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Rachel K. Villani
Louisiana State University and Agricultural and Mechanical College

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MULTI-SCALE HABITAT ASSOCIATIONS OF SHOREBIRDS DURING SPRING MIGRATION IN SOUTHWESTERN LOUISIANA RICE FIELDS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Renewable Natural Resources

by
Rachel K. Villani
B.S. Louisiana State University, 2007
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ABSTRACT

Rice is the most common wetland crop in the world, and important for waterbirds and shorebirds worldwide, including the United States. In Louisiana, shorebirds use rice fields during spring migration, and are an important for foraging and refueling during migration. However, competing land uses and restoration projects may reduce the availability of rice fields, and impact the landscape that shorebirds use during migration. To determine how shorebirds use the landscape, I evaluated local and landscape factors affecting shorebird use of rice fields during spring migration in southwestern Louisiana. Using five habitat suitability zones (HSZs) based on rice density and canopy cover, I performed stratified random surveys at rice fields within each of the 5 HSZs. I surveyed 94 fields in 2008 and 85 fields in 2009. I quantified all habitat types within 3 km of each field, recorded habitat conditions during each visit, and recorded all shorebirds observed. Mixed modeling analyses indicated that shorebird density was primarily influenced by local field conditions: flooding extent ($p<00001$), the percent of the field perimeter bordered by trees ($p=0.0075$), surveyed rice field area ($p<0.0001$), and rice height ($p<0.0001$). Shorebirds responded positively to flooding extent, and negatively to tree border, field area, and rice height. Overall shorebird density was not influenced by any landscape variables at any scale (1, 1.5, 2, 2.5, or 3 km). The percent of non-rice crop ($p=0.0437$) and fallow land ($p=0.0400$) immediately adjacent to surveyed fields was a positive influence on density of the seven most common species, and HSZ was a positive influence on shorebird habitat use for 3 of the most common species or species groupings: Dowitchers (2 spp), Peeps (3 spp), and Yellowlegs (2 spp). These species comprised > 50 % of all birds observed, indicating the importance of HSZ for individual species. Rice density was significantly higher in HSZ4 and HSZ5, and the percent of forest (an alternate measurement of canopy cover) was significantly lower in HSZs 4 and 5.

These results support the validity of the habitat suitability model. By maintaining rice production in the higher HSZs, suitable local habitat conditions would be provided for shorebirds.

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CHAPTER 1
INTRODUCTION

Nearly half of all natural wetlands in the continental United States have been lost since the 18th century (Tiner 1984, Brinson and Malvárez 2002), primarily because of conversion to agriculture, including rice (Tiner 1984, Brinson and Malvárez 2002). Rice is the most common wetland crop in the world by area (Czech and Parsons 2002), and is the most important crop for waterbirds worldwide (Taft and Elphick 2007, Eadie et al. 2008). In Spain, the Ebro Delta supports 40 shorebird species in the winter (Czech and Parsons 2002), and around the Mediterranean, 29 species of waterbirds used rice fields in the spring (Tourenq et al. 2001, Czech and Parsons 2002, Tourenq et al. 2003). In the United States, rice fields in California's Central Valley support an estimated 374,000 shorebirds of 33 species in the winter (Shuford et al. 1998), and 225,000 shorebirds of 14 species were estimated to winter in south-central Louisiana based on a one day multi-person census in February 1988 (Remsen et al. 1991). These studies, and others (Fasola and Ruiz 1996, Elphick 2000, Maeda 2001, Elphick and Oring 2003, Manley et al. 2004, Lourenço and Piersma 2009), indicate that rice fields play an important role globally in providing habitat for waterbirds.

Rice production is often intermixed with other land uses to form a diverse agriculture-dominated landscape. Similar to most agriculture regions, changes in rice-dominated landscapes occur throughout the year with the production and harvest of different crops, seasonal crop rotations, implementation of different management methods (e.g. disking, flooding, fertilizing, applying herbicide), and field rotations (Bennett et al. 2006). Southwestern Louisiana (SWLA) is no exception. This region is a mosaic of rice fields, row crops (e.g. corn, soybeans, and sugarcane), crawfish ponds, pastures, and developed residential/urban areas. Rice fields may be fallow or in production, may or may not be rotated with crawfish production in the winter, and

rice field management can vary annually (Huner et al. 2002). Rice fields can potentially be transformed from standing vegetation to open mudflat in the span of a single day; as a result, rice field management practices influence the landscape and create a montage of constantly changing habitat.

Rice field management often coincides with shorebird habitat needs during spring migration in the U.S. (Farmer and Parent 1997, Czech and Parsons 2002). Shorebirds use rice fields primarily for foraging (Czech and Parsons 2002), utilizing the mudflats and shallow water areas that rice fields provide during the planting and early growth stages. This is ideal for shorebirds because most species prefer foraging sites with shallow flooding and sparse vegetation or mudflats (Huner et al. 2002, Niemuth et al 2006). Once rice reaches a certain height, it becomes less suitable because foraging shorebirds typically prefer foraging area vegetation to be less than half their body height (Helmers 1993) because vegetation height may reduce their ability to locate prey (Rottenborn 1996).

It is likely that shorebirds, like other birds, select habitat at multiple scales (Taft and Haig 2006, Elphick 2008). Buler et al. (2007) found that songbirds initially select sites with high density of forest cover and then select sites based on food availability at a finer, more local scale; shorebirds may have a similar selection strategy. Fairbairn and Dinsmore (2001) found that breeding waterbird species richness increased with increased density of wetland habitat in a 3 km area surrounding a utilized site. Elphick (2008) determined that shorebird use of rice fields during the winter in California was positively associated with area of refuge or semi-natural wetland in the surrounding area. Chan et al. (2007) found that wintering waterbirds (which includes shorebirds) in Taiwan responded differently to different landscape scales, and suggests that multiple scales are important for waterbirds. Thus, conservation of shorebird habitats in

SWLA could be enhanced by an understanding of the factors that influence shorebird habitat suitability at multiple spatial scales.

CHAPTER 2
MULTI-SCALE HABITAT CHARACTERISTICS OF RICE FIELDS IN SOUTHWESTERN LOUISIANA

INTRODUCTION

Landscape ecology is a relatively new field of science, and has undergone extensive development in the last 30 years in the U.S. (Turner 2005). The field of landscape ecology is defined by the importance of spatial heterogeneity (Turner 2005). Spatial heterogeneity is the mixture of different land cover types that comprise the landscape, and is often the central question in many studies (Turner 2005). In addition to spatial heterogeneity, the configuration of habitat in the landscape can also be important, as it may influence animal movements and distribution (Turner 2005). Determining the influence of the surrounding landscape on a local response is another useful application of landscape ecology (Mazerolle and Villard 1999, Turner 2005).

An abundance of studies have examined local responses of organisms to variables measured at a variety of scales (Mazerolle and Villard 1999, Lee et al. 2002, Van Buskirk 2005, Bennett et al. 2006). At the local scale, shorebirds are negatively influenced by rice or vegetation height (Helmers 1992, Colwell and Dodd 1995, Rottenborn 1996) and tree presence (deciduous trees and woodlands; Cole et al. 2002, Jing et al. 2007), they are positively associated with shallow water (Weber and Haig 1996, Davis and Smith 1998a), and they are positively influenced by flooding extent (Niemuth et al. 2006, Eadie et al. 2008, Elphick 2008), and field area (Paracuellos and Tellería 2004, Webb et al. 2010). At a broader scale, shorebirds have been positively influenced by wetland area and rice field arrangement (Webb et al. 2010).

There has been extensive research on wintering shorebirds in rice fields (Remsen et al. 1991, Elphick and Oring 1998, Sanzenbacher and Haig 2002, Elphick and Oring 2003, Taft and

Haig 2006, Elphick 2008), but little research on landscape effects on migrating shorebirds (Maeda 2001). In the Rainwater Basin of Nebraska, shorebirds were influenced by the amount of wetlands within 10 km (Webb et al. 2010). In South America, the presence of rice fields in a more connected spatial arrangement may be more important than the total rice area for waterbirds, including shorebirds (Guadagnin and Maltchik 2007). Also, studies have shown that increased landscape connectivity at stopover sites allows shorebirds to utilize more sites for foraging with less energy output (Farmer and Parent 1997). However, there has been no research on this topic in SWLA, which is one of the main rice producing regions in the country.

Shorebird migration

There are over 200 species of shorebirds worldwide, and they are some of the most migratory animals in the world, often undertaking long distance migration between their wintering and breeding grounds (Helmers 1992, Harrington et al. 2002). In the Americas, many species of shorebirds spend the winter in South and Central America, travel through North America, and breed in the Arctic. From March to May, shorebirds pass through SWLA on their way north to the breeding grounds (Helmers 1992, Skagen et al. 1999, Norling et al. unpublished manuscript). Twedt et al. (1998) found the rice fields in the Mississippi Alluvial Valley supported more shorebirds than moist soil units or soybean fields during the spring. A considerable number of shorebirds have been recorded using rice fields in SWLA during the spring, thus emphasizing the importance of this region as stopover habitat (Norling et al. unpublished manuscript).

Stopover habitat is vitally important because this is where shorebirds stop to feed and rest before continuing on their journey north, and they regularly utilize multiple sites to meet their needs during migration (Farmer and Parent 1997, Taft and Haig 2006). This migration strategy

requires ample available habitat along the entire migration path, and a lack of stopover habitat may be detrimental to shorebird survival and breeding success (Helmers 1992, Farmer and Parent 1997, Davis and Smith 1998a). Fortunately, shorebirds are able to find and utilize habitat opportunistically, even within a few hours of a site becoming suitable (Skagen and Knopf 1994), which is important in an ever changing agricultural system like SWLA. During migration, rice fields provide excellent stopover habitat for migrating shorebirds because they provide shallow water and mudflat areas for foraging and refueling (Helmers 1992).

Rice production

More than 1.2 million hectares of rice are produced annually in the United States (Chambers and Childs 2000). Production is concentrated in the Central Valley of California and the south central United States, including the Gulf Coastal Plain (Figure 1; Setia et al. 1994, Czech and Parsons 2002, Pierluissi 2006, Eadie et al. 2008). In 1987-1993, between 170,000 and 247,000 ha of rice were produced annually in Louisiana (Hohman et al. 1994). In 2007, Louisiana produced 149,000 ha of rice; and in 2008, the area increased to 184,000 ha, with the greatest concentration occurring in SWLA (LSU AgCenter 2007, LSU AgCenter 2008). Consequently, there is an abundance of rice fields for shorebirds to utilize in SWLA.

In SWLA, rice is planted from early March through mid-May (D. Groth, LSU AgCenter Rice Research Station, pers. comm.). Once the seedlings sprout, farmers periodically flush the rice fields with water to keep the ground moist. Fields are flooded to a depth of 7-10 cm (Linscombe et al. 1999, Huner et al. 2002) until a few weeks before harvest when they are drained (Hohman et al. 1994). Harvest usually occurs in late summer (Pierluissi 2006), from mid-July through September (D. Groth, LSU AgCenter Rice Research Station, pers. comm.). Rice fields may be rotated with other crops, including crawfish, soybeans, and grain sorghum, or

may be used for cattle grazing or simply left fallow (Avery and Lorio 1999, Huner et al. 2002, Eadie et al. 2008). See Huner et al. (2002) for a more detailed description of rice production in Louisiana.

