empididae				0.01 (N/A)
	Stratiomyidae		0.03 (0.02)	0.04 (0.02)	0.13 (0.03)
	Tabanidae	0.08 (N/A)	0.05 (0.02)	0.06 (0.03)	0.06 (0.02)
	Canacidae			0.02 (N/A)	0.01 (N/A)
	Ephydridae		0.02 (N/A)	0.01 (N/A)	1.00 (0.92)
	Muscidae		0.06 (0.04)		
	Sciomyzidae				0.01 (N/A)
Ostracoda (class)			0.70 (0.68)	0.08 (N/A)	0.41 (0.23)
Amphapoda					
	Talitridae	0.04 (N/A)			

Table 3.3. Continued

		Crawfish		Rice	
Order	Family	Canal	Well	Canal	Well
Decapoda					
	Cambaridae	0.04 (N/A)	0.32 (0.13)		0.04 (0.02)
	Palaemonidae		0.02 (N/A)	0.03 (N/A)	0.13 (0.10)
Archaeognatha					
Araneae		0.04 (N/A)	0.12 (0.07)	0.39 (0.17)	0.20 (0.05)
Isopoda					
	Asellidae	0.04 (N/A)	0.03 (N/A)		
Gastrapoda (class)					
	Physidae	1.00 (0.89)	0.78 (0.28)	3.24 (0.73)	2.27 (1.00)
	Planorbidae	0.71 (0.51)	0.12 (0.05)	3.13 (2.43)	0.20 (0.08)
Veneroida					
	Corbiculidae				>.01 (N/A)
	Sphaeriidae				0.03 (0.03)
Annelida (phylum)		23.75 (23.20)	0.82 (0.70)	3.77 (2.24)	0.18 (0.10)
Arhynchobdellida					
	Eropdellidae		0.10 (0.08)	0.02 (N/A)	
	Hirudinidae	0.04 (N/A)	0.01 (N/A)	0.30 (0.22)	0.13 (0.07)
Rhynchobdellida					
	Glossiphoniidae	0.75 (N/A)			0.02 (0.01)
	Piscicolidae				0.16 (0.13)
Perciformes					
	Centrarchidae		0.03 (0.02)		0.01 (N/A)
Cyprinodontiformes					
	Poeciliidae	0.17 (N/A)	0.40 (0.19)	0.13 (0.09)	0.06 (0.03)
Anura					
	Ranidae		0.03 (0.02)	0.51 (0.45)	0.18 (0.06)
Terrestrial			0.07 (0.05)	0.21 (0.17)	0.04 (0.02)

The months of May and June had the highest number of invertebrate families (Table 3.2). July had the lowest density and biomass levels of any month sampled (Table 3.2). Biomass in May was very similar to July (Table 3.2). February had the highest biomass due to a large number of crawfish present in crawfish ponds (Table 3.2). October, while having the second lowest number of families present, had the greatest density (Table 3.2).

Rice fields had 72 families present while crawfish ponds had only 54 families (Table 3.2). Average density and biomass was greater in crawfish ponds than in rice fields (Table 3.2). There were 70 families present in well sites and only 61 families in canal sites (Table 3.2). Canal sites also had a lower density and biomass than well sites. Tilled fields had more families and higher density but less biomass than did non-tilled fields (Table 3.2).

Field class was statistically significant for predicting crawfish density. As was expected, crawfish ponds supported more crawfish ($F_{1, 47} = 6.86$, $p = 0.01$) and had greater crawfish biomass than did rice fields ($F_{1, 47} = 4.96$, $p = 0.03$) (Fig. 3.1, Table 3.3, Table 3.4). None of the other management types were statistically significant for crawfish density: seeding method ($F_{3, 47} = 0.78$, $p = 0.51$), tillage ($F_{2, 47} = 1.66$, $p = 0.20$) and irrigation (($F_{2, 47} = 1.09$, $p = 0.34$) nor were they statistically significant for crawfish biomass: seeding method ($F_{3, 47} = 0.86$, $p = 0.46$), tillage ($F_{2, 47} = 1.22$, $p = 0.30$), and irrigation ($F_{2, 47} = 1.65$, $p = 0.20$).

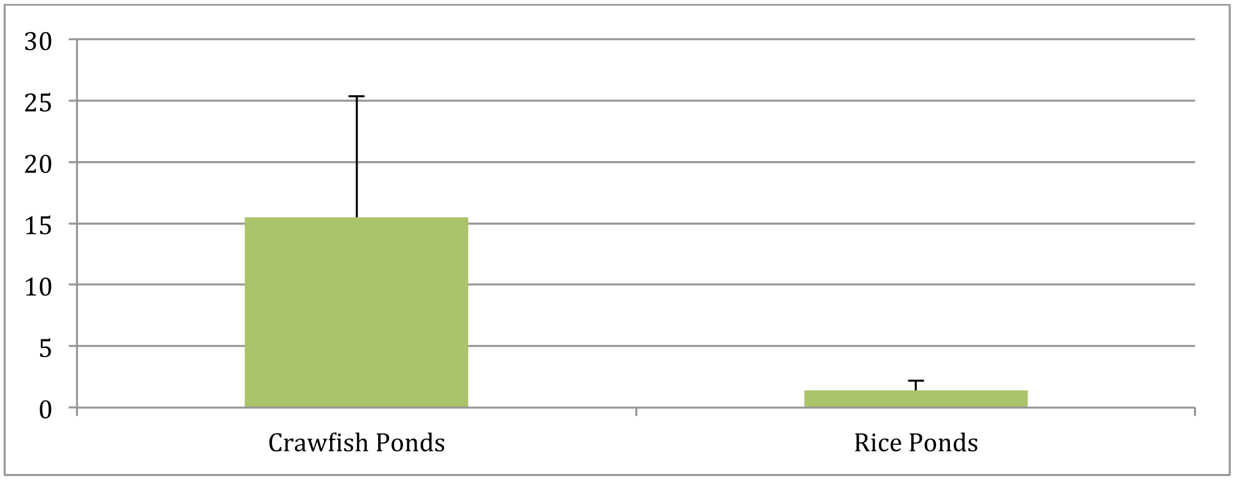

Fig. 3.1. Comparison of Cambaridae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class types.

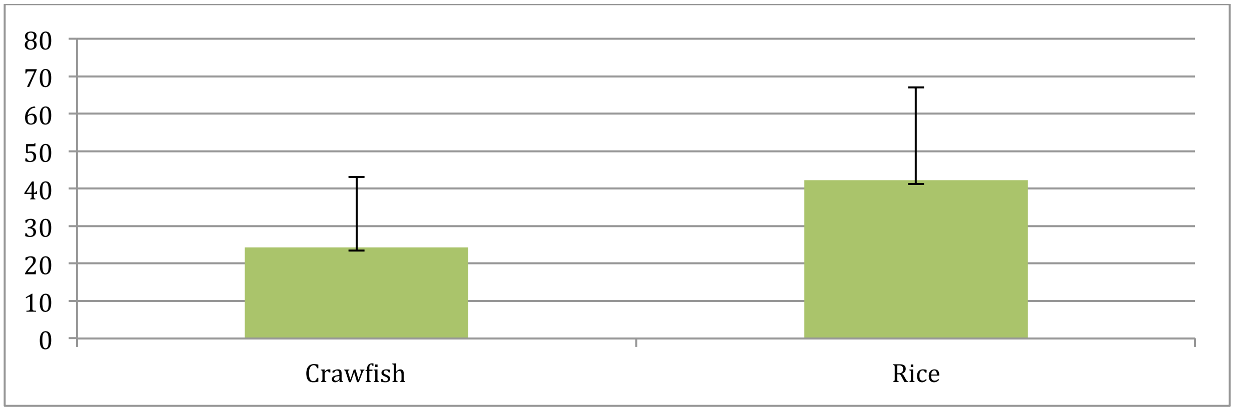

Fig. 3.2. Comparison of Chironomidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class types.

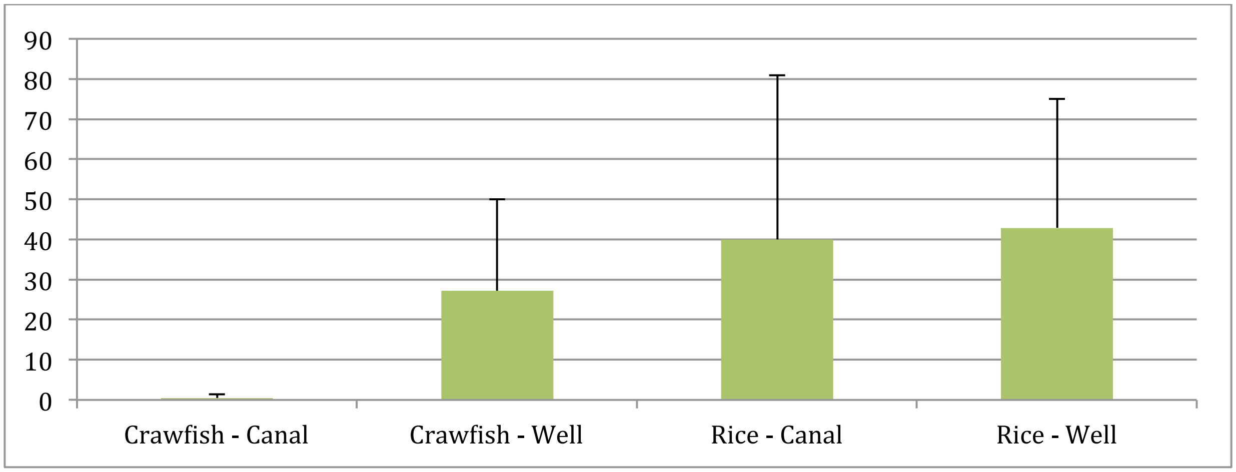

Fig. 3.3. Comparison of Chironomidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

A diversity of macroinvertebrate responses to management activities and field types were observed. The density of Chironomidae was statistically ($F_{1, 80} = 7.02$, $p < 0.01$) higher in rice fields (42.18 ± 12.70) than crawfish ponds (24.42 ± 9.54) (Fig 3.2). Chironomidae was influenced by source of irrigation as well, with well water fields having a higher density than canal irrigated fields, especially in crawfish ponds ($F_{2, 80} = 4.00$, $p = 0.02$) (Fig 3.3).

Irrigation was found to be statistically significant for several families of invertebrates. For three of the most abundant families: Baetidae (38.56% of individuals collected), Corixidae (23.14% of individuals collected) and Notonectidae (6.59% of individuals collected) source of irrigation was the single greatest factor affecting density. All three families had statistically significantly higher levels of density in fields irrigated with well water than fields irrigated with canal water (Baetidae: $F_{2, 80} = 3.19$, $p = 0.04$), (Corixidae: $F_{2, 80} = 6.71$, $p < 0.01$), (Notonectidae: $F_{2, 80} = 3.39$, $p = 0.03$) (Fig 3.4, Fig 3.5, Fig 3.6).

For the family Planorbidae and order Annelida, irrigation had a statistically significant but opposite effect. Fields irrigated with canal water had a higher level of density for Planorbidae ($F_{2, 80} = 5{,}74$, $p < 0.01$) and Annelida ($F_{2, 80} = 4.11$, $p = 0.02$) than fields irrigated with well water (Fig 3.7, Fig 3.8).

Tillage was a significant factor for determining density in the order Annelida and Coenagrionidae family. For Annelids, tilled fields had higher density than no-till fields ($F_{2, 80} = 3.20$, $p = .04$) (Fig 3.9). For Coenagrionidae, the effect of tillage was not as obvious. Coenagrionidae had a higher density in no-till rice fields then tilled rice, but a higher abundance in tilled crawfish ponds then no-till crawfish ponds ($F_{2, 80} = 3.12$, $p = 0.0496$) (Fig 3.10).