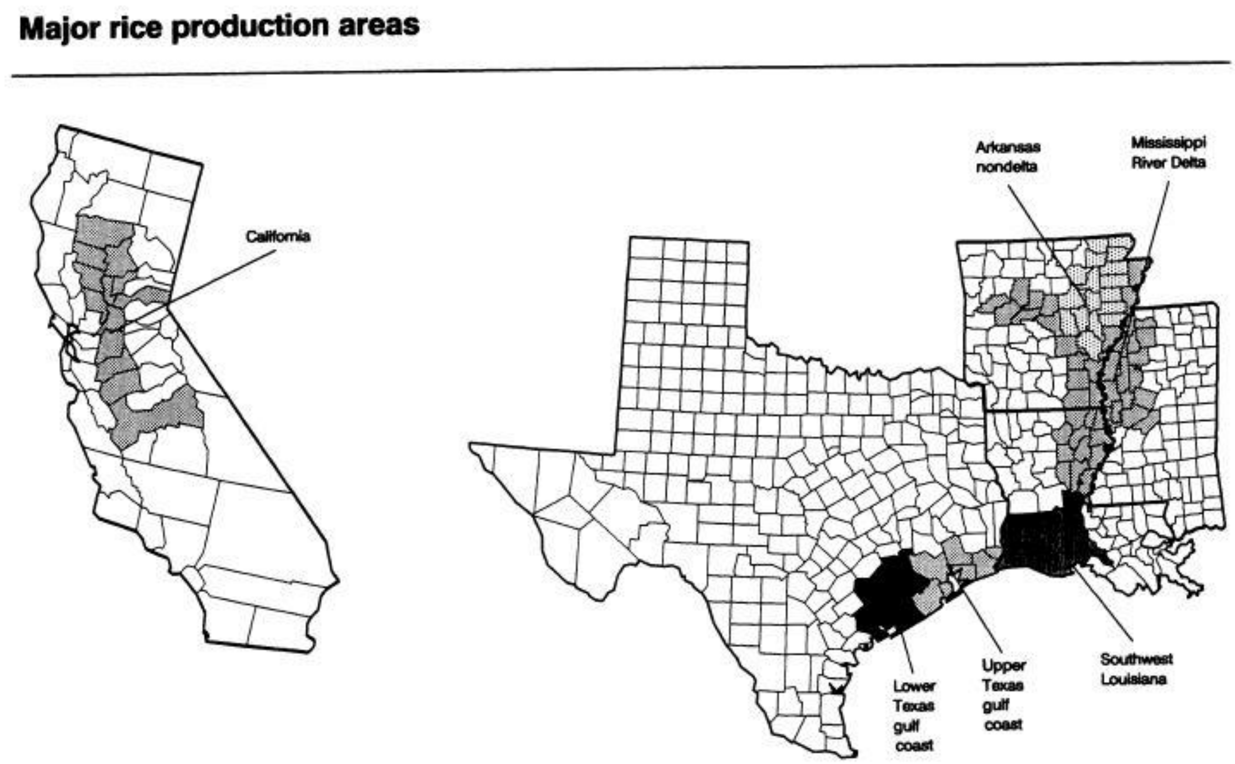

Figure 1. Rice production areas in the United States (reproduced from Setia et al. 1994).

Rice fields provide important habitat for shorebirds using this region, but compete for land area with other agricultural crops, cattle, and human development. Furthermore, the Natural Resources Conservation Services (NRCS) has developed a prairie restoration plan that would restore 11,000 ha of land in the rice region to coastal prairie, which would likely be unsuitable habitat for shorebirds and have an impact on habitat availability. This plan would take rice fields in seven parishes out of production, thereby removing shorebird habitat from being available. Fields selected for restoration would be planted in native grassland species in an effort to increase diversity and restore native species.

To minimize impacts on shorebirds while restoring native habitat, a better understanding of multi-scale habitat use by shorebirds is needed. Pickens et al. (2009) developed a habitat suitability model for several species of waterbirds in SWLA, including shorebirds. Currently, the model predicts shorebird habitat suitability based upon rice density and canopy cover. This model could be tested by acquiring the necessary empirical data to validate model predictions. The objectives of this study are to 1) evaluate local and landscape scale habitat factors that affect density and abundance of shorebirds in rice fields of southwestern Louisiana, and 2) to evaluate the reliability of the Pickens et al. (2009) model in predicting shorebird densities.

METHODS

Habitat Suitability Zones

Pickens et al. (2009) used several factors to create the habitat suitability zones (HSZs) for shorebirds in SWLA. The model was based on rice density within 5 km and canopy cover within 3 km. The models were created by calculating land cover densities for rice and canopy cover using 2004 aerial photography and the U.S. Geological Survey canopy cover data in ArcGIS. Rice density and canopy cover were transformed into quantile rankings (1-3) and then multiplied together to create the habitat suitability model. The rankings were then transformed into rankings of 0-5, with 0 being non-habitat (excluded in this study), and 1-5 indicating the five zones of habitat suitability.

Areas with high rice density and low canopy cover were considered preferred shorebird habitat. There were five predicted HSZs, ranging from 1 to 5 (colored areas, Figure 2). HSZ 5 (dark green) depicts the areas predicted to have the most suitable shorebird habitat (high rice density, low canopy cover). HSZ 1 (red) depicts the areas predicted to have the least suitable habitat (low rice density and high canopy cover).

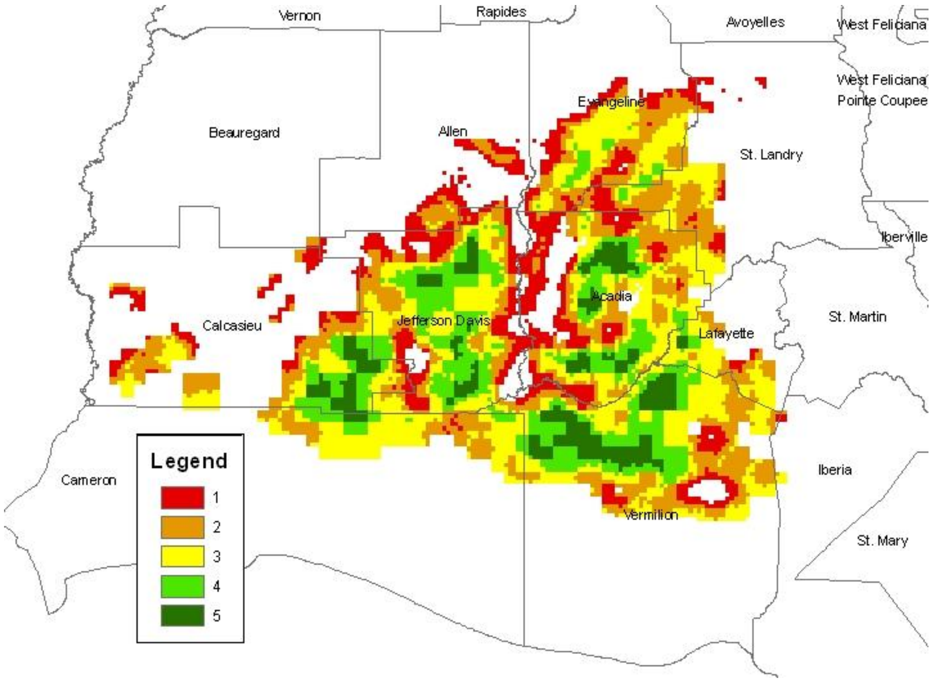

Figure 2. Habitat suitability zones and study area in southwestern Louisiana.

Site Selection

I used 2004 aerial photography of southwestern Louisiana to digitize potential rice fields in ten parishes (Acadia, Allen, Calcasieu, Cameron, Evangeline, Iberia, Jefferson Davis, Lafayette, St. Landry, and Vermilion) within the HSZ framework using ArcMap 9.1 and 9.3 (ESRI, Redlands, California). With that information, I randomly selected fields that were bordered by a public road. A total of 20 sites were selected in each HSZ, for a grand total of 100 randomly selected sites. To avoid overlapping landscapes as much as possible, I attempted to have all fields at least 6 km apart. In 2008, I ground checked the selected sites to make sure they were in rice production for that year. Any site that was not being used for rice production was replaced with the next closest field that was in rice production. In 2009, I ground checked all the fields that were surveyed in 2008. Fields that were in rice production again were retained, and fields that were not were replaced by the next closest rice field, which was often immediately adjacent. In addition to the sites selected randomly by HSZ, I also included two rice fields on

Lacassine National Wildlife Refuge (NWR) as part of the study in 2008 and 2009 because this refuge is considered to be an important shorebird site (USFWS 2002). These sites were not random, but were within the HSZ framework and occurred on two very different portions of the refuge.

Although initially I randomly selected 100 rice fields (20 in each of the five different HSZs), I was not always able to survey exactly 20 fields in each HSZ for a variety of reasons. In some cases, there simply were not any rice fields in the area where a randomly selected field was supposed to be located. In other cases, rice fields were present but not far enough apart for more than one to be included. I ended each field season with 13 to 21 sites per HSZ. I surveyed 94 rice fields in 2008 and 85 rice fields in 2009 (Table 1). Only 12 (of 94) fields from 2008 were in rice production again in 2009. Fields ranged from 0.36 to 19.24 ha (±4.2057 ha, n = 94) in 2008 and from 0.51 to 15.721 ha (±3.14 ha, n = 84) in 2009.

Table 1. Number of rice fields by habitat suitability zone (HSZ) in 2008 and 2009.

HSZ	2008	2009
1	18	16
2	15	13
3	19	20
4	21	16
5	21	20
Total	94	85

Multi-Scale Habitat Characteristics

This project was planned using a multi-scale design to assess habitat use by shorebirds at multiple scales. I quantified or calculated habitat at seven scales: the rice field scale (field), immediately adjacent to the fields (0 km), within 1km (1km), within 1.5 km (1.5 km), within 2 km (2 km), within 2.5 km (2.5 km) and within 3 km (3km). At each landscape scale (1, 1.5, 2, 2.5, and 3 km) the center of the field was used to calculate the radius and surrounding area. I chose these scales because wetland birds were affected by the amount of wetland area in 3 km in

Iowa (Fairbairn and Dinsmore 2001), and shorebirds were affected by the amount of open water in 1 km in Taiwan (Chan et al. 2007). Because rice fields are agricultural wetlands (Czech and Parsons 2002) and are also open water for the early portion of the growing season, I hypothesized that shorebirds would similarly be influenced by rice fields at the 1 and 3 km scale in SWLA. Also, because studies (Farmer and Parent 1997, Butler et al. 2002) have shown that shorebirds move very little once at a stopover site, I chose to include multiple finer scales in an attempt to determine at what scale shorebirds might be selecting habitat for their small movements while at stopover sites.

During each visit to the fields to conduct surveys, I recorded three identifier variables: year (YEAR), survey point (POINT), and survey period (SP). At the field scale, I recorded the percent cover of water (PWATER), percent cover of mud (PMUD), percent cover of other vegetation (POTHER), percent cover of rice (PRICE), flooding extent (not flooded, partially flooded, completely flooded; FLOODED), rice height in centimeters (RICEHT), and water depth in centimeters (WDEPTH). Using aerial photography, I also measured the percent of each field perimeter bordered by tree line or forest (TREEBORD) and the area of each field in hectares (FAREA).

To quantify the landscape surrounding each field, I identified and recorded all the habitat types (rice, forest, developed areas, non-rice crops, crawfish, and fallow areas) within 3 km of each survey field by driving all public roads and recording the habitat types on a map printout of the 2004 aerial photos. I then calculated percent of habitat types at each landscape scale (0 km, 1 km, 1.5 km, 2 km, 2.5 km, 3 km). I calculated the percent of rice (RICE), forest (FOR), human developed areas (DEVEL), non-rice crops (e.g. soybean, sugarcane, wheat; NRC), crawfish production (CRAW), and fallow areas (FALL) for each scale. Because the six variables were

calculated the same way for each scale, each habitat type (e.g. RICE) was followed by a number indicating scale (e.g. RICE0, RICE10, RICE15, RICE20, RICE25, or RICE30).

Surveys

Surveys were completed every 8 days, for a total of 8 survey periods in 2008 and 2009. I completed shorebird surveys from 22 March – 28 May 2008 and 22 March – 24 May 2009 (Table 2).

Table 2. Survey period dates for 2008 and 2009.

Survey Period	2008	2009
1	22 – 29 March	22 – 29 March
2	30 March – 6 April	30 March – 6 April
3	8 – 15 April	7 – 14 April
4	16 – 23 April	15 – 22 April
5	24 April – 2 May	23 April – 30 April
6	3 – 10 May	1 – 8 May
7	11 – 20 May	9 – 16 May
8	21 – 28 May	17 – 24 May

Survey points were located on the edge bordered by a public road so I could complete roadside surveys for shorebirds. The survey points remained the same for the duration of the project. I surveyed the rice fields during daylight hours (half an hour after sunrise to half an hour before sunset) using Eagle Optics Ranger SRT 10x50 binoculars and a Kowa Prominar TSN-664ED 20-60x spotting scope. To counteract a potential time of day effect, the order in which fields were surveyed was randomized so that each field was not sampled at the same time repeatedly. All shorebird species and numbers within the boundaries of the rice field were recorded. Flyovers were not recorded because they were not directly using the rice field.

At each field, I recorded the species, type of habitat being used, distance and bearing from observation point, and behavior at the time of observation. All birds within sight were recorded, and care was taken to minimize disturbance when arriving at each field. Distance to each bird or flock of birds was measured using a Bushnell Yardage Pro Sport 450 laser

rangefinder. If there were distinct flocks of birds, I recorded the bearing and distance to the center of the flock and the number of individuals per species in the flock. For each bird or flock of birds detected, I recorded the type of habitat being used at the time of observation as mudflat/bare ground, mud/water interface, open water, water with rice, mud with rice, or undetermined. I also recorded the behavior of all birds (foraging, resting/sleeping, perching, locomotion, preening, panic flight, cannot determine, and other) at the time of observation. Water depth at each location was estimated based on the height of the water on each bird (mudflat, covering the foot, foot to ankle, ankle to body, or cannot determine) and leg length. I only recorded water depth as "cannot determine" when a bird's legs were obstructed from view. Also, I recorded the stage of production that each field was in at each visit as pre-production/no manipulation yet, pre-planting treatment [tilling, herbicide application], planting [by air application or drill seeding], or production/growth stage. Not all production stages were recorded for all rice fields because it was not possible to always observe pre-planting treatments or the planting method.

Some species of shorebirds are difficult to distinguish in the field, and in instances when the exact species could not be determined I grouped similar species. All Long-billed and Short-billed Dowitchers (*Limnodromus scolopaceus* and *Limnodromus griseus*, respectively) were recorded as "dowitchers" because they are very difficult to tell apart in the field. In instances where Lesser and Greater Yellowlegs (*Tringa flavipes* and *Tringa melanoleuca*, respectively) could not be identified to species, they were classified as "yellowlegs." Black-bellied Plovers (*Pluvialis squatarola*) and American Golden-Plovers (*Pluvialis dominica*) can be very difficult to tell apart when not in breeding plumage; therefore I identified these as "*Pluvialis* spp" unless positively identified. Also, Marbled and Hudsonian Godwits (*Limosa fedoa* and *Limosa*

haemastica, respectively) that could not be identified positively were classified as "godwit." Finally, any Least, Semipalmated, and Western Sandpipers (*Calidris minutilla*, *Calidris pusilla*, and *Calidris mauri*, respectively) that could not be identified to species were recorded as "peeps." I treated these five groupings as species.

Statistical Analyses

Variables from multiple scales were included in subsequent analyses. Identifier variables included year (YEAR), survey point (POINT), and survey period (SP). At each rice field visit, I recorded the percent of water, mud, rice, and other vegetation (PWATER, PMUD, PRICE, and POTHER) within the field boundaries. At the rice-field scale, I also included rice height in centimeters (RICEHT), flooding extent (yes, no, partially; FLOODED), average water depth in centimeters (WDEPTH), percent of the field perimeter bordered by tree line or forest (TREEBORD), length of the field perimeter in meters (PERIM), field area in hectares (FAREA), and shorebird density as the response variable (SBDENS). At each landscape scale (0 – 3 km), I included the percent of each habitat type at each scale, including the percent of rice (RICE), forest (FOR), developed areas (DEVEL), non-rice crops (sugarcane, soybean, wheat; NRC), crawfish (CRAW), and fallow areas (FALL). I also included the habitat suitability zones (HSZ) derived by Pickens et al. (2009).

I used an Analysis of Variance (ANOVA; PROC MIXED, SAS vers. 9.1.3, SAS Institute, Cary, NC) to compare shorebird density between HSZs and survey period, and to compare rice density between HSZs. All analyses were evaluated for statistical significance at the $\alpha = 0.05$ level. Shorebird density was log-transformed for normality.

To examine the influence of habitat variables measured across multiple scales, I performed a hierarchical regression tree analysis by employing a mixed general linear model

(PROC MIXED, SAS version 9.1.3, SAS Institute, Cary, NC) similar to Girvetz and Greco (2009) to systematically determine the important variables at each scale. I included two random effects (YEAR and POINT) with the remaining habitat variables (PWATER, PMUD, PRICE, POTHER, RICEHT, FLOODED, WDEPTH, TREEBORD, PERIM, SBDENS, RICE, FOR, DEVEL, NRC, CRAW, and FALL) as fixed effects, and I included FAREA as a covariate. In order to better approximate the assumptions of normality for the general linear mixed model, I used the log of shorebird density as the response variable in my models. Shorebird density was log-transformed for normality. Starting at the finest scale (the rice field scale) and systematically working to the broadest scale (the 3 km scale), I analyzed the following scales, in order: rice field, 0 km, 1 km, 1.5 km, 2 km, 2.5 km, and 3 km. Consequently, variables that were statistically significant ($\alpha = 0.05$) at the rice field scale were retained, and variables from the next broader scale were added until all scales were evaluated. At each scale, only statistically significant variables were retained as the process continued until all scales had been tested and only statistically significant variables from all scales remained (Girvetz and Greco 2009).

To determine community effects of habitat variables and shorebird community interactions, I used a multivariate analysis of variance (MANOVA; PROC GLM, SAS vers. 9.1.3, SAS Institute, Cary, NC) to compare responses of the shorebird community to habitat variables, which included local variables and all landscape variables. The shorebird community is defined as the seven most abundant species (>700 birds) observed in this study. The shorebirds included in the MANOVA were Dowitchers, Lesser Yellowlegs, Yellowlegs, Peeps, Stilt Sandpipers (*Calidris himantopus*), Least Sandpipers, and Pectoral Sandpipers (*Calidris melanotos*). Overall community-wide responses to habitat variables were evaluated with Wilk's Lambda ($\alpha = 0.05$), and specific species responses were interpreted only for habitat variables

with statistically significant overall community-wide effects. Densities were log-transformed for normality.

I also examined the influence of habitat variables measured across scales on the seven most common species, but only included the survey periods where these birds were primarily present. I used the same approach as the general linear mixed modeling with all species and all dates included, described in detail above. This analysis was completed with a truncated dataset, and utilized only Dowitchers, Lesser Yellowlegs, Yellowlegs, Peeps, Stilt Sandpipers, Least Sandpipers, and Pectoral Sandpipers for survey periods 1, 2, 3, 4, and 5 from each year. Species densities were log-transformed for normality.

Landscape Analyses

I used Fragstats 3.3 (McGarigal and Marks 1995, McGarigal et al. 2002) to conduct the landscape analyses. Fragstats is capable of computing many landscape metrics based on landscape patterns. I used this program to assess landscape heterogeneity and arrangement of rice fields in each landscape, and then to compare between and among landscapes and HSZs. I defined a single landscape as a rice field in one year (e.g. Field 177 in 2008) and all land within 3 km of that field. I used Fragstats to calculate multiple variables at the class and landscape level. Class variables are variables that are calculated for each habitat (or patch) type (e.g., area, patch density), while landscape variables are calculated once for the entire landscape. Fragstats has been used this way in similar studies (Farmer and Parent 1997, Guadagnin and Maltchik 2007).

At the class level, I used the following variables to assess rice field availability, isolation, and fragmentation: rice class area (AREA), rice patch density (RDENS), rice mean Euclidean nearest neighbor distance (ISOL), and the rice interspersion and juxtaposition index (RFRAG; Table 3). I included AREA because it is a direct measure of habitat availability. I included ISOL

because this variable indicates rice patch isolation, or how far apart one patch of rice is from the next patch of rice. Finally, I included RFRAG as a measure of rice fragmentation because it calculates the degree of intermixing of rice with other habitat types (Table 3).

Table 3. Fragstats variables and measurement definitions.

Level	Measurement	Unit	Variable
Class	Area of rice fields	ha	AREA
	Rice mean Euclidean nearest neighbor distance (measures isolation)	m	ISOL
	rice fragmentation (interspersion and juxtaposition index)	%	RFRAG
Landscape	Patch richness	# of patch types	PRICH
	Landscape shape	none	SHAPE
	Landscape fragmentation/heterogeneity (interspersion and juxtaposition index)	%	LFRAG

At the landscape level, I used the following variables to assess landscape heterogeneity and arrangement: patch richness (PR), landscape shape index (SHAPE), interspersion and juxtaposition index (LFRAG). I included PRICH because it is a simple measure of the number of different patch types within the landscape. I included SHAPE as a measure of the complexity of the landscape (a higher value indicates a more complex landscape). Finally, I included LFRAG because it is a measure of landscape fragmentation, which means it is essentially a measure of landscape heterogeneity (Table 3).

RESULTS

Shorebird Distribution and Summary

In 2008 and 2009 I observed a total of 23,126 shorebirds representing 26 species, including 10,642 shorebirds of 24 species in 2008 and 12,484 shorebirds of 24 species in 2009 (Table 4). Dowitchers, Lesser Yellowlegs, Yellowlegs, Peeps, Stilt Sandpipers, Least

Table 4. Shorebird abundance by year.