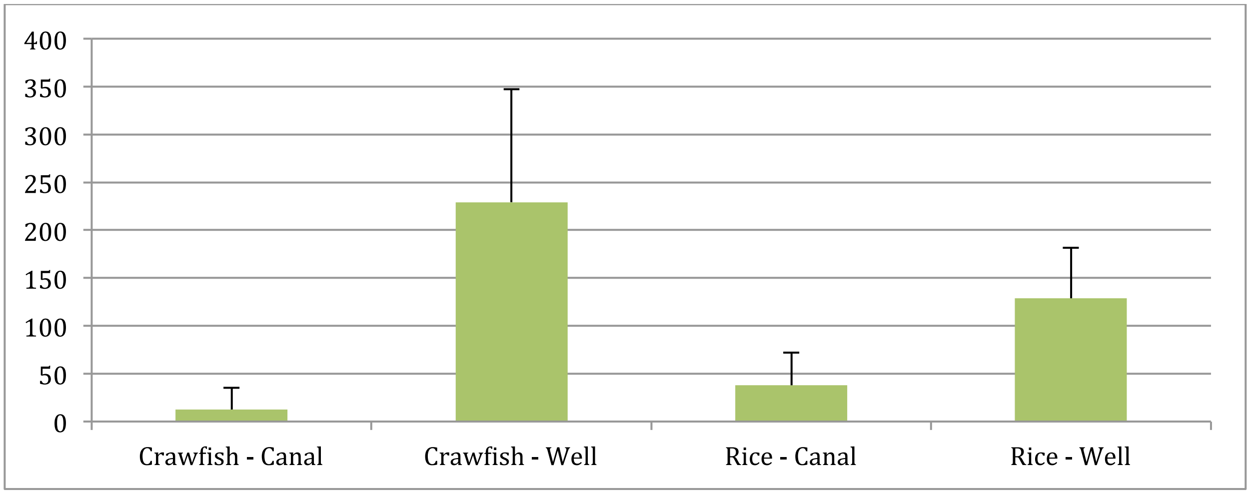

Fig. 3.4. Comparison of Baetidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

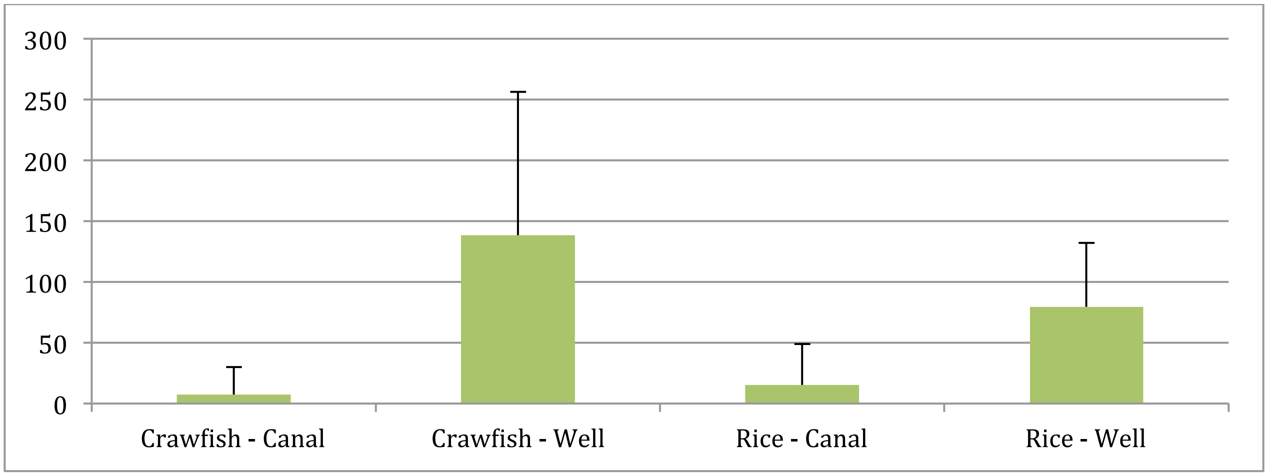

Fig. 3.5. Comparison of Corixidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

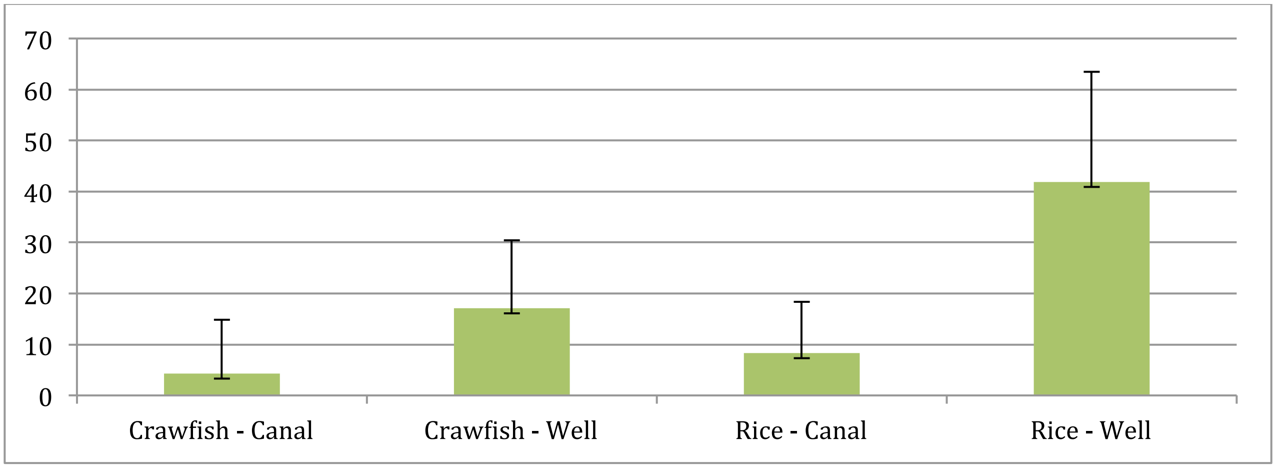

Fig. 3.6. Comparison of Notonectidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

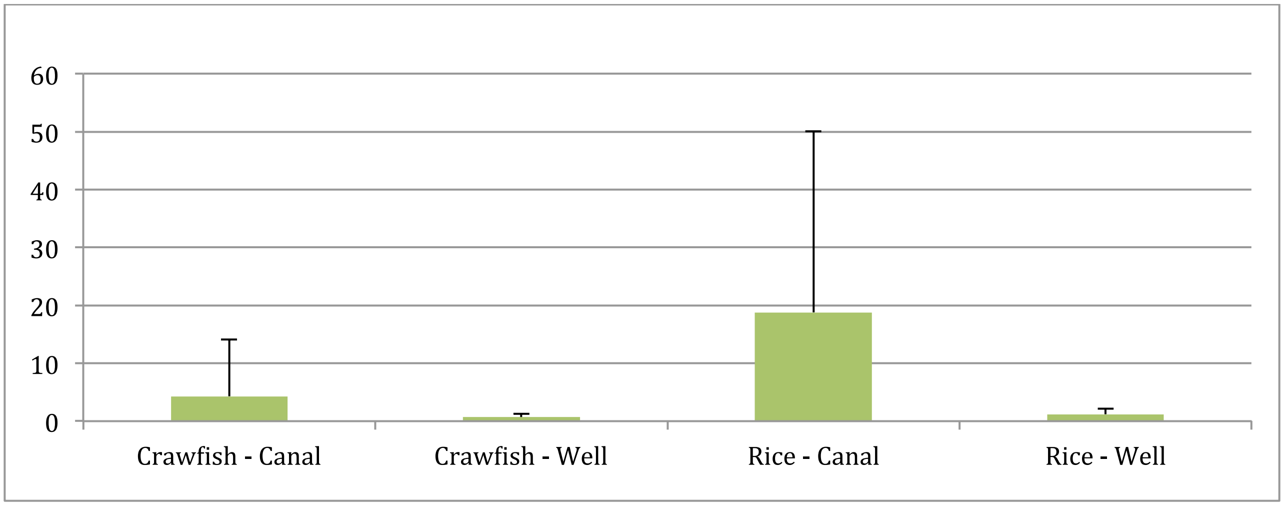

Fig. 3.7. Comparison of Planorbidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

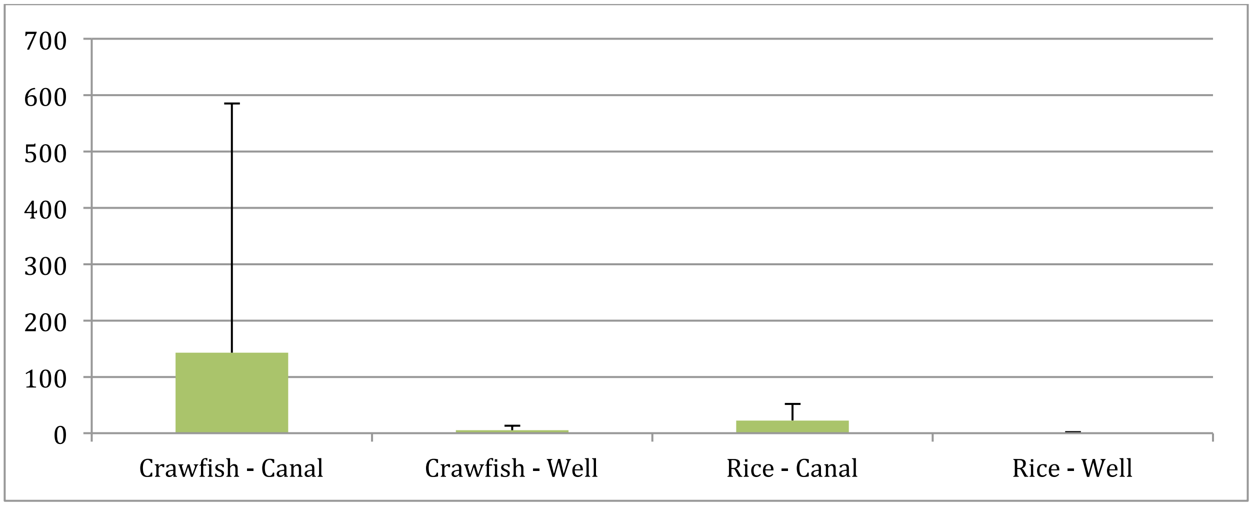

Fig. 3.8. Comparison of Annelida mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

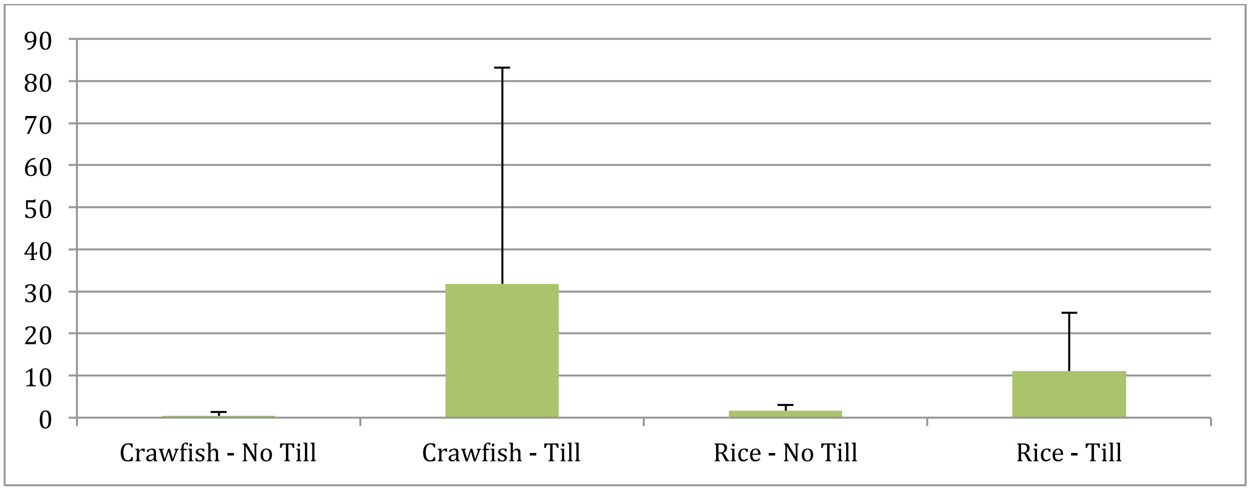

Fig. 3.9. Comparison of Annelida mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by tillage method.