Species	Scientific Name	2008	2009	Total
Dowitchers	*Limnodromus scolopaceus* or *L. griseus*	3,321	3,029	6,350
Lesser Yellowlegs	*Tringa flavipes*	1,743	1,750	3,493
Yellowlegs	*Tringa flavipes* or *T. melanoleuca*	1,276	2,072	3,348
Peeps	*Calidris minutilla*, *C. mauri*, or *C. pusilla*	734	1,631	2,365
Stilt Sandpiper	*Calidris himantopus*	416	1,219	1,635
Least Sandpiper	*Calidris minutilla*	308	566	874
Pectoral Sandpiper	*Calidris melanotos*	327	373	700
Dunlin	*Calidris alpina*	471	111	582
Pluvialis spp.	*Pluvialis dominica* or *P. squatarola*	349	144	493
Semipalmated Sandpiper	*Calidris pusilla*	468	0	468
Black-necked Stilt	*Himantopus mexicanus*	281	156	437
Greater Yellowlegs	*Tringa melanoleuca*	182	123	305
Semipalmated Plover	*Charadrius semipalmatus*	122	112	234
Killdeer	*Charadrius vociferus*	111	75	186
Whimbrel	*Numenius phaeopus*	149	1	150
Ruddy Turnstone	*Arenaria interpres*	131	2	133
Western Sandpiper	*Calidris mauri*	119	10	129
Buff-breasted Sandpiper	*Tryngites subruficollis*	41	9	50
American Golden-Plover	*Pluvialis dominica*	0	37	37
White-rumped Sandpiper	*Calidris fuscicollis*	0	8	8
Godwit	*Limosa haemastica* or *L. fedoa*	7	0	7
Hudsonian Godwit	*Limosa haemastica*	2	4	6
Upland Sandpiper	*Bartramia longicauda*	0	5	5
Wilson's Phalarope	*Phalaropus tricolor*	1	3	4
Wilson's Snipe	*Gallinago delicate*	3	1	4
Black-bellied Plover	*Pluvialis squatarola*	2	0	2
Unidentified	*unknown*	78	1043	1121
Total		10,642	12,484	23,126

Sandpipers, and Pectoral Sandpipers were the most common species (Table 4). Shorebirds were encountered at 72 of 94 sites (76.5%) in 2008 and at 66 of 85 sites (77.6%) in 2009.

Shorebirds were observed primarily in flooded rice fields (66.2 % - 2008; 79.1 % - 2009). Of all shorebirds observed, 84 – 90 % were observed foraging (Table 5).

Table 5. Percent of shorebirds engaged in each behavior in 2008 and 2009.

Behavior	2008	2009
Foraging	0.85	0.90
Locomotion	0.00	0.00
Panic flight	0.00	0.02
Preening	0.07	0.02
Resting	0.05	0.04
Standing	0.02	0.01
Unknown	0.00	0.01

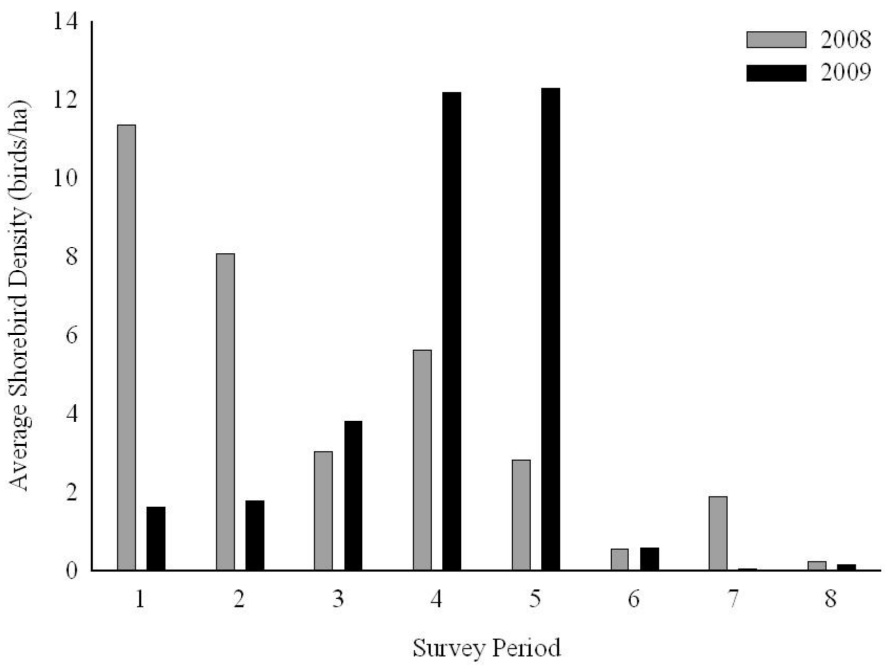

Figure 3. Mean shorebird density by survey period in 2008 and 2009.

Table 6. Mean shorebird density (birds/ha), standard deviation (Std), and range by habitat suitability zone in 2008 and 2009.

	2008			2009		
HSZ	Mean	Std	Range	Mean	Std	Range
1	0.17	0.81	0-6.19	1.76	7.10	0-48.08
2	2.24	7.89	0-58.72	3.19	10.90	0-77.34
3	5.87	32.20	0-325.32	6.53	22.38	0-150.77
4	4.55	21.55	0-191.45	4.35	19.39	0-181.28
5	5.64	21.56	0-187.65	5.63	34.37	0-375.55

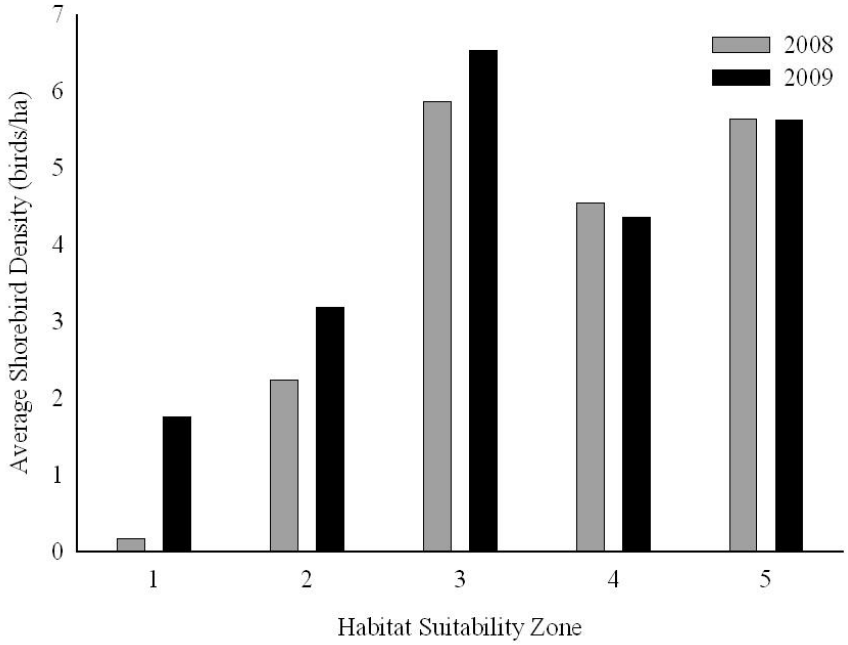

Figure 4. Mean shorebird density in each habitat suitability zone in 2008 and 2009.

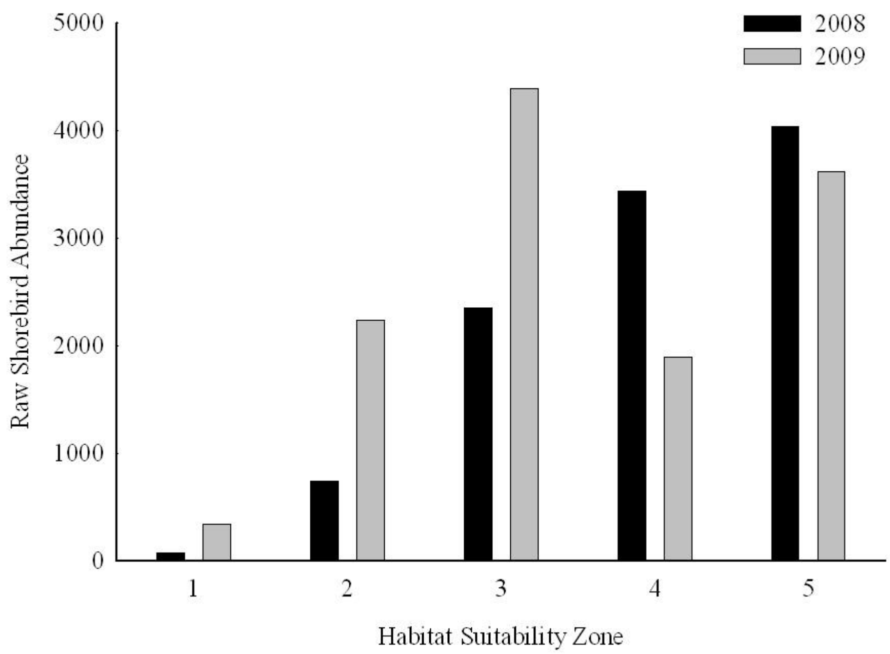

Figure 5. Shorebird abundance in each habitat suitability zone in 2008 and 2009.

Shorebird density was averaged for all sites in each survey period (SP) in 2008 and 2009. Shorebird density patterns were different in 2008 and 2009, with shorebird density peaking early in the season in 2008 and peaking mid-season in 2009 (Figure 3). In 2008, shorebird density did not differ between survey periods (p-values between 0.1026 – 1.0000, df = 192, SE range = 0.4439 – 0.6952). In 2009, shorebird density was higher in SP4 compared to SP7 (p = 0.0255, df = 152, SE = 0.7919) and SP8 (p = 0.0096, df = 152, SE = 0.6179), and it was higher in SP5 compared to SP6 (p = 0.0311, df = 152, SE = 0.5383), SP7 (p = 0.0178, df = 152, SE = 0.7919), and SP8 (0.0058, df = 152, SE = 0.6179; Figure 3).

Mean shorebird density was between 0.17 and 5.87 birds/ha in 2008 and between 1.76 and 6.53 birds/ha in 2009 (Table 6) and did not differ among HSZs (all p-values between 0.2289 – 0.9998; Figures 4 and 5).

Habitat Analyses

I analyzed and characterized descriptions of each HSZ. Rice density and canopy cover were the variables used to predict the HSZs. Rice density was higher in HSZ4 (p = 0.0069, df = 173, SE = 0.0230) and HSZ5 (p = <0.0001, df = 173, SE = 0.0225) compared to HSZ1, was higher in HSZ4 (p = 0.0065, df = 173, SE = 0.0243) and HSZ5 (p = <0.0001, df = 173, SE = 0.0238) compared to HSZ2, and was higher in HSZ5 (p = 0.0058, df = 173, SE = 0.0217) compared to HSZ3. Forest density was lower in HSZs 3, 4, and 5 compared to HSZ1 (p = <0.0001, df = 146, SE = 0.2870 (HSZ3), 0.2936 (HSZ4), and 0.3178 (HSZ5)) and HSZ2 (p = <0.0001, df = 146, SE = 0.3053 (HSZ3), 0.3115 (HSZ4), and 0.3344 (HSZ5), Figure 7). The percent of rice in the surrounding area (at all scales: 0, 1, 1.5, 2, 2.5, and 3 km) steadily decreased with distance from the survey fields in all HSZs in both years. The percent of rice in the surrounding landscape was always higher in HSZs 3-5 in 2008, and was usually higher in

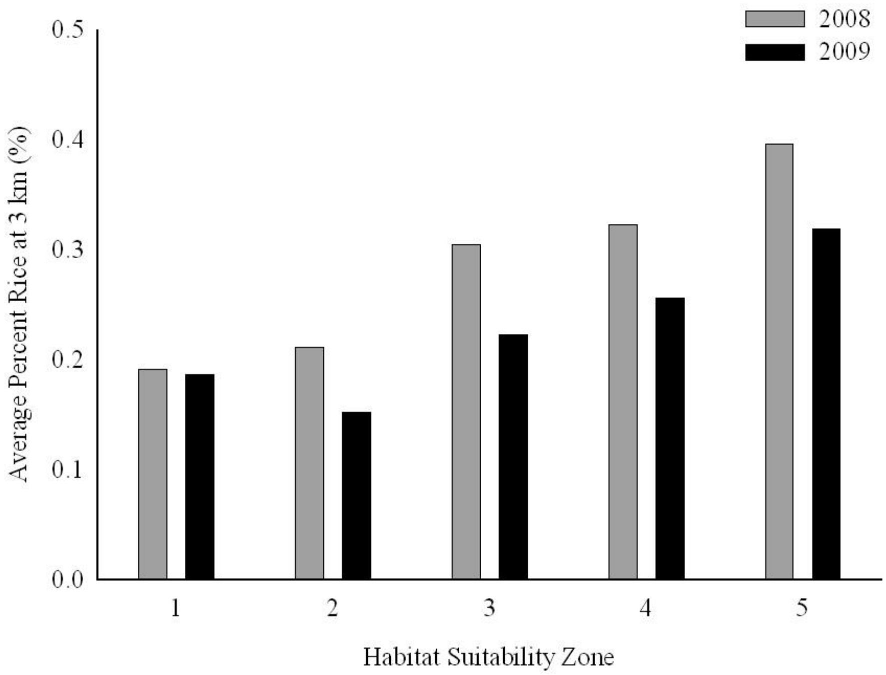

Figure 6. Average percent of rice in 3 km landscapes in each habitat suitability zone (2008 n = 94 fields, 2009 n = 85 fields).