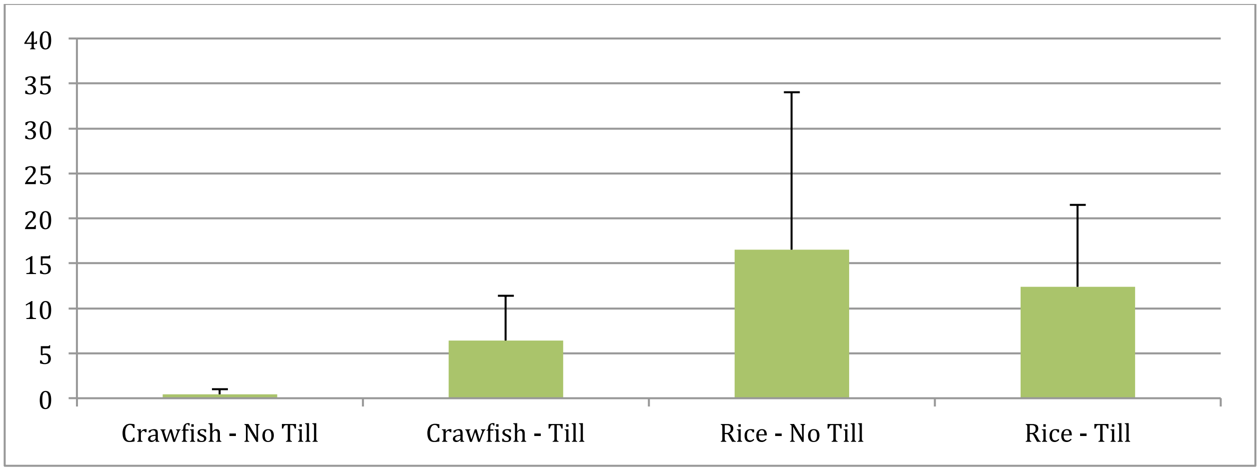

Fig. 3.10. Comparison of Coenagrionidae mean density (CPUE) (w/ 95% confidence intervals) across all sampling dates and sites between field class by tillage method.

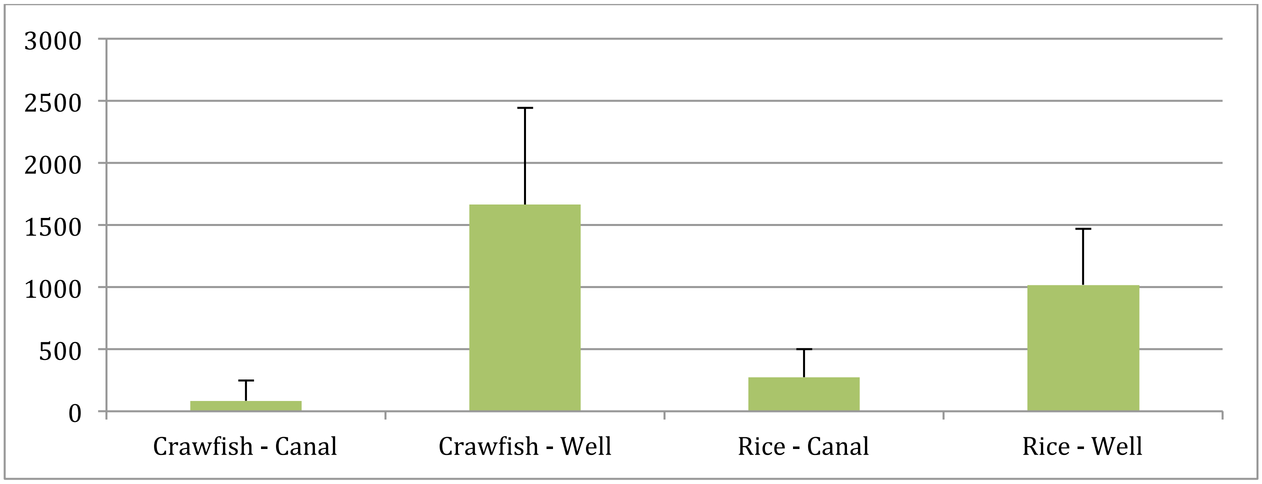

Fig. 3.11. Comparison of Baetidae mean biomass (CPUE, g dry weight) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

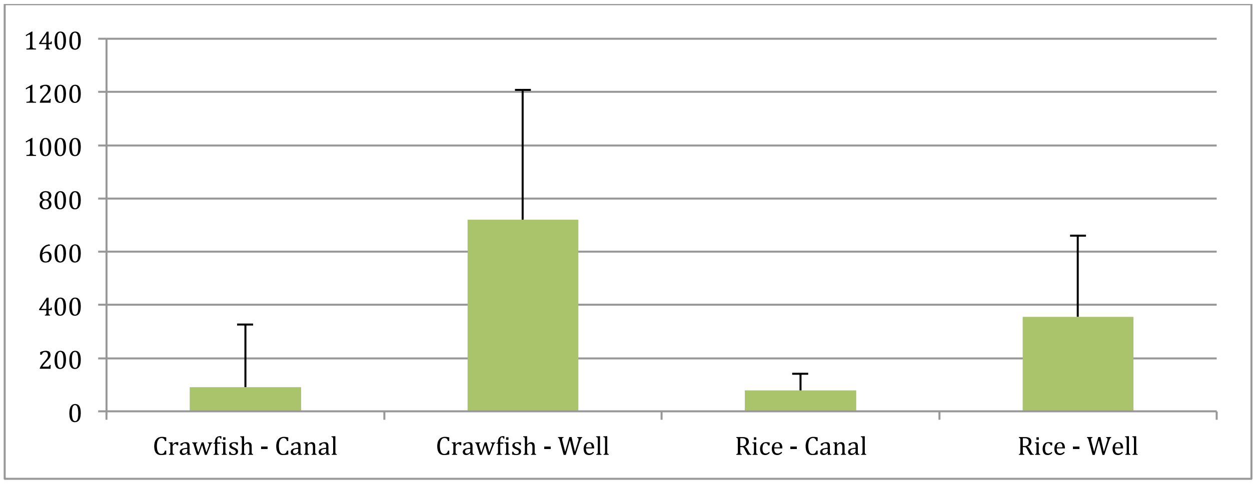

Fig. 3.12. Comparison of Corixidae mean biomass (CPUE, g dry weight) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

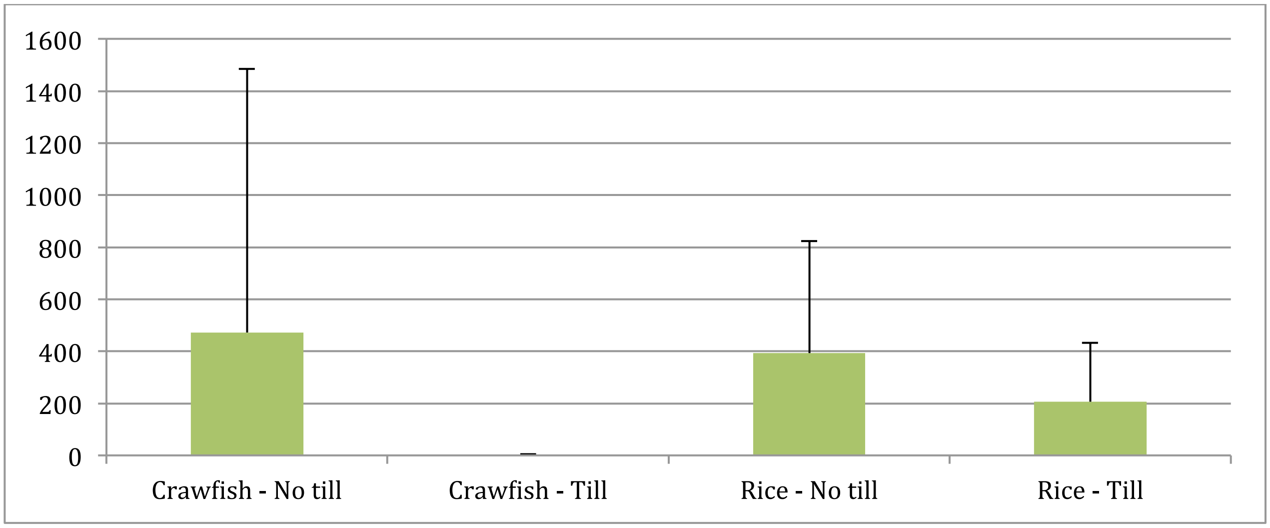

Fig. 3.13. Comparison of Ranidae mean biomass (CPUE, g wet weight) (w/ 95% confidence intervals) across all sampling dates and sites between field class by tillage method.

Biomass followed the same pattern as density for Baetidae and Corixidae. Both families had greater biomass in fields irrigated with well water than those fields irrigated with canal water (Baetidae: $F_{2,80} = 3.64$, $p = 0.30$), (Corixidae: $F_{2,80} = 4.13$, $p = 0.01$) (Fig 3.11, Fig 3.12).

The family Ranidae had its highest biomass levels in fields that had not been tilled with no-till rice fields and no-till crawfish ponds having significantly higher biomass levels then those fields that had been tilled ($F_{2,80} = 3.30$, $p = 0.04$) (Fig 3.13).

No fish or reptiles were captured with the use of minnow traps in crawfish ponds irrigated with canal water but, only 4 fields in this category were sampled (Table 3.4). Crawfish ponds irrigated with well water had the highest density of crawfish (16.38 ± 5.51) (Table 3.4). The fish species *Gambusia affinis* (7.50 ± 3.61) and *Ameiurus melas* (3.15 (N/A)) were most abundant in well irrigated crawfish ponds (Table 3.4). *Lepomis macrochirus*, while highly variable, appeared to be most dense in canal irrigated rice fields (8.79 ± 6.03) (Table 3.4). *Lepomis symmetricus* (10.27 ± 5.44) was most dense in well irrigated rice (Table 3.4). Anurans were more abundant in rice fields than crawfish ponds with Hylidae most dense in well irrigated rice (3.92 ± 1.38), and Ranidae most dense in canal irrigated rice (9.50 ± 4.98) (Table 3.4).

Caloric content was significantly higher ($F_{2,80} = 3.12$, $p = 0.04$) in no-till crawfish fields (11,558 Kcals/Ha ± 3,573) than in tilled crawfish fields (5,792 Kcals/Ha ± 977) or either tillage method in rice fields: no-till rice (3,599 Kcals/Ha ± 548), tilled rice (2,514 Kcals/Ha ± 396) (Fig 3.15). Caloric content within no-till crawfish ponds was also highly variable with 95% confidence level mean caloric values ranging from 18,560 Kcals/Ha to 4,556 Kcals/Ha (Fig 3.15).

While not statistically significant ($F_{2,80}$ = 1.62, p = 0.20), crawfish ponds irrigated with well water had a greater caloric value per hectare than crawfish ponds irrigated with well water or either irrigation source for rice fields (Fig 3.16). Mean densities in crawfish ponds irrigated with canal water and rice fields irrigated with well water were similar but there was much greater variability amongst crawfish ponds than in rice fields (Fig 3.16).

Although not statistically compared, invertebrate Shannon-Wiener Diversity among field classes illustrated some differences. Shannon-Wiener Diversity calculated from total sampling effort across all sites and sampling dates indicated higher diversity in rice fields compared with crawfish fields (Figure 3.14). The ordination STRESS "badness of fit" criteria is just above the 0.15 guidelines for "good" fit (Clarke 1993), which indicated that the data have some structure or pattern. Monthly family similarity was not statistically significantly different (R^2 = 0.04, P = 0.28). This low R^2 between the invertebrate similarity with month suggested that month was a poor explanation of the structure or pattern.

Shannon-Wiener Diversity Index

Crawfish		Rice	
Canal	Well	Canal	Well
1.16	1.58	2.67	2.10

Figure 3.14. Shannon-Wiener diversity index comparing field classes crawfish and rice by irrigation type.

Table 3.4. Mean nekton density (CPUE (SE)) by field class and irrigation type.

Mean nekton density (CPUE (SE)) by field class and irrigation type.

			Crawfish		Rice	
Order	Family	Species	Canal	Well	Canal	Well
Decapoda						
	Cambaridae		10.00 (4.69)	16.38 (5.51)	1.07 (0.40)	1.62 (0.52)
	Palaemonidae				0.21 (0.11)	
Siluriformes						
	Ictaluridae					
		Ameiurus melas		3.15 (N/A)	0.71 (N/A)	
		Ameiurus natalis			0.14 (N/A)	
Perciformes						
	Centrarchidae					
		Lepomis macrochirus		6.50 (6.30)	8.79 (6.03)	2.00 (1.77)
		Lepomis miniatus			0.36 (N/A)	
		Lepomis symmetricus		2.19 (1.64)	2.50 (2.42)	10.27 (5.44)
		Micropterus salmoides			0.07 (N/A)	
Cyprinodontiformes						
	Poeciliidae					
		Gambusia affinis		7.50 (3.61)	1.86 (0.87)	2.04 (1.70)
Anura						
	Hylidae		0.25 (N/A)	0.08 (0.05)	0.57 (0.31)	3.92 (1.38)
	Ranidae		0.25 (N/A)	0.15 (0.15)	9.50 (4.98)	2.50 (1.50)
Squamata						
	Colubridae					
		Nerodia erythrogaster			0.21 (0.11)	
		Nerodia fasciata		0.04 (N/A)	0.07 (N/A)	
		Nerodia rhombifer				0.08 (N/A)

Table 3.5. Mean caloric value (Kcals/g) by family

Family (* denotes species)	Mean Kcals/g
Belostomatidae	5.93
Ameiurus natalis*	5.69
Dytiscidae	5.55
Lepomis miniatus*	5.44
Nerodia fasciata*	5.33
Ameiurus melas*	5.32
Aeshnidae	5.20
Lepomis symmetricus*	5.15
Lepomis macrochirus*	5.08
Coenagrionidae	5.01
Nerodia rhombifer*	5.00
Micropterus salmoides*	4.96
Hydrophilidae	4.94
Libellulidae	4.94
Corixidae	4.73
Notonectidae	4.70
Gambusia affinis*	4.54
Baetidae	4.28
Nerodia erythrogaster*	4.24
Other	4.15
Ranidae	3.78
Cambaridae	3.65
Hylidae	3.56
Physidae	0.99
Planorbidae	0.31

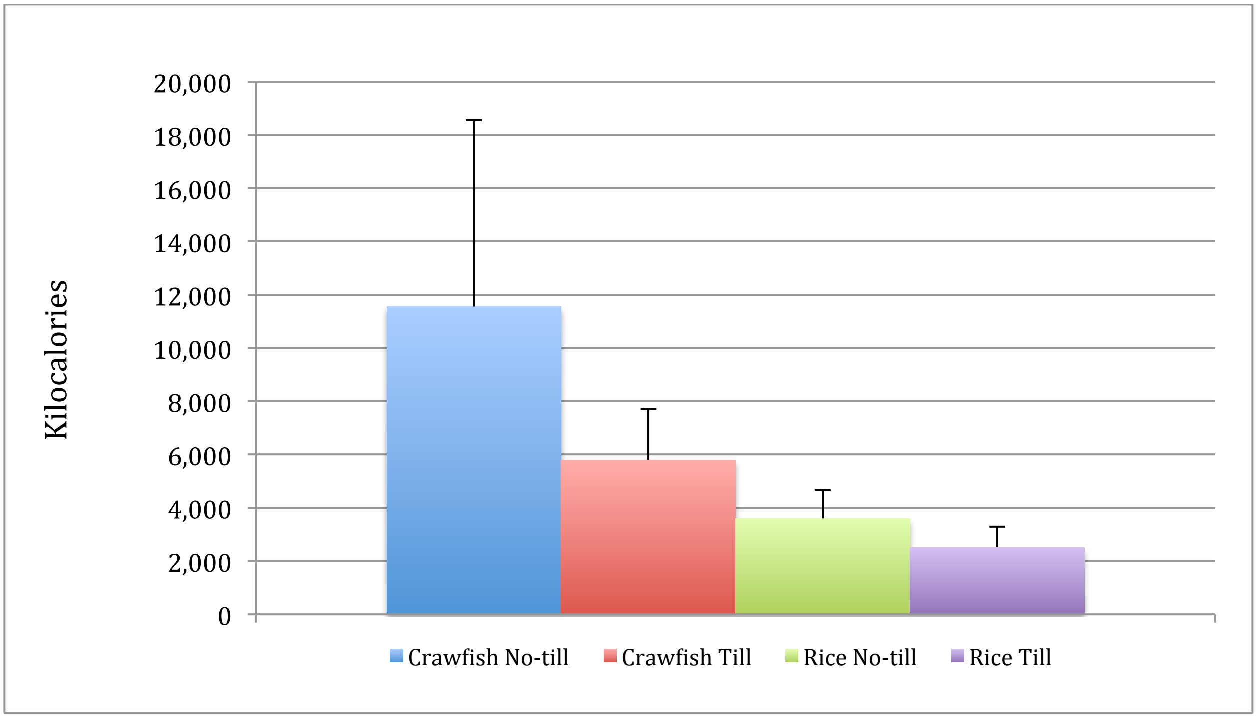

Fig. 3.15. Macroinvertebrate energy available (Kcals/ha) between field class by tillage method.

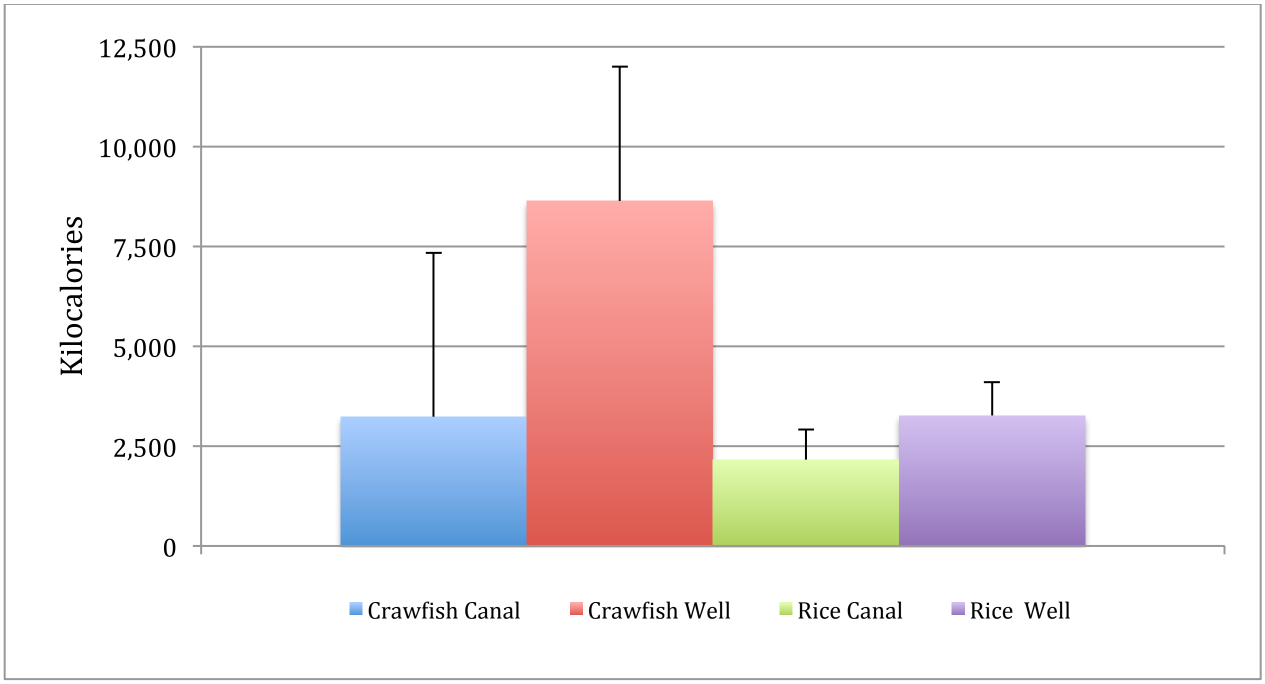

Fig. 3.16. Macroinvertebrate energy available (Kcals/ha) between field class by irrigation type.

DISCUSSION

The results of this study indicate that rice fields in southwest Louisiana and southeast Texas support situationally diverse invertebrate assemblages. A 2010 study of natural freshwater marshes in Southwest Louisiana found 33 invertebrate families present (Kang 2011). The 68 invertebrate families present in rice fields and crawfish ponds, 41 of which were unique compared to natural wetlands, show that invertebrate diversity can actually be greater in "working wetlands" than natural wetlands of the same region. Comparing mean density per m^2 of invertebrates in permanent connected ponds (46.47) and temporarily connected ponds (16.72) of natural marsh (Kang 2011) and mean density per m^2 of invertebrates in canal irrigated crawfish ponds (31.90), well irrigated crawfish ponds (77.81), canal irrigated rice fields (39.58) and well irrigated rice fields (62.83) it appears that "working wetlands" can also support a greater density of invertebrates than can natural wetlands (Table 3.3). It is important to note, however, that the rice and crawfish fields were located in a landscape with a variety of other habitats, whereas Kang (2011) reported values were in an extensive marsh system. Thus, the "working wetlands" supported the invertebrates expected in natural systems and additional invertebrates that appeared to be facultatively exploiting these habitats, despite not necessarily being wetland obligates.

Irrigation seemed to be the largest factor affecting invertebrate density amongst the most common families in the study. Three of the four most abundant families, Baetidae, Corixidae, and Notonectidae all showed significantly higher levels of density in fields that were irrigated with well water as opposed to canal water. Irrigation also was associated with higher levels of density in well-irrigated fields for Baetidae and Corixidae regardless of field classification. Life history strategies could, in part, explain this outcome. These families include species with short life cycles and adaptations to intermittent dry habitats and are probably exploiting these well-irrigated fields after inundation, before predators have a chance to get established (Huryn et al. 2008). This could also explain the peak of abundance in June and the decrease in July when invertebrate predator populations have probably been established (Mercer 2015), which given predator-prey dynamics reported by Mercer (2015) may be a better explanation than emerging to avoid early drying. A lack of predators such as fish, amphibians and predatory invertebrates that would be present in canal water could also be responsible for well water irrigated fields having higher abundance levels (Huryn et al. 2008). Another possibility could be high residual levels of insecticides in canal water that would not be present in ground water (Mize et al 2008). A study of southwestern Louisiana streams showed that abundance and taxa richness of macroinvertebrate communities declined significantly with increases in concentrations of fipronil (a pesticide) and rice-cultivation land-use intensity (Mize et al. 2008). This study did not include water quality sampling but this potential effect cannot be ruled out.

The family Chironomidae was significantly more dense in rice fields than in crawfish ponds. Irrigation seems to influence Chironomidae abundance in crawfish ponds where ponds irrigated with well water were significantly higher than canal irrigated ponds but did not affect density levels in rice fields. This could be due to the longer hydroperiod in crawfish ponds, which would expose chironomids to a higher risk of predation by other macroinvertebrates, fish and amphibians (Merritt et al. 2008; Mercer 2015).

The family Planorbidae and order Annelida showed significantly higher levels of density in fields and ponds irrigated with canal water. This could be due to their preferred dispersal strategy that would favor transport via canals as opposed to insect families that have the ability to disperse aerially (Merritt et al. 2008; Van Leeuwen et al. 2013; Patrick et al. 2014).

Tillage was a significant factor contributing to density for Coenagrionidae and the order Annelida. Annelids preferred tilled fields possibly due to the incorporation of more organic material in the soil during the tillage process (Wilson et al. 2007). Coenagrionidae preferred no-till rice fields, probably do to the length of time spent estivating in the larval stage before adults could disperse aerially, which puts them at greater risk of damage from tillage (Tennessen et al. 2008).

The only factor that significantly contributed to the biomass levels for Ranidae was tillage. Ranidae preferred no-tilled crawfish ponds followed by no-tilled rice fields to their tilled counterparts. The tillage process might be damaging estivating Ranids, leading to a reduction in biomass.