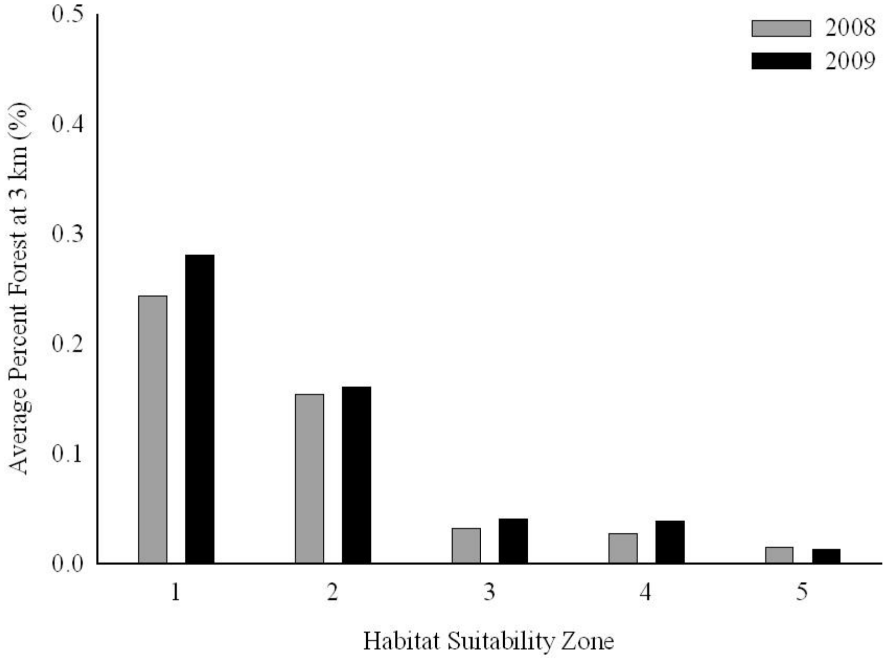

Figure 7. Average percent of forest in 3 km landscapes in each habitat suitability zone (2008 n = 94 fields, 2009 n = 85 fields).

HSZs 3-5 in 2009 (Table 7). The percent of forest in the surrounding area (at all scales: 0, 1, 1.5, 2, 2.5, and 3 km) increased with distance from the survey fields in all HSZs in both years, and was always higher in HSZs 1-2 than in HSZs 3-5 (Table 7).

The results indicate that the distribution and abundance of rice varies among years. Although there were only 9 more sites in 2008, there were approximately 20,000 more hectares of rice in 2008 than in 2009 in the study area. It is possible that the difference in sites explains the difference in rice availability; however, that would mean that the 9 “missing” landscapes would have had 2,222 ha of rice each, or be comprised of 78.6% rice. However, this is highly unlikely because we did not have a 3 km landscape during the entirety of this study that was comprised of over 67.5% rice.

Analyses of the relationships among shorebirds and local and landscape habitat characteristics indicated that only three variables were related to the log-transformed shorebird density: FLOODED, TREEBORD, and RICEHT. All three variables were from the rice field scale; no variables from the broader scales influenced shorebird density (Table 8).

The results of the MANOVA indicated species-specific responses by the seven most abundant species to the various habitat variables. The only variables that influenced all seven species were FLOODED, RICEHT, and HSZ (Table 9); although responses among the seven most common species to these variables varied. Most species were positively influenced by flooding extent, all were negatively influenced by rice height, and only 3 species were positively influenced by HSZ (Table 10).

The results of the general linear mixed modeling with the limited dataset (only the seven most common species in SPs 1-5) indicated the importance of two local variables: FLOODED and TREEBORD. It also indicated the importance of two landscape variables: NRC0 and

Table 7. Rice field and forest cover (decimal percentage) of the surrounding area (at 0 [immediately adjacent], 1, 1.5, 2, 2.5, and 3 km) by habitat suitability zone in 2008 and 2009. Values are decimal percentage (e.g. 0.52 = 52%) plus or minus the standard deviation.

	2008					2009				
	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5
RICE0	0.52 (±0.28)	0.49 (±0.33)	0.56 (±0.27)	0.52 (±0.20)	0.55 (±0.29)	0.46 (±0.33)	0.49 (±0.26)	0.47 (±0.32)	0.51 (±0.25)	0.58 (±0.27)
RICE10	0.36 (±0.17)	0.34 (±0.20)	0.44 (±0.16)	0.38 (±0.16)	0.46 (±0.19)	0.33 (±0.14)	0.28 (±0.12)	0.30 (±0.18)	0.32 (±0.15)	0.38 (±0.11)
RICE15	0.30 (±0.14)	0.30 (±0.19)	0.39 (±0.13)	0.36 (±0.17)	0.43 (±0.15)	0.28 (±0.13)	0.21 (±0.11)	0.26 (±0.17)	0.29 (±0.17)	0.37 (±0.12)
RICE20	0.25 (±0.11)	0.26 (±0.15)	0.35 (±0.12)	0.35 (±0.15)	0.41 (±0.15)	0.23 (±0.13)	0.17 (±0.10)	0.24 (±0.14)	0.27 (±0.16)	0.34 (±0.14)
RICE25	0.21 (±0.08)	0.23 (±0.14)	0.33 (±0.12)	0.34 (±0.15)	0.40 (±0.15)	0.20 (±0.12)	0.16 (±0.10)	0.23 (±0.12)	0.26 (±0.14)	0.33 (±0.14)
RICE30	0.19 (±0.08)	0.21 (±0.12)	0.30 (±0.13)	0.32 (±0.14)	0.40 (±0.15)	0.19 (±0.10)	0.15 (±0.10)	0.22 (±0.12)	0.26 (±0.12)	0.32 (±0.14)
FOR0	0.05 (±0.13)	0.06 (±0.15)	0.01 (±0.04)	0 (±0)	0.01 (±0.02)	0.07 (±0.18)	0.06 (±0.15)	0 (±0)	0 (±0)	0 (±0)
FOR10	0.07 (±0.08)	0.08 (±0.11)	0.01 (±0.02)	0.01 (±0.02)	0.01 (±0.12)	0.08 (±0.09)	0.06 (±0.10)	0.01 (±0.02)	0.01 (±0.02)	0.00 (±0.01)
FOR15	0.12 (±0.09)	0.10 (±0.11)	0.01 (±0.01)	0.01 (±0.03)	0.01 (±0.02)	0.13 (±0.10)	0.08 (±0.10)	0.03 (±0.04)	0.01 (±0.01)	0.00 (±0.00)
FOR20	0.16 (±0.09)	0.13 (±0.12)	0.01 (±0.01)	0.03 (±0.05)	0.01 (±0.01)	0.20 (±0.10)	0.11 (±0.11)	0.03 (±0.04)	0.03 (±0.04)	0.00 (±0.00)
FOR25	0.21 (±0.09)	0.14 (±0.12)	0.02 (±0.02)	0.03 (±0.05)	0.01 (±0.02)	0.24 (±0.08)	0.14 (±0.11)	0.03 (±0.04)	0.04 (±0.06)	0.01 (±0.01)
FOR30	0.24 (±0.10)	0.15 (±0.13)	0.03 (±0.04)	0.03 (±0.05)	0.01 (±0.02)	0.28 (±0.08)	0.16 (±0.12)	0.04 (±0.04)	0.04 (±0.06)	0.01 (±0.02)

FALL0 (Table 11). NRC0 is the percent of the immediately adjacent area occupied by non-rice crops (sugarcane, wheat, soybean, etc.) and FALL0 is the percent of the immediately adjacent area occupied by fallow area or pasture.

Table 8. Results of general linear mixed modeling indicating only the final significant variables based on α = 0.05.

Effect	Estimate	Standard Error	DF	F-value	p-value
Intercept	1.2710	0.2515	1		0.1244
FLOODED	0.8819	0.1001	2,209	77.58	<0.0001
TREEBORD	-0.00183	0.000681	1,209	7.26	0.0076
RICEHT	-0.1403	0.01776	1,209	62.37	<0.0001

Table 9. Results of the MANOVA indicating only the final significant variables based on α = 0.05.

Effect	Wilk's Lambda Value	DF	F-value	p-value
FLOODED	0.8984	1151	18.59	<0.0001
RICEHT	0.9469	1151	9.23	<0.0001
HSZ	0.9858	1151	2.37	0.0211

Table 10. Results of the MANOVA indicating community responses by species to important variables (variables were evaluated at α = 0.05 level, and a negative sign indicates a negative response while no sign indicates a positive response).

Species	FLOODED	RICEHT	HSZ
Dowitchers	<0.0001	- <0.0001	0.0010
Lesser Yellowlegs	<0.0001	- <0.0001	0.3279
Yellowlegs	<0.0001	- <0.0001	0.0206
Peeps	0.1651	- 0.0156	0.0172
Stilt Sandpipers	<0.0001	- 0.0626	0.0595
Least Sandpipers	0.2541	- 0.0042	0.3379
Pectoral Sandpipers	0.0013	- 0.0011	0.0746

Table 11. The results of the general linear mixed modeling using only the seven most common species and survey periods 1-5, showing only significant variables.

Effect	Estimate	Standard Error	DF	F-value	p-value
FLOODED	0.6658	0.2512	70	7.03	0.0099
TREEBORD	-0.0025	0.0010	70	6.91	0.0105
NRC0	3.3014	1.6158	100	4.17	0.0437
FALL0	3.1175	1.4981	100	4.33	0.0400

Landscape Analyses

At the class level, total rice area was 76,588.4 ha in 2008 and 56,214.4 ha in 2009. Average rice interspersion and juxtaposition was 77.7 in 2008 and 78.0 in 2009; a value of 100

indicates maximum interspersion of rice with other land cover types (a more heterogeneous landscape). These values indicate that rice was readily available for use based on available area and that rice was highly intermixed with the other land cover types to comprise a heterogeneous landscape.