Analysis showed that the family Cambaridae made up 27.74% of total biomass collected in the sweep net samples. The total biomass present in the crawfish ponds and rice fields are probably much larger as D-frame net sampling techniques do not accurately sample crawfish and error on the side of underestimating the crawfish population (Budnick 2015; Gray et al. 2013; Kaller et al. 2013). As expected, abundance and biomass of crawfish was higher in crawfish ponds then in rice fields but beyond that there were no significant differences between management types.

Caloric content was highest in crawfish fields that had not been tilled. This was possibly due to a greater amount of residual plant biomass that serves as a forage base for crawfish; crawfish biomass was the main contributor to the caloric value of fields. While not statistically significant crawfish ponds did have a greater caloric value per hectare than rice fields, with crawfish ponds irrigated with well water having the highest caloric value. The lack of significance was probably due to a great deal of variation amongst crawfish ponds.

A caveat is that the caloric value per hectare is only calculated based on sweep net sampling. Due to the use of this method the more mobile prey items such as fish, amphibians, reptiles and crawfish present in the fields are underrepresented in this estimate. This is important to note, as these are the main prey items for most wading birds foraging in rice fields and crawfish ponds (Kushlan and Hafner 2000). Cattle egrets, shorebirds and waterfowl are probably the main beneficiaries of high macroinvertebrate densities (Kushlan and Hafner 2000; Manley et al. 2004; Stafford et al. 2010). While not direct prey items, macroinvertebrates are a forage base for the fish, amphibians, reptiles and rodents that wading birds depend on for nourishment. Future studies need to utilize a more suitable method of capture to target crawfish, fish, amphibians (both tadpoles and adults) as well as reptiles. Throw traps would possibly be a better method but more than likely multiple sampling methods will be needed to give an accurate estimate of these highly mobile prey items (Gray et al. 2013; Kaller et al. 2013).

There are many variables that could contribute to the variability between fields such as levels of residual pesticides or herbicides, dissolved oxygen levels and hydroperiod that were not measured in this study (Mesleard et al. 2005; Suhling et al. 2000; Mullie et al. 1991; Stenert et al. 2010; Stenert et al. 2009; Wilson et al. 2007; Mize et al. 2008). No distinction was made between whether a field was tilled in the fall after harvest or in the spring before harvest, but this could have an effect of certain invertebrate families based on emergence dates and estivation periods (Huryn et al. 2008). Also, no distinction was made between different methods used to irrigate fields with canal water. Some fields are irrigated by opening gates and allowing water to freely flow into and out of fields while others are mechanically pumped which could destroy organisms in the process.

Based on the classification system described in chapter 2, field class, irrigation and tillage are the three most important factors effecting macroinvertebrate density and biomass in this study. Wildlife managers may benefit from considering how proportional changes in these classifications may change in the future and what affect it will have on macroinvertebrate diversity and density within and among rice and crawfish management types.

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CHAPTER 4
THE EFFECTS OF RICE AND CRAWFISH FIELD TYPES AND LANDSCAPE CHARACTERISTICS ON WADING BIRD USAGE

INTRODUCTION

Rice agriculture covers 1.5 million km^2 worldwide and over 40% of the world's human population depends on it (Fores and Comin 1992). The most important artificial heron habitat in the world is rice (Kushlan and Hafner 2000). Previous studies investigating waterbird use of rice fields have shown that flooded rice fields might provide equivalent foraging habitat to seminatural wetlands and, because of reduced predation threat, may be a safer habitat for waterbirds (Elphick 2000). A survey conducted in 1988 showed that Great Blue Heron, Great Egret, Snowy Egret, White Ibis, White-faced Ibis, Killdeer, Western Sandpiper, Dunlin, Long-billed Dowitcher and Common Snipe (Remsen et al. 1991), are among the 260 species of birds utilizing "working wetlands" in Southwest Louisiana as wintering habitat.

Rice fields and crawfish ponds, along with the canals and ditches that make up the agricultural landscape, provide valuable nesting and brood-rearing habitat (Pickens and King 2012). Breeding bird use of rice fields is composed of five categories: 1) nesting in standing crops; 2) nesting on levees within fields or at field perimeters; 3) nesting in associated canals and ditches; 4) nesting on other wet areas that exist because of rice cultivation; and, 4) use of fields for foraging while breeding in adjacent habitat (Pierluissi 2010). Waterbird nesting concentrations tend to be greater in "dense" rather than "less dense" stands of rice (Hohman et al. 1994). Mottled ducks, which also occupy the region, prefer to nest in permanent pastures with knolls and idle fields located near rice fields (Durham and Afton 2003).

The foraging opportunity that rice fields and crawfish ponds provide are thought to be extremely valuable but determining why waterbirds choose the fields they forage in can be difficult. *Waterbird feeding habitat requirements can be generalized to a degree, the suitability of a site is very much a local matter owing to an array of factors including such variables as the species, intraspecific and interspecific competitors, energy needs, seasonal nesting and migration schedule, prey type, abundance and availability, present and past hydrological conditions, vegetation cover and interspersion, distance to suitable nesting or roost sites, distance to other feeding patches, predators and disturbance regime, all of which may vary within an annual cycle or from one year to the next* (Kushlan and Hafner 2000).

A variety of invertebrates, fish and amphibians are found in rice fields (Gonzalez-Solis et al. 1996). Waterbirds utilize this diverse array of available forage, including seeds (dabbling ducks, geese, cranes), leaves (geese), tubers and rhizomes (geese, swans, cranes), invertebrates (shorebirds, waterfowl), and some vertebrates, such as fish and amphibians (wading birds) (Ma et al. 2009; Richardson et al. 2001). Rice fields provide abundant foraging opportunities at certain times of the year in the form of waste rice left in the field after harvest, as well as ratoon crops left in the field for crawfish production (Manley et al. 2004; Stafford et al. 2010).

Crawfish were always present in the region but commercial production started to alter the landscape around the 1950s (Huner et al. 2009). Waterbird populations increased in Louisiana and decreased in Texas and Florida as commercial crawfish production in the region increased (Fleury and Sherry 1995). Crawfish impoundments in the region are utilized by waterfowl, grebes, pelicans, cormorants, Anhingas, rails, coots, gallinules, shorebirds, gulls and turns (Huner et al. 2009). Crawfish agriculture provides significant small vertebrates and macroinvertebrate food resources for predaceous waterbirds (Huner et al. 2009). Crawfish ponds provide an abundant and concentrated source of protein especially during periods of drawdown when mudflats are exposed (Ma et al. 2009). Crawfish pond use by wading birds peaks during drawdown periods, which may increase reproductive success by concentrating prey available to wading birds during the nesting season (Fleury and Sherry 1995). Abundant food attracts large numbers of waterbirds and is important for the formation of waterbird colonies during the breeding periods in the Everglades (Bancroft et al. 1994). In addition, rice fields and crawfish ponds provide natural forage in the form of moist soil plant seeds and green forage (Manley et al. 2004).

Bird abundance has also been shown to be related to both water level and the vegetation community, but water level generally has the greatest effect (Bancroft et al. 2002). Wading birds appear to select habitat on the basis of environmental cues such as water depth and submerged aquatic vegetation (Gawlik 2002; Lantz et al. 2010). Studies of California wetlands showed a maximum diversity and abundance of waterbirds occurred at average depths of 10-20 cm (Colwell and Taft 2000; Taft et al. 2002; Elphick and Oring 1998).

It has been proposed that wading bird feeding constraints can be viewed as a continuum with White Ibis, Wood Storks and Snowy Egrets (Searchers) on one end and Great Blue Herons and Great Egrets on the other (Exploiters) with Glossy Ibises, Little Blue Herons and Tricolor Herons between the two extremes (Gawlik 2002). Within this continuum, the giving-up-density of prey increases with increasing water depth; fish prey was depleted more rapidly in shallow impoundments and less rapidly in deeply flooded impoundments (Gawlik 2002). It also appears that waterbirds in the Everglades may become more selective in choosing foraging sites in dry years than in wet years (Pierce and Gawlik 2010).

Agricultural management practices seem to affect waterbird use around the globe. Waterbird numbers in French rice fields were lower in dry-sown fields then wet-sown fields (Tourenq et al. 2003). Species richness of waterbirds was greater in conventionally harvested fields than in stripped fields of California's Sacramento Valley and species richness was consistently greater in flooded fields than non-flooded fields (Day and Colwell 1998). Louisiana fields that are tilled and flooded before spring planting provide abundant forage for Fulvous Whistling ducks (Hohman et al. 1996).

The heavy dependence of waterbirds on rice fields may be hazardous because rice cultivation is subject to suddenly changing agricultural practices (Fasola and Ruiz 1996). Market forces, such as futures prices of rice and alternative crops, drive the amount of rice hectarage planted each season. The cost of agricultural inputs such as seed, fertilizers, herbicides, pesticides, fuel prices and water availability are just some of the factors that can influence landscape level changes from year to year. With the loss of natural wetlands in the region, understanding the habitat provided by rice and crawfish agriculture and how that habitat changes annually and inter-annually is vitally important for wildlife managers to understand.

The objective of this study is to determine the effects of rice and crawfish field types and landscape characteristics on wading bird use. By determining what field classifications waterbirds tend to prefer we can provide wildlife managers with insight as to what "working wetlands" are most important to foraging waterbirds in the region.

METHODS

Sample Site Selection

Sample sites were selected by utilizing a stratified random sampling method based upon the proportion of rice planted in the parish/county in 2012 (Louisiana) and 2011 (Texas). Rice hectarage estimates were obtained from www.lsuagcenter.com for Louisiana parishes and from www.nass.usda.gov for Texas counties. A grid of township and range sections was constructed in GIS for each county. A random number generator was used to select sample sections. If a sample section chosen by the random number generator had less then 50% agriculture, the site was dropped and a new section was chosen. A total of 50 sections across the region were selected (about 50 square miles in total). Once sites were selected, all landowners within each section were identified and contacted to gain access to sample sites and to identify the person(s) responsible for agricultural management of the land. Those directly involved in the agricultural management of the land were asked to answer a survey based on the management practices currently utilized in selected fields and to identify individual field boundaries. Due to a lack of landowners willing to grant permission to the interior of their property, one side of each section was randomly chosen so serve as a 1.6 km line transect. It is from these transects that bird surveys were conducted. The surveys took between 3-4 days to complete depending on time of year as daylight hours varied.

The survey allowed fields to be categorized based on type of crop and rotation. The field categories are rice, crawfish, fallow, pasture, soybeans, sugarcane, milo or other. Additional information was collected to help explain potential variation between fields of the same category. The additional information collected was tillage (till or no till), planting method (drilled or aerially seeded) and source of irrigation (ground water well or surface/canal water). For crawfish ponds the forage crop available (natural vegetation or ratoon rice) was also determined.

Wading Bird Survey

Wading bird surveys were conducted in conjunction with vegetation samples from April 1, 2013, through April 30, 2014. All waterbirds (wading birds, shorebirds and waterfowl) visually detected within a field along each line transect were documented and the distance from the line transect was estimated. Only birds present in the field upon arrival were counted and care was taken not to recount birds as they frequently moved from field to field.

Data Analysis

Analyses of the relationship between waterbird counts with field type and field management methods was restricted to the 6 most numerous bird species or groups (dark ibises, waterfowl, cryptic shorebirds). For each of the nine bird species or group counts, nested generalized linear mixed models were constructed and evaluated following the procedure outlined in Bolker et al. (2008) and Zuur et al. (2009). Candidate models with one of six probability distributions (normal, log-normal, Poisson, negative binomial, zero-inflated Poisson, and zero-inflated negative binomial) and the corresponding canonical link function, were compared by AICc. Estimation of maximum likelihood was by Laplace approximation. All models included field size and sample date as random variables, and crop type, seeding method nested within crop type, tillage method nested within crop type, and irrigation method nested within crop type were the fixed explanatory variables. The model with the probability distribution and link combination with lowest AICc was selected for inference. Statistical significance for inference was set at 0.05. All analyses were performed in SAS, vers. 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

Over a 12 month period 3,503 fields were surveyed. The survey yielded 304 Little blue herons (*Egretta caerulea*), 66 Great blue herons (*Ardea Herodias*), 514 Great egrets (*Ardea alba*), 346 Snowy egrets (*Egretta thula*), 913 Cattle egrets (*Bubulcus ibis*), 2,086 dark ibis (*Plegadis chihi* & *Plegadis falcinellus*), 1,357 White ibis (*Eudocimus albus*), 1 Black-crowned night heron (*Nycticorax nycticorax*), 30 Roseate spoonbills (*Platalea ajaja*), 11 Wood storks (*Mycteria americana*), 4 Double-crested cormorants (*Phalacrocorax auritus*), 8 Tricolored herons (*Egretta tricolor*), 1 Anhinga (*Anhinga anhinga*), 1 American bittern (*Botauru lentiginosus*), 205 gulls, 4,389 waterfowl and 3,543 shorebirds.