Total rice area generally increased with HSZ (Table 12), and was higher in HSZs 4 and 5. Average landscape shape (SHAPE) ranged from 7.1 to 9.2 in 2008 and from 7.3 to 10.2 in 2009; a value of 1 indicates one cover square of habitat, and values greater than 1 indicates an increase in edge length and a decrease in patch aggregation. Patch richness ranged from 5 to 10 patch types per landscape in 2008 and 5 to 9 patch types per landscape in 2009. This means that there were always 5-9 different land cover types, indicating a diverse landscape.

Table 12. Total rice area (ha) in each habitat suitability zone in 2008 and 2009.

HSZ	2008	2009
1	24.91	19.75
2	21.31	13.41
3	37.18	30.76
4	46.80	29.67
5	58.95	43.33

Table 13. Mean of rice fragmentation (RFRAG) and landscape fragmentation (LFRAG) in 2008 and 2009 in each habitat suitability zone (HSZ), expressed as a percentage.

	RFRAG		LFRAG	
HSZ	2008	2009	2008	2009
1	78.0	80.9	78.3	79.4
2	75.8	78.6	73.9	74.5
3	75.9	77.4	74.0	75.1
4	74.9	77.0	73.9	75.6
5	83.3	76.8	78.2	76.6

Rice fragmentation in 2008 ranged from 74.9 to 83.3 percent, and in 2009 ranged from 77.0 to 80.9 percent. These values indicate that rice fields were highly intermixed and were adjacent to multiple different land cover types, indicating a heterogeneous landscape. Landscape fragmentation ranged from 73.9 to 78.3 percent in 2008, and 74.5 to 79.4 percent in 2009 (Table

13). These values indicate that all the land cover types comprising the landscape were highly intermixed and juxtaposed to one another, further supporting that the landscape was a heterogeneous mosaic.

DISCUSSION

The landscape analyses indicate that the rice landscape is diverse and that the distribution and abundance of rice varies among years. Although there were only 9 more sites in 2008, there were approximately 20,000 more hectares of rice in 2008 than in 2009 in the study area, possibly because of the effects of Hurricane Ike on salinities of irrigation water and soil salinities in some rice fields during 2009. In spite of differences in the landscape among years, the predictions of rice and forest density by the habitat suitability model were supported. Rice density was higher in HSZ4 and HSZ5 than in the lower HSZs. In addition, forest density (the measure of canopy cover) was lower in HSZs 3-5 compared to HSZ1 and HSZ2. Forest density at all scales (0, 1, 1.5, 2, 2.5, and 3 km) decreased with an increase in HSZ, further supporting the lower forest density in higher HSZs. These results verify that rice density was higher and forest density was lower in the higher quality HSZs (4-5), which was expected based on the model. This indicates that the habitat suitability model was accurate in characterizing rice and forest density.

Overall shorebird densities and abundance were more affected by local habitat factors than by landscape factors. The limited influence of landscape characteristics is contrary to my expectation as other studies have found that migrating shorebirds are affected by landscape conditions (Fairbairn and Dinsmore 2001, Maeda 2001, Chan et al. 2007, Webb et al. 2010). The results could be because I chose an inappropriate scale for my study, there was a relatively homogenous landscape at broader spatial scales, and/or the lumping of shorebird species that use

the landscape in different ways and thus masking landscape effects in analyses of overall shorebird density.

To further this finding of a limited landscape influence, two factors at the 0 km scale were a positive influence when only the most common species in SP1-5 were considered: NRC0 and FALL0. These two variables at the immediately adjacent scale suggest that overall shorebird densities are not influenced by the landscape, and may be concentrating in rice fields that are juxtaposed to non-habitat areas. This also suggests that shorebirds can find and utilize isolated rice fields even those that occur amid other habitat types. These results further support our results that the landscape was not an influence on shorebirds foraging in rice fields in the spring in this region.

In California, the landscape surrounding pastures used by wintering shorebirds was determined as statistically unimportant; however, the researchers did acknowledge that all study sites were within known foraging habitat (intertidal zones) and therefore the scale they used may not have been large enough (Colwell and Dodd 1997). Therefore it is possible that shorebirds are selecting sites in SWLA based on a scale (broader or finer) or based on a factor that we did not consider. However, conducting our study at a broader scale simply was not possible because of the finite size of the study area and the availability of rice fields.

Differences in the mean percent of rice available at each scale were relatively small. At all scales, landscapes contained approximately 30-38% rice in 2008, and 24-32% rice in 2009. These minor changes in the percent of rice availability at the measured scales may have been insufficient to initiate a landscape response from shorebirds.

Although overall shorebird densities did not differ among landscape variables measured in this study, some evidence suggests that the landscape did have some impact on overall

shorebird densities. For example, overall shorebird densities among HSZs did not differ but the rice fields with the highest average shorebird densities from either year primarily occurred in HSZs 3-5: 32 of 39 and 26 of 37 of the rice fields with the highest mean shorebird density (>1 bird/ha) were located in HSZs 3-5 in 2008 and 2009, respectively. Furthermore, most sites with zero shorebirds (and therefore zero shorebird density) occurred in HSZ1 and HSZ2 in 2008 (13 of 22), although this relationship was not as strong in 2009 (9 of 19).

Several local habitat features were important for overall shorebird density: flooding extent (+), tree border (-), and rice height (-). However, analyses of the seven most common species indicated species-specific differences: HSZ was important for three species, flooding extent and rice height were important for five species, and tree border was no longer important for any of the seven most common species (Table 8). Dowitchers, Yellowlegs, and Peeps were positively influenced by HSZ, and their combined totals accounted for over 50% of all birds observed each year, which suggests that HSZ may be an influence on how individual species utilize the landscape.

Flooded areas are known shorebird foraging areas (Niemuth et al 2006, Eadie et al. 2008, Elphick 2008), particularly flooded rice fields in the spring (Helmers 1993). Elphick and Oring (2003) found that winter shorebird densities were greater in flooded rice fields. Shorebirds in this study were positively associated with flooding extent, and the density of Dowitchers, Lesser Yellowlegs, Yellowlegs, Stilt Sandpipers, and Pectoral Sandpipers per field was positively related to the amount of the field flooded (Table 9). Only Peeps and Least Sandpipers were not influenced by field flooding in this study, however, this may be a result of my inability to separate shallow flooding from deeper flooding, as these species have shorter tarsus lengths (Cooper 1994) and prefer mudflats and shallow-flooded areas. These species were frequently

observed on mudflat and in water less than 2 cm deep, and never in water deeper than 4 cm. Similarly, in northwest Texas, Least Sandpipers were documented as preferring mudflat over shallow water the majority of the time (53.2%), while Western Sandpipers preferred mudflat almost half the time (43.5%; Davis and Smith 1998a).

Overall shorebird densities were greater in rice fields with limited to no tree border. Predatory birds have been documented to use wetlands (Laubhan and Fredrickson 1993), and may be attracted to large flocks of shorebirds (Bijlsma 1990), particularly during migration (Ydenberg et al. 2004). In China, shorebirds avoided areas near woodlands despite their relatively high food abundance in favor of areas more than 4 km from woodlands (Jing et al. 2007). Merlins (*Falco columbaris*), American Kestrels (*Falco sparverius*), Cooper's Hawks (*Accipiter cooperii*), Peregrine Falcons (*Falco peregrinus*), and Northern Harriers (*Circus cyaneus*) have all been documented to hunt and target shorebird flocks from nearby perches (Page and Whitacre 1975, Kus et al. 1984, Ydenberg et al. 2002). Cooper's Hawks and other predatory birds are present in southwestern Louisiana during the spring. Therefore, it is possible that shorebirds may be avoiding these areas because they are a potential source of predators.

Foraging shorebirds typically use vegetation less than half their height (Helmers 1992), and have been documented to prefer shorter vegetation, even < 10 cm (Rottenborn 1996, Colwell and Dodd 1997). The majority of shorebirds in this study were observed foraging, and this is an expected activity in migratory shorebirds (Davis and Smith 1998b, De Leon and Smith 1999). This may allow shorebirds to better find and capture prey, and possibly even allow shorebirds to better detect predators (Colwell and Dodd 1995). Therefore, it is reasonable to expect that shorebirds would select shorter rice fields in southwestern Louisiana for better foraging sites and possibly better predator awareness.

The relationship among overall shorebird density and landscape characteristics may have also been influenced by lumping species that use the landscapes differently. For example, the abundance and density of three of the seven most common species differed among HSZs. Dowitchers, Yellowlegs, and Peeps were positively influenced by HSZ, indicating that they utilized what was expected to be higher quality (and therefore more attractive) habitat based on the habitat suitability model. Lesser Yellowlegs did not differ among HSZs; however, Lesser Yellowlegs likely comprised part of the Yellowlegs species grouping, which did respond positively to HSZ. These three species (Dowitchers, Yellowlegs, and Peeps) comprised >50% of all shorebirds observed each year, which indicates that HSZ is an important factor to take into consideration when managing for shorebird habitat, at least for some species.

While all shorebirds were influenced by localized features and some species were influenced by HSZ, there were differences in species abundances between years that were not attributed to habitat features. Semipalmated Sandpipers, Whimbrels, Dunlin, Ruddy Turnstones, and Western Sandpipers were more abundant in 2008, while Peeps, Stilt Sandpipers, and Unknowns were more abundant in 2009. There are multiple explanations for the differences in abundance between years. In 2008, Semipalmated Sandpiper abundance was driven by a large flock (450 birds) of birds present at one rice field with ideal conditions (good lighting and short distance) that allowed me to identify the birds to species, rather than to "Peep." This is also true for Western Sandpiper abundance in 2008, when conditions allowed me to identify a flock (100 birds) of birds to species. In most other situations, birds were unable to be identified as Least, Western, or Semipalmated Sandpipers for the majority of the time due to conditions (poor lighting or distance) and were classified as "Peep." It is likely that White-rumped and Baird's Sandpipers were also included in the Peep group. These ideal conditions allowed me to identify

these species when otherwise they would have been classified as Peeps, so this accounts for the discrepancy in abundance of Western and Semipalmated Sandpipers between years.

Whimbrels were rare in 2008 (1 bird observed), but 149 birds were observed in 2009. However, compared to other shorebirds, all Whimbrels were observed in a relatively narrow window of time (between 24 April to 10 May, 2008, and between 7 April and 30 April, 2009). Because Whimbrels complete migration quickly in the spring (Skeel and Mallory 1996), the birds observed in this study in 2009 were likely caught at a brief stopover during migration. Ruddy Turnstones were observed only in late April and May both years, which is just prior to the large staging event that occurs in Delaware Bay (late May; Nettleship 2000), suggesting they migrate through SWLA later in the season than other species.

Peeps were more abundant in 2009 than 2008, and may be a result of the species grouping or the variable nature of shorebird migration. There is no pattern or trend that is apparent to explain differences in Dunlin abundance between years. Stilt Sandpipers were also more common in 2009, but were primarily observed between SP3 and SP6 (7 April to 10 May), possibly indicating the migration period for this species. Unknowns were more common in 2009 than 2008, but this difference can be attributed to several large flocks of shorebirds that occurred at distances greater than 250 m away from the survey point, which limited exact identification.