Bird use of fields was not randomly distributed. The vast majority of fields (3,111 or 88%) had no waterbirds present at the time of survey (Fig 4.1). 93 fields or 2% of fields surveyed had just one bird present (Fig 4.1). 11 fields contained between 251-500 birds most of which were shorebirds and wintering waterfowl (Fig 4.1). Most of the fields that had birds present during the survey (253 or 7% of fields) contained 1-10 waterbirds (Fig 4.1).

Bird use varied among habitat conditions and while not all results were statistically significant they do paint a picture of landscape conditions present when wading birds were detected. Little Blue Herons numbers were evenly split between crawfish ponds and rice

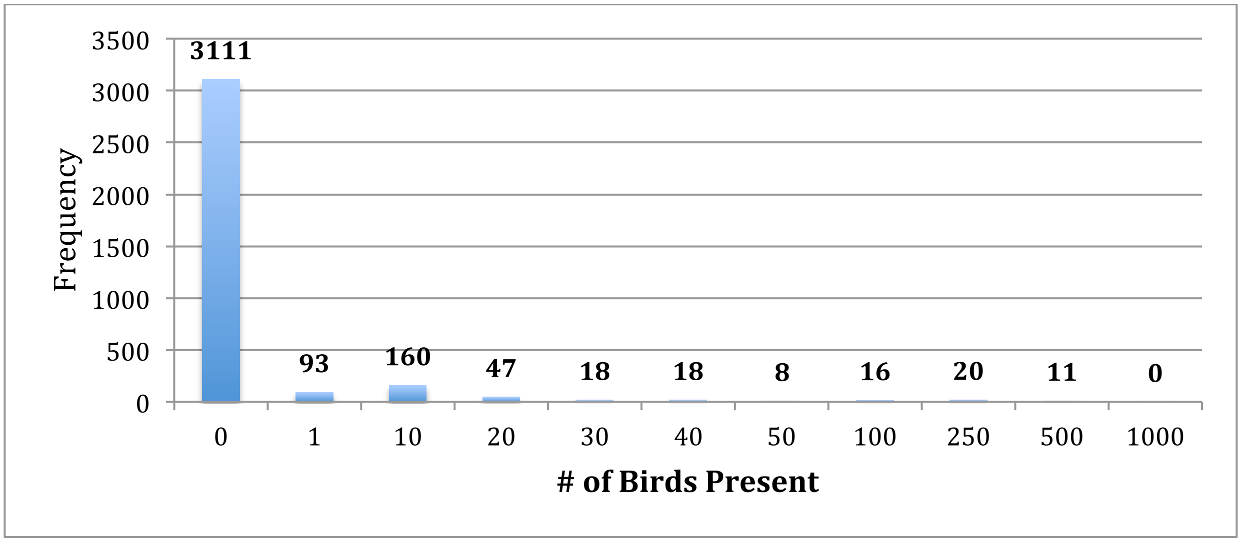

Fig 4.1. Distribution of waterbirds among line transects (# of fields surveyed/# of birds present).

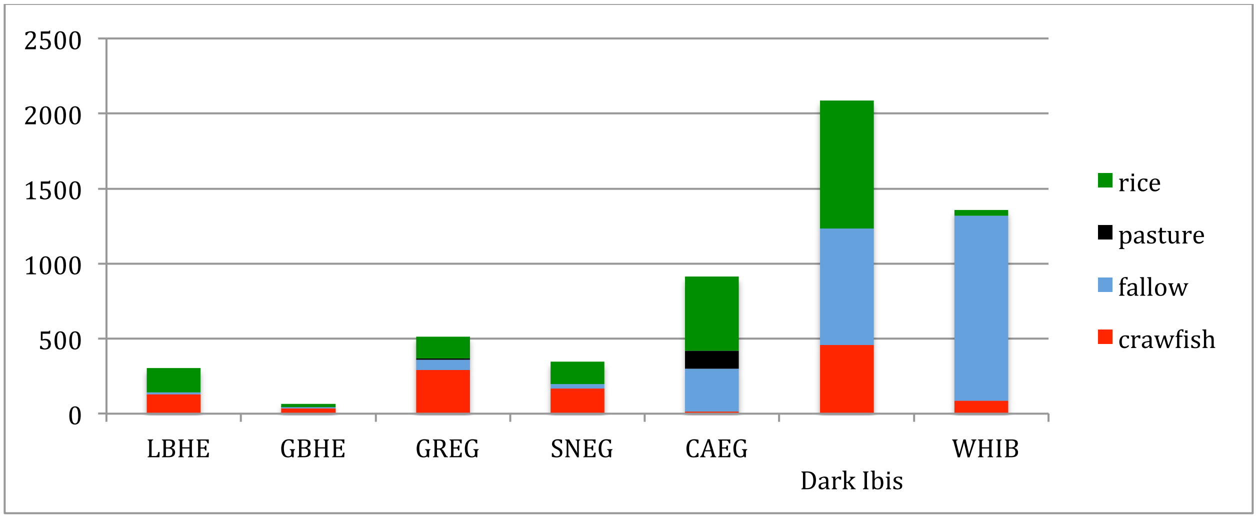

Fig 4.2. Distribution of wading birds (total # of birds) by field class.

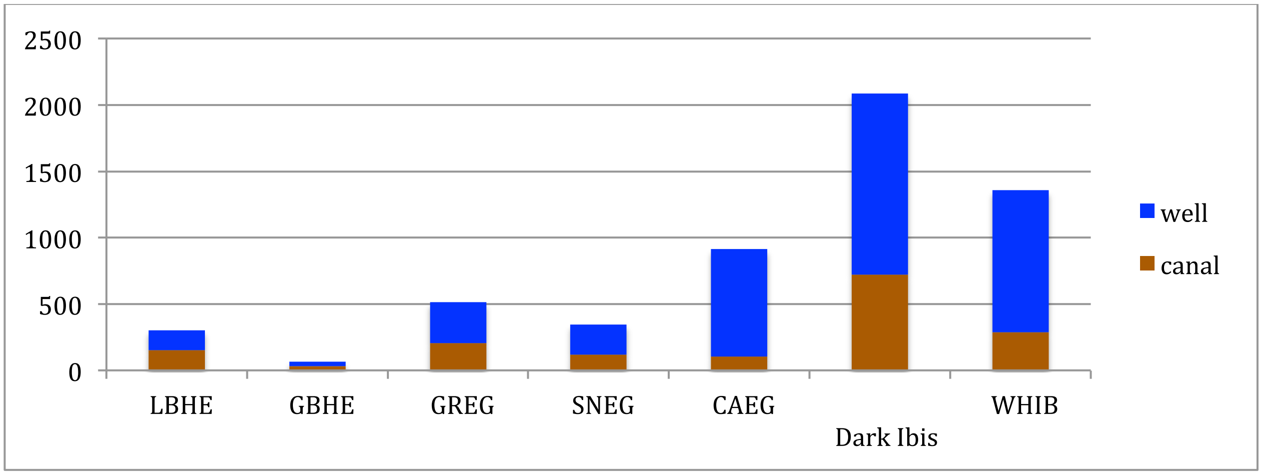

Fig 4.3. Distribution of wading birds (total # of birds) by irrigation type.

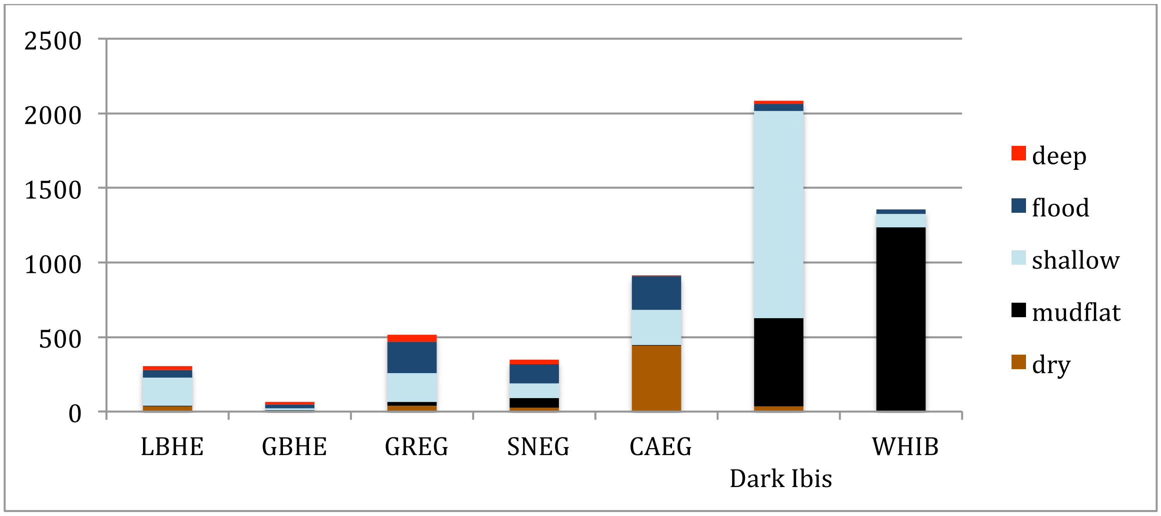

Fig 4.4. Distribution of wading birds (total # of birds) by water depth.

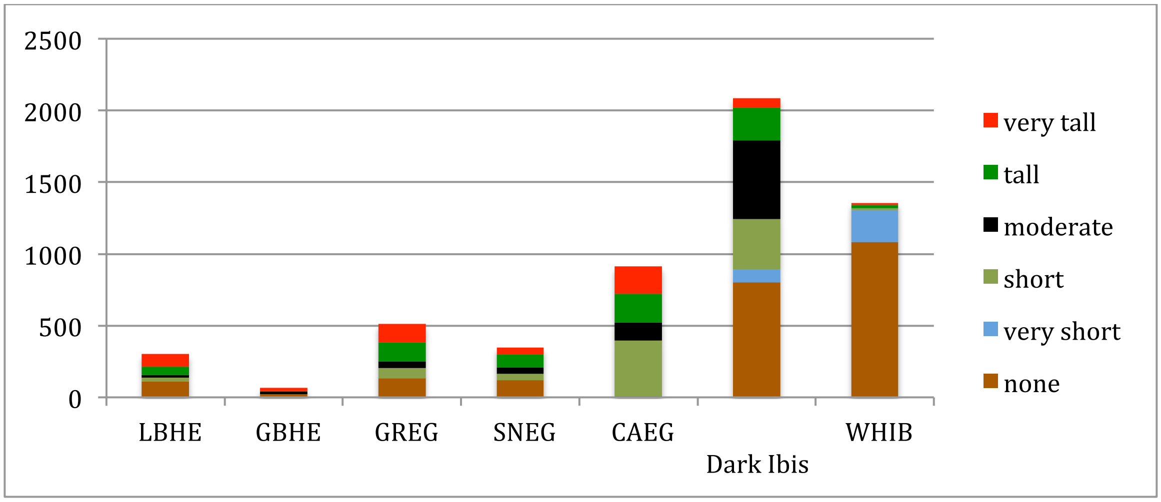

Fig 4.5. Distribution of wading birds (total # of birds) by vegetation height.