CHAPTER 3
CONCLUSION

Despite none of the measured landscape variables in this study being important for overall shorebird densities, HSZ (a predicted landscape variable) was important for three of the most abundant species. Rice density was significantly higher in HSZ4 and HSZ5, confirming that more rice actually was present in higher quality HSZs, and the percent of forest (a surrogate measurement of canopy cover) on the landscape was significantly lower in HSZs 4 and 5. Furthermore, although overall shorebird density did not differ among HSZs, rice fields with high shorebird densities were often located in HSZs 3-5. These results support the habitat suitability model created by Pickens et al. (2009), which based the predictions of habitat suitability on rice density and canopy cover with the expectation of higher shorebird densities in higher HSZs.

By maintaining rice production as a component of the landscape in the higher quality HSZs, suitable local habitat would be provided for shorebirds. Rice fields in these areas would automatically be surrounded by less forest cover. These fields would have suitable water depths for most shorebirds because rice field water management in SWLA regularly floods fields to a shallow depth. However, the whole purpose of rice cultivation is to grow rice, so shorebird aversion to tall rice is not an issue that can be controlled, and is only an issue later in the growing season and not for the entirety of spring migration.

The Natural Resources Conservation Service (NRCS) has recently proposed a project to remove rice fields from production and plant native grasses for coastal prairie restoration in SWLA. Coastal prairie historically covered more than 400,000 ha, but is now restricted to less than 242 ha dispersed among agricultural or developed areas, and along railroad rights-of-way (Smith 1996, Allain et al. 1999, Grace et al. 2000, USGS 2000, Allen et al. 2001, Lester et al.

2005) The project goal is to restore up to 11,331 ha of land to coastal prairie in seven parishes (Acadia, Allen, Calcasieu, Cameron, Evangeline, Jeff Davis, and St. Landry) by establishing native grasses, areas of shallow water, and rare habitat (USDA 2007). Texas and Louisiana state agencies are also embarking on similar state plans to restore coastal grasslands, and in SWLA the state project is adjacent to the NRCS project area (USDA 2007).

I suggest conserving rice fields in higher quality HSZs for shorebird conservation and that prairie restoration take place in lower quality shorebird habitat (HSZ1 and HSZ2). This would allow NRCS to complete their restoration objectives, while still managing the landscape to provide quality habitat for spring migrating shorebirds. Shorebirds in this study utilized flooded, short rice, with limited trees nearby. Conserving higher HSZs would inherently provide this suitable habitat, which leads me to believe that HSZ is an important factor that should be taken into consideration for conservation and management.

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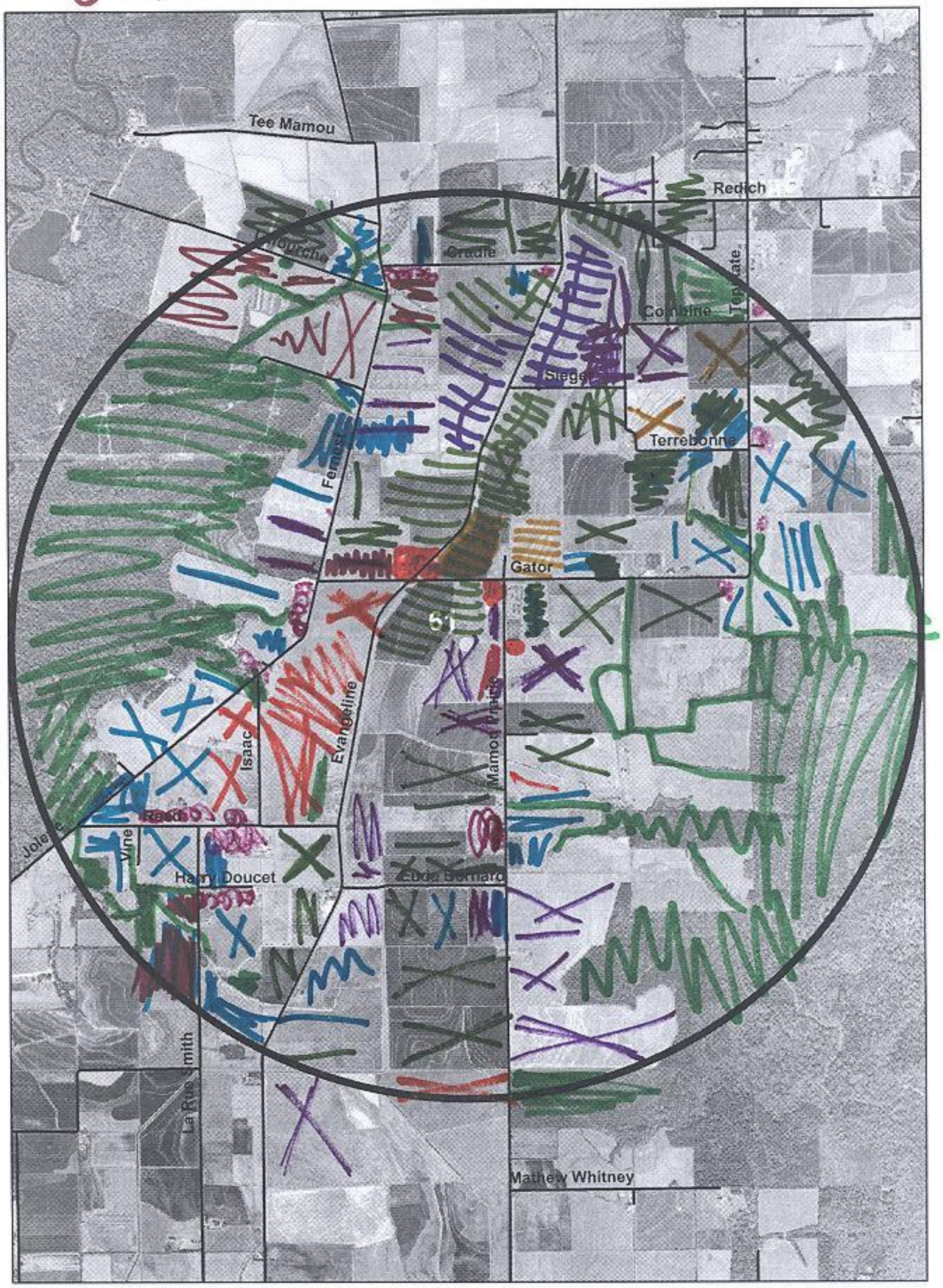
APPENDIX A: SCIENTIFIC NAMES OF SHOREBIRDS

Species	Scientific Name
American Golden-Plover	*Pluvialis dominica*
Black-bellied Plover	*Pluvialis squatarola*
Black-necked Stilt	*Himantopus mexicanus*
Buff-breasted Sandpiper	*Tryngites subruficollis*
Dowitchers	*Limnodromus scolopaceus* or *L. griseus*
Dunlin	*Calidris alpina*
Godwit	*Limosa haemastica* or *L. fedoa*
Greater Yellowlegs	*Tringa melanoleuca*
Hudsonian Godwit	*Limosa haemastica*
Killdeer	*Charadrius vociferus*
Least Sandpiper	*Calidris minutilla*
Lesser Yellowlegs	*Tringa flavipes*
Long-billed Dowitcher	*Limnodromus scolopaceus*
Marbled Godwit	*Limosa fedoa*
Pectoral Sandpiper	*Calidris melanotos*
Peeps	*Calidris minutilla*, *C. mauri*, or *C. pusilla*
Pluvialis spp.	*Pluvialis dominica* or *P. squatarola*
Ruddy Turnstone	*Arenaria interpres*
Semipalmated Plover	*Charadrius semipalmatus*
Semipalmated Sandpiper	*Calidris pusilla*
Short-billed Dowitcher	*Limnodromus griseus*
Stilt Sandpiper	*Calidris himantopus*
Unidentified	*unknown*
Upland Sandpiper	*Bartramia longicauda*
Western Sandpiper	*Calidris mauri*
Whimbrel	*Numenius phaeopus*
White-rumped Sandpiper	*Calidris fuscicollis*
Wilson's Phalarope	*Phalaropus tricolor*
Wilson's Snipe	*Gallinago delicate*
Yellowlegs	*Tringa flavipes* or *T. melanoleuca*

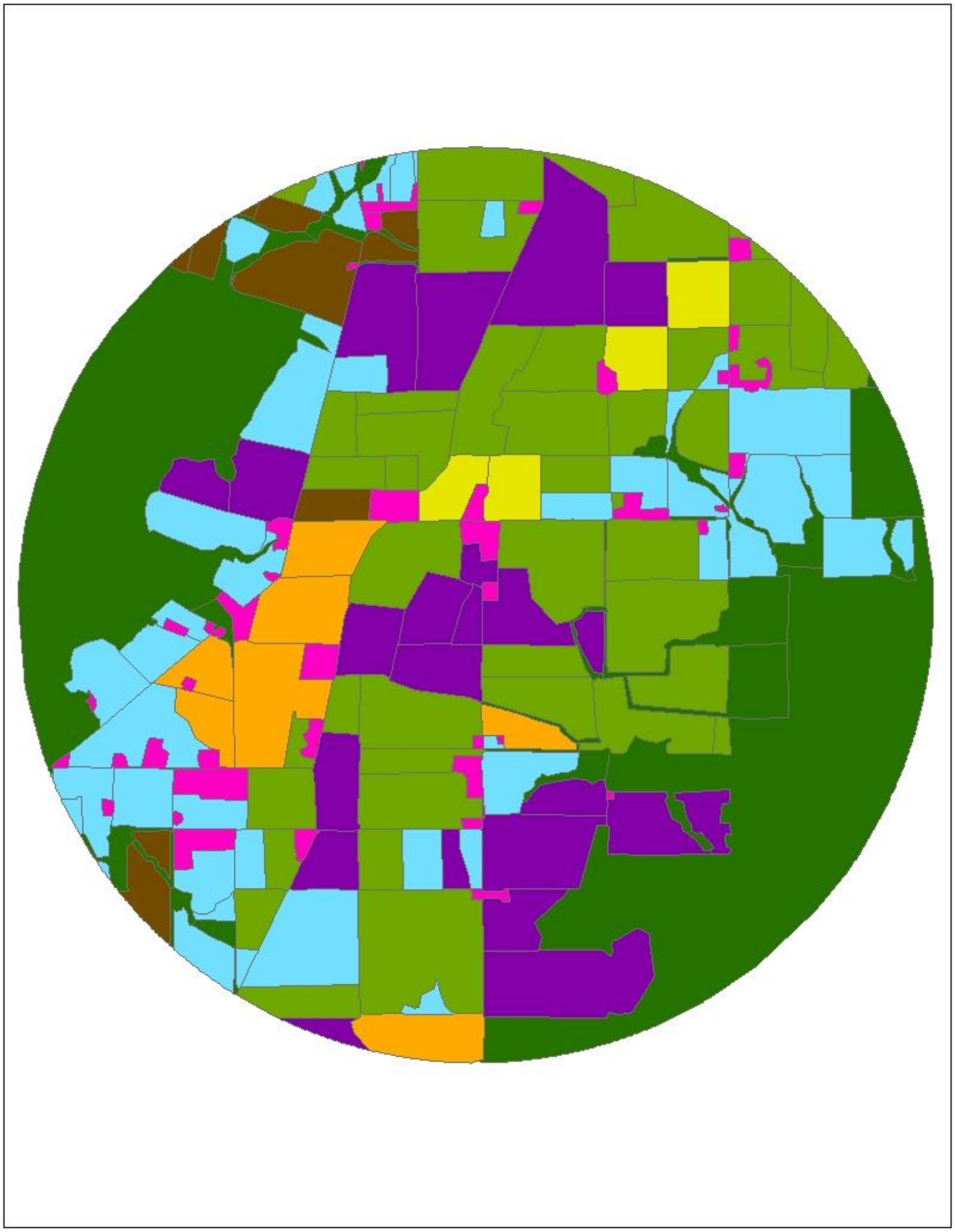
APPENDIX B: 2008 GROUND TRUTHED LANDSCAPE (SITE 61)