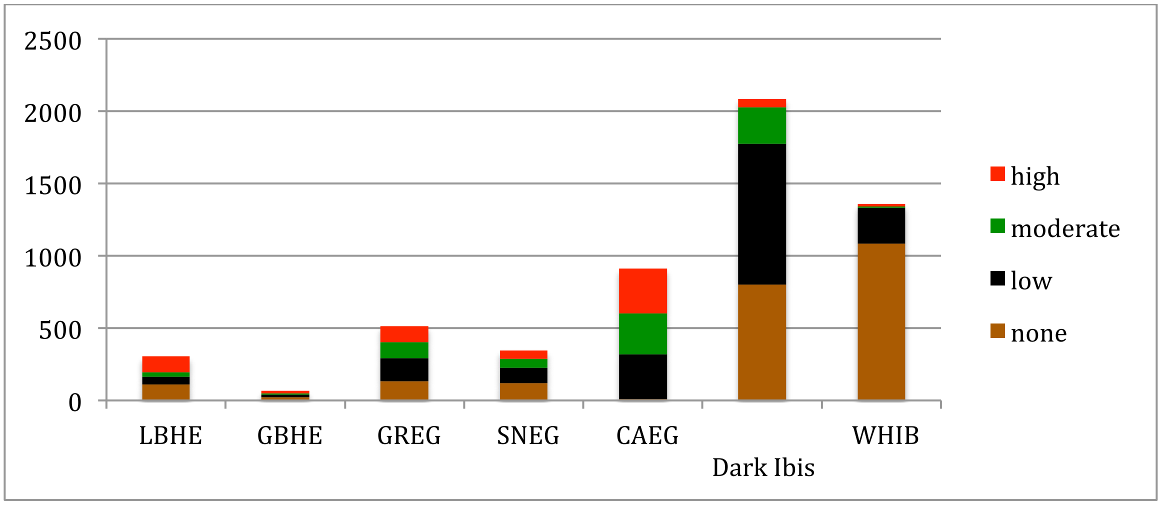

Fig 4.6. Distribution of wading birds (total # of birds) by vegetation density.

fields (Fig 4.2). Little Blue Heron use was also fairly evenly split between canal and well-irrigated fields (Fig 4.3). More Little Blue Herons were detected in shallowly flooded fields than any other water depth (Fig 4.4). Little Blue's were also detected about evenly in fields with no vegetative cover and fields with very tall, dense cover (Fig 4.5, Fig 4.6). Ibis's were most often detected in fallow, well-irrigated fields with shallow to mudflat conditions and little to no vegetative cover (Fig 4.2 – Fig 4.6). Great Egrets were most often detected in crawfish ponds and well irrigated fields with shallow to flooded water depths but didn't seem to prefer any one vegetation height or density category (Fig 4.2 – Fig 4.6).

Agricultural management practices that affected bird density varied by species. Little Blue Herons, Great Blue Herons and shorebirds use of fields appears to be influenced by the field classification and the source of irrigation. The survey found statistically more Little Blue Herons using crawfish ponds irrigated with canal water than crawfish ponds irrigated with ground water or rice fields in general ($F_{3, 2375} = 3.62$, $p = 0.01$) (Fig 4.7). The same was true for Great Blue Herons ($F_{3, 2375} = 5.63$, $p < 0.01$) (Fig 4.8). Shorebirds were more common in crawfish ponds irrigated with canal water than those irrigated with well water, as well as rice fields irrigated with canal or well water ($F_{3,2375} = 3.31$, $p = 0.01$) (Fig 4.9).

Cattle Egret use was influenced by irrigation and seeding method. They preferred fields irrigated with well water ($F_{3, 2377} = 5.09$, $p < 0.01$) (Fig 4.10) and rice fields that were drill seeded as opposed to aerially seeded fields ($F_{3, 2375} = 6.75$, $p < 0.01$) (Fig 4.11).

Waterfowl were the only group of birds that were influenced by the method of tillage. Waterfowl were more abundant in crawfish ponds, rice fields and fallow fields that had not been tilled in the last year ($F_{3, 2375} = 6.16$, $p < .01$) (Fig 4.12).

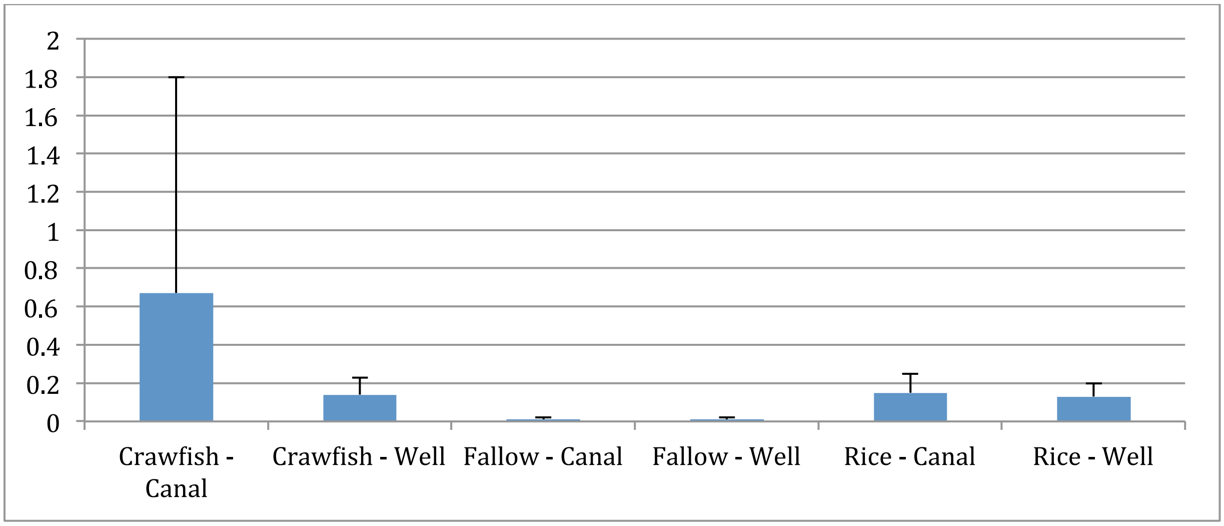

Fig 4.7. Comparison of Little Blue Heron mean density (# birds/ha) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

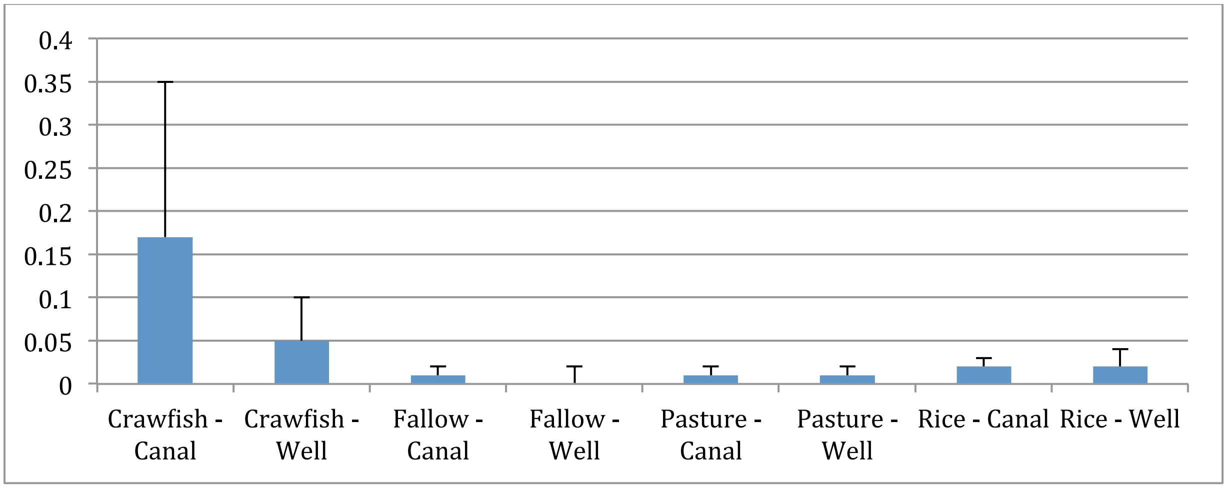

Fig 4.8. Comparison of Great Blue Heron mean density (# birds/ha) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

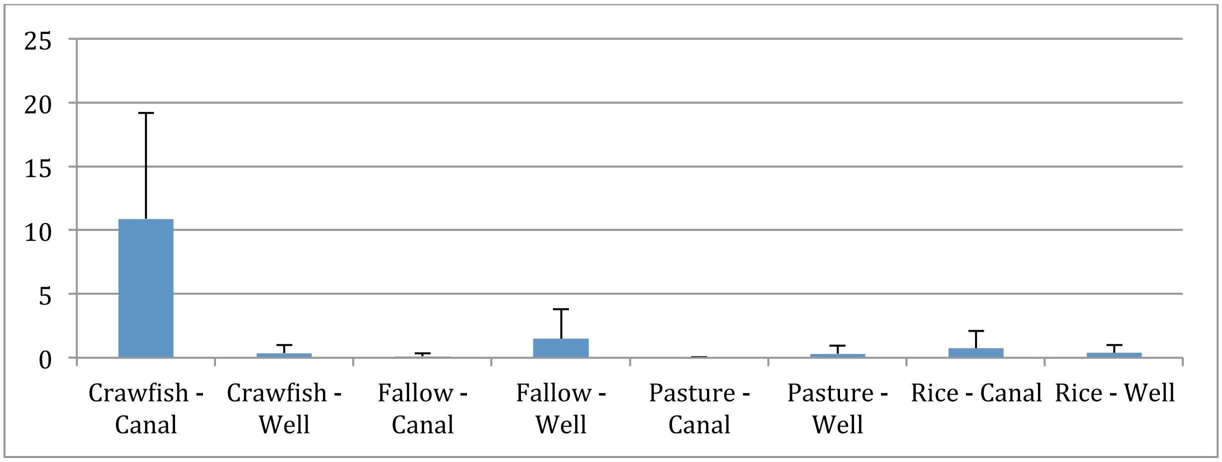

Fig 4.9. Comparison of shorebird mean density (# birds/ha) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

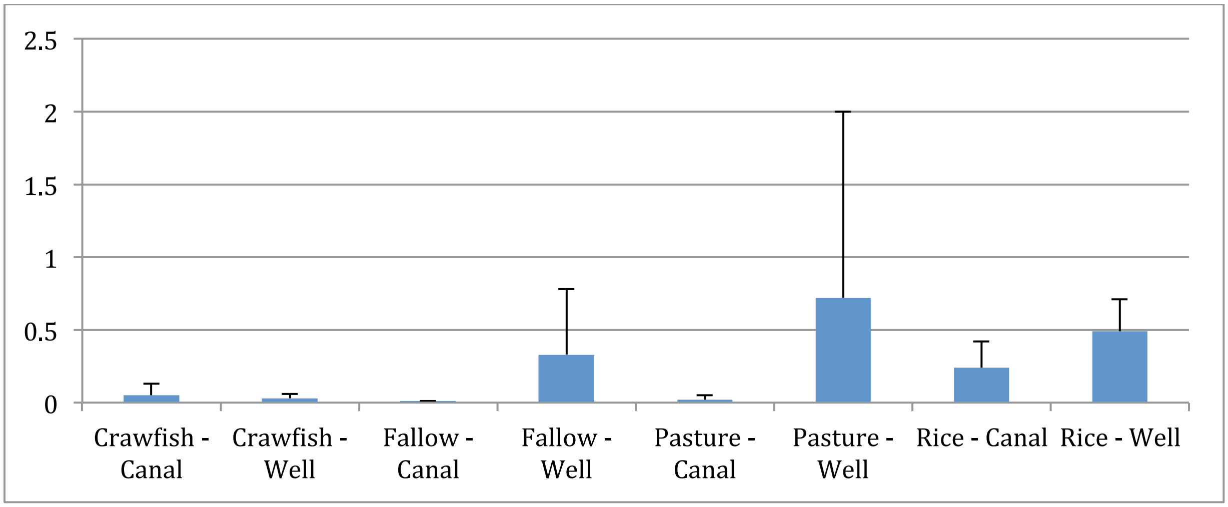

Fig 4.10. Comparison of Cattle Egret mean density (# birds/ha) (w/ 95% confidence intervals) across all sampling dates and sites between field class by irrigation type.

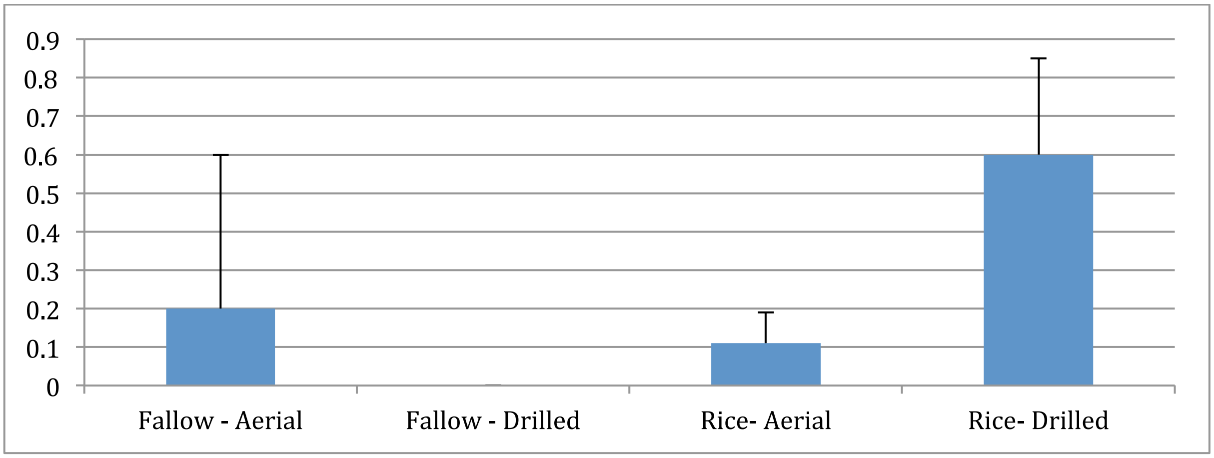

Fig 4.11. Comparison of Cattle Egret mean density (# birds/ha) (w/ 95% confidence intervals) across all sampling dates and sites between field class by seeding method.

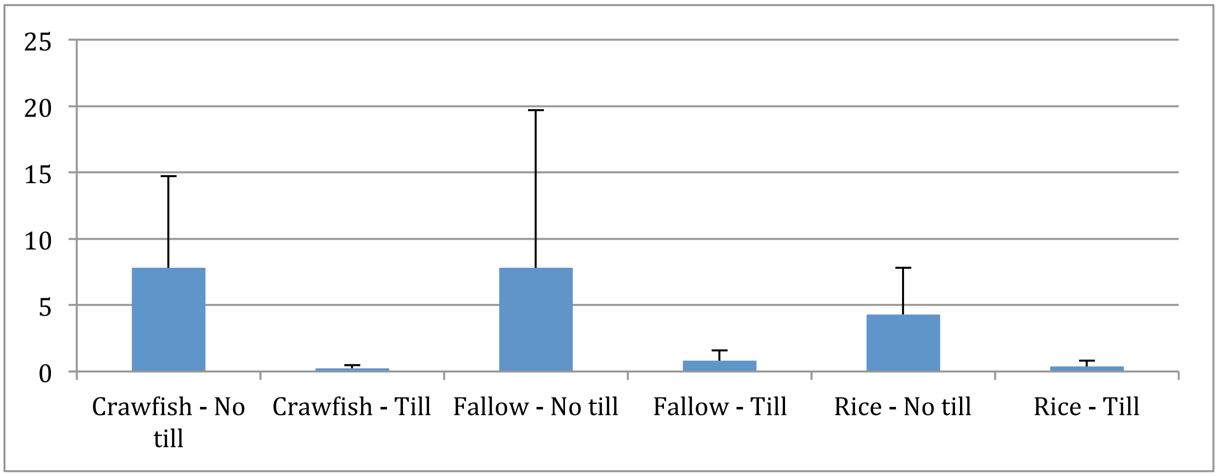

Fig 4.12. Comparison of waterfowl mean density (# birds/ha) (w/95% confidence intervals) across all sampling dates and sites between field class by tillage method.

DISCUSSION

Overall, irrigation, seeding method, and tillage practices appeared to have an influence on whether birds used these “working wetlands.” Interestingly, field class itself was less informative than the practices occurring within the field type. Importantly, birds were not sampled at most fields, suggesting that although the fields could support birds (Chapter 3), for some reason currently unclear, most fields were not supporting birds. Although some insights into the relationship between birds with field management are herein, it is clear that further investigation is warranted into the overwhelming number of unused fields.

Little Blue Herons and Great Blue Herons seemed to prefer crawfish ponds that were irrigated with canal water to any other field type. It should be noted that one canal irrigated crawfish pond in Jefferson Davis parish, surveyed in July, during a drawdown, contained 77 Little Blue Herons. Although diet was not sampled in this study, this may be because crawfish make up a significant portion of heron diets in the region. Alternatively, but not necessarily exclusively, access the herons would have to the canals themselves that support other prey items of interest to herons such as fish and amphibians (Kushlan and Hafner 2000). While methods did not effectively sample crawfish (Chapter 3), fish and amphibians, the low density and biomass of invertebrates was probably due to a trophic cascade effect initiated by the presence of invertebrate predators (such as fish and amphibians) that are themselves prey items for herons. Canal irrigated fields also tend to be located in the southern portion of the region adjacent to natural marsh and scrub/shrub habitat that contains a high number of colonial waterbird rookeries. Distance from rookeries (Kushlan and Hafner 2000) could be a factor that explains why some species tend to prefer canal irrigated fields but with a lack of information about rookery locations in the northern portion of the region it is difficult to determine. The bird use of this field classification is surprising given the actual nekton sampling conducted in Chapter 3 that found no fish present in canal-irrigated crawfish ponds (n=4). This could be due to a low number of samples collected from this field classification type but a more in depth study in the future may shed some light on this phenomenon.

Shorebirds preferred crawfish ponds irrigated with canal water and were mostly detected during periods of drawdown when mudflats accommodated shorebirds with accessible and concentrated prey items such as aquatic invertebrates. Crawfish ponds when drawn down tend to have little to no vegetation as opposed to rice fields that have dense vegetation present at times of draw down. The lack of vegetation might be preferred by shorebirds allowing them to detect the approach of predators while foraging in crawfish mudflats but does not explain a preference for canal irrigated fields as opposed to well irrigated fields. The results of the invertebrate study in Chapter 3 showed that the greatest macroinvertebrate density occurred in well-irrigated fields rather than canal irrigated fields.

Cattle Egrets preferred fields that were irrigated with well water. This is potentially because Cattle Egrets' preferred prey items are invertebrates (Kushlan and Hafner 2000) and Chapter 3 found macroinvertebrates to have higher levels of density in well irrigated fields. Cattle Egrets also tended to prefer rice fields that had been drill seeded as opposed to fields that had been aerially seeded. In a previous study greater macroinvertebrate abundance was observed in rice fields cultivated using drill-sowing techniques compared to aerially sown fields, possibly due to the incorporation of organic material into the soil during planting (Wilson et al. 2007), which could explain the increase in Cattle egret use.

Waterfowl were found to have significantly higher numbers in fields that had been no-till fields, no matter what the crop type. Within crawfish, fallow and rice fields waterfowl were more abundant in fields that had not been tilled possible due to access to a greater volume of waste rice and moist soil plant seeds left undisturbed (Manley et al. 2004). It should be noted that the heaviest waterfowl use of rice and crawfish impoundments is probably occurring at night (Link et al. 2011A; Link et al. 2011B) and further research is needed to determine if nocturnal use of no-tilled fields is similar to diurnal use.

The ability to survey waterbirds in this study was limited by several factors. The first and major factor was lack of landowner cooperation in granting access to surveyed fields. Many birds were probably present in the area but view from the highway was often obstructed by main levees or smaller rice levees with very tall vegetation. The visual barriers surely lowered the detection probability of birds in a significant portion of fields surveyed. Landowner access would have allowed birds to be observed at a shorter distance, as well as provided the ability to flush birds from densely vegetated fields. Future studies of waterbirds in the region would probably be more effective as telemetry studies. The possibility of using drones to access bird use of interior fields when access is denied might also be a viable alternative but could also carry liabilities of its own.

Rice fields and crawfish ponds in the region are not the only habitat types being utilized by waterbirds. Wooded streams and rivers, as well as natural wetlands in the southern portion of the region, also served as suitable habitat and the proportion of time spent by waterbirds in these habitats vs “working wetlands” should also be understood. Waterbird use of native habitats and alternative habitats other then rice and crawfish agriculture must be filling the void during stressful times of the year. Telemetry studies might also shed some light on distances traveled from rookery sites to foraging sites in the region, as this could also be a major reason that some areas were more heavily utilized by waterbirds then others. Telemetry studies could potentially determine how much time is spent foraging in the canals and drainage ditches, which are very much a part of this agricultural landscape, as opposed to foraging in the fields themselves.

This study has shown that waterbird use of fields in the region is not evenly distributed. Source of irrigation, seeding method and tillage all appear to affect waterbird use of rice fields and crawfish ponds in the region. Future studies will be able to build on these finding and utilize the field classification system developed in Chapter 2 in order to better understand waterbird use of working wetlands in the coastal prairies of Louisiana and Texas.

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CHAPTER 5
GENERAL CONCLUSIONS

The goals of this thesis were to develop a classification system for rice fields and crawfish ponds based upon tillage, forage crop (for crawfish fields), water depths, vegetation density, vegetation structure, and other visible parameters. Quantify the distribution of rice fields and crawfish ponds in various stages across the landscape through time. Evaluate the relationship between field classification and habitat characteristics and invertebrate densities (including crawfish) in selected field types through time. Then determine the effects of rice field and crawfish pond types and landscape characteristics on wading bird use.

The classification system developed in Chapter 2 allowed us to describe the intra-annual variability in resources available to waterbirds and other wetland dependent wildlife throughout the coastal prairie region of Southwest Louisiana and Southeast Texas. The classification system is valuable, however, an integration of this type of habitat data with average waterbird densities within the various habitat types could lead to more effective conservation planning for a wide-variety of waterbird species in the region.

The results in Chapter 3 of this study indicate that rice fields and crawfish ponds in Southwest Louisiana and Southeast Texas support diverse macroinvertebrate assemblages. Based on the classification system described in Chapter 2, field class, irrigation and tillage are the three most important factors effecting macroinvertebrate density and biomass in this study. Wildlife managers will be able to use the caloric value estimate of macroinvertebrates to help meet the annual energetic needs of waterbirds in the region.

In Chapter 4 of the study we found that waterbird use of fields in the region is not randomly distributed. Source of irrigation, seeding method and tillage all appear to affect waterbird use of rice fields and crawfish ponds. Based on limitations, mostly due to a lack of access to private property, the ability to survey waterbirds in this study was limited. Future studies of waterbirds in the region will consider the limitations present when surveying private lands and design their studies accordingly.

A clear understanding of the high temporal and spatial variability of habitat available to waterbirds in the region, due to individual management decisions made by private landowners, will be very useful to wildlife managers. The habitat characteristics affecting macroinvertebrate community density and biomass and in turn waterbird use of rice and crawfish agriculture also advances our knowledge of this artificial wetland system. This study that has built on the work of previous researchers will provide valuable information for those wishing to understand how this complicated artificial wetland system functions.

VITA

Cullen C. Foley was born in June 1979, in Natchez, MS. He is the son of Edward J. Foley, Jr. and Karen G. Foley. He is the second of their three children; his brother Logan G. Foley being the eldest and sister Kate G. Foley the youngest. He graduated from Cathedral High School in Natchez, MS in 1997. Cullen attended the University of Mississippi and graduated in 2001 with a B.B.A in Finance.

In 2001, Cullen began a 10-year career in banking at Concordia Bank & Trust Co. in Vidalia, LA. He served the bank in many capacities during his tenure before receiving the title Controller, which he held for 3 years. He spent one year as a financial representative for Northwestern Mutual Financial before deciding to pursue a career in conservation.

He entered Louisiana State University, as an undergraduate, in 2011 to strengthen his background in ecology. Cullen was accepted to the graduate program in Renewable Natural Resources at LSU in the fall of 2012 and is expected to graduate in August 2015. His studies focused on wetlands, aquatic macroinvertebrate communities and waterbird use of rice and crawfish agriculture in southwestern Louisiana and southeastern Texas.