LGT Done

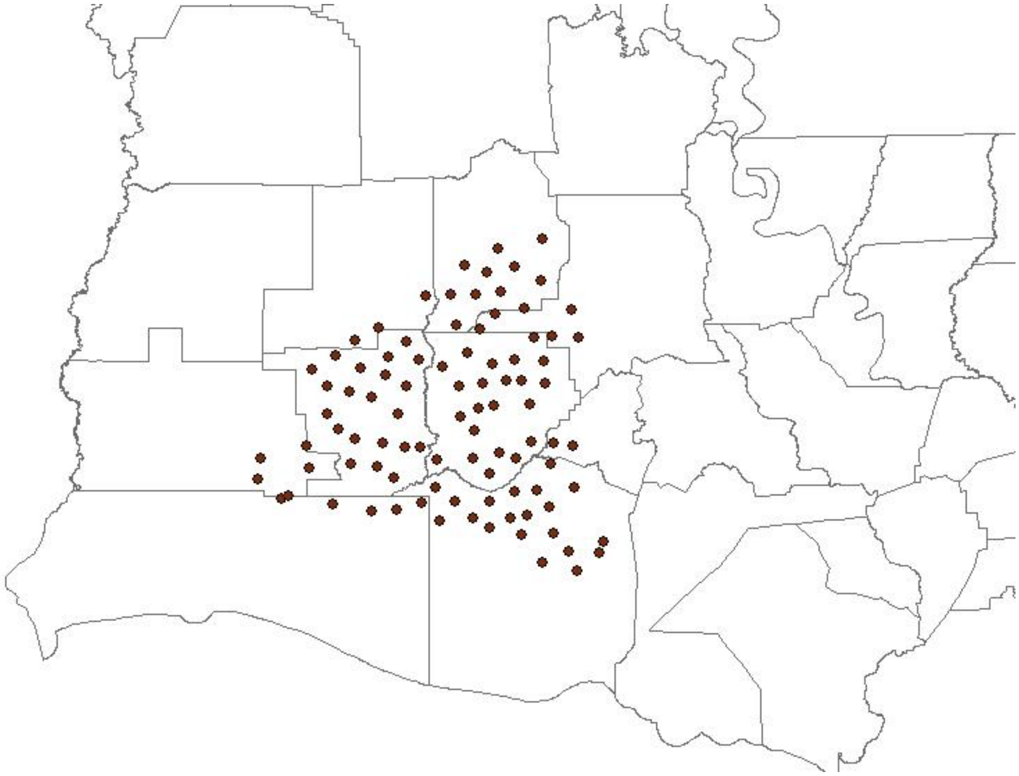
61



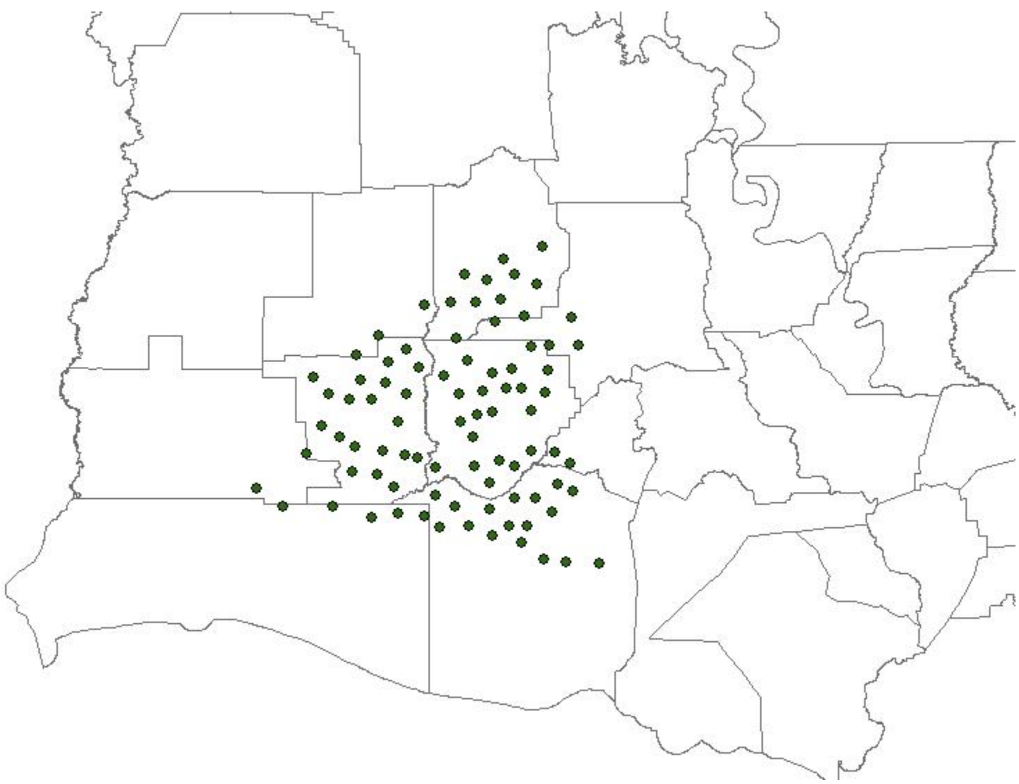
APPENDIX C: 2008 DIGITIZED LANDSCAPE (SITE 61)



APPENDIX D: MAP OF 2008 AND 2009 SURVEY FIELDS



Map of 2008 survey fields.



Map of 2009 survey fields.

APPENDIX E: PHOTOGRAPHIC PROGRESSION OF RICE PRODUCTION

11April 2008

18 April 2008

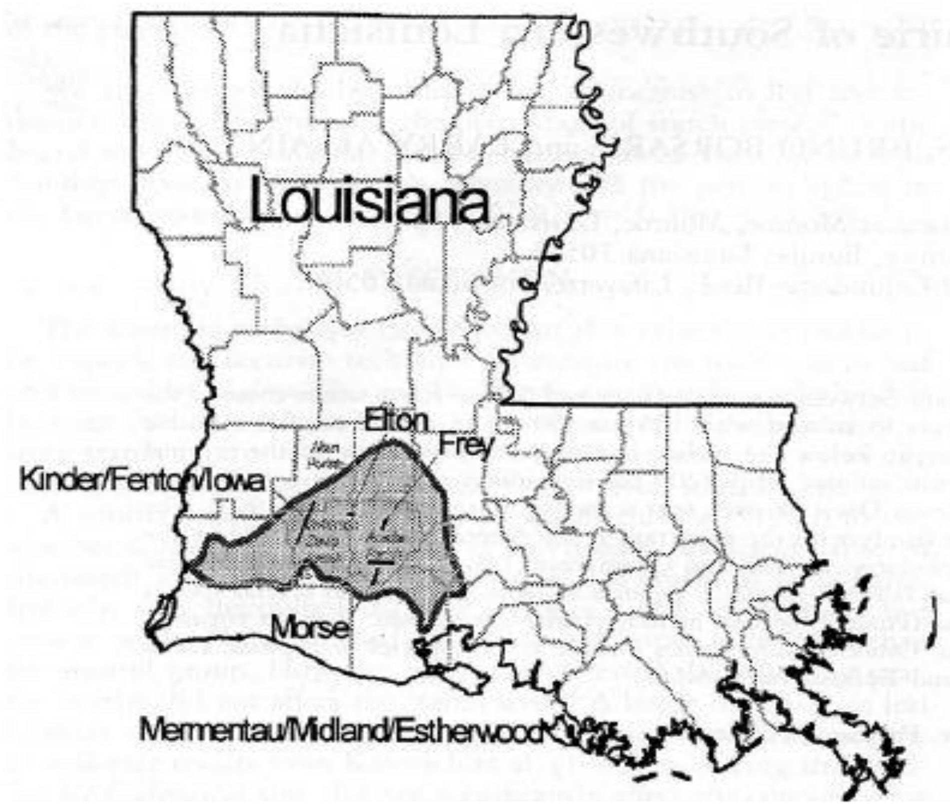
1 May 2008

9 May 2008

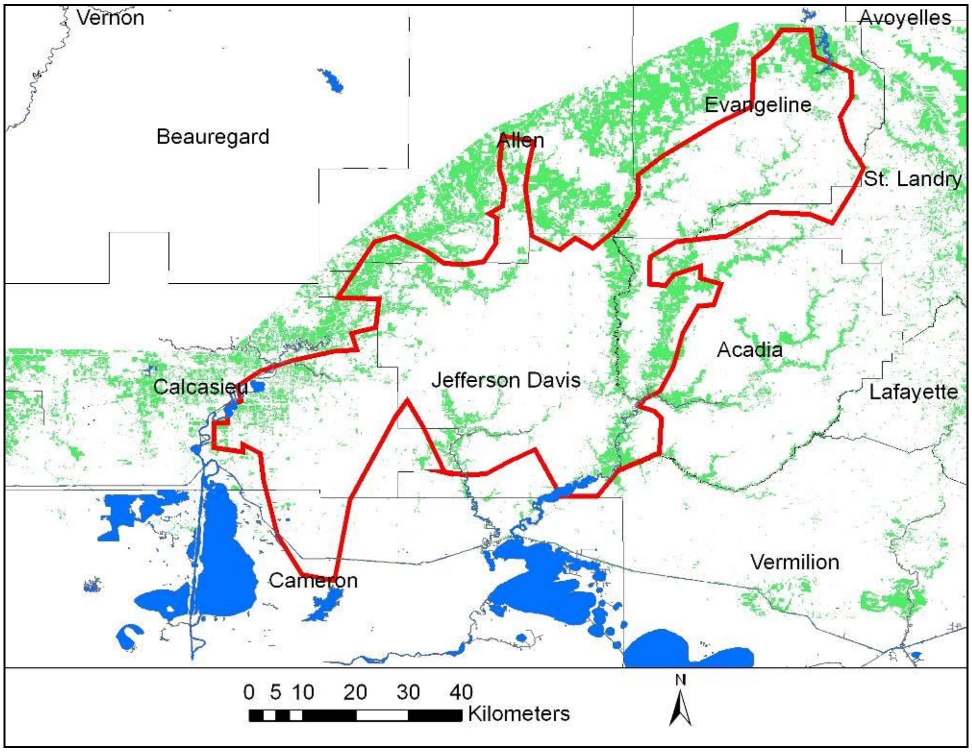
13 May 2008

22 May 2008

APPENDIX F: FORMER RANGE OF COASTAL PRAIRIE IN SOUTHWESTERN LOUISIANA (ALLEN ET AL. 2001)



APPENDIX G: MAP OF PROPOSED NRCS PRAIRIE RESTORATION AREA.



APPENDIX H: MEAN AND STANDARD DEVIATIONS OF ALL LANDSCAPE VARIABLES AT EACH SCALE, BY HABITAT SUITABILITY ZONE, IN 2008 AND 2009.

	2008					2009				
	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5
RICE0	0.52 (±0.28)	0.49 (±0.33)	0.56 (±0.27)	0.52 (±0.20)	0.55 (±0.29)	0.46 (±0.33)	0.49 (±0.26)	0.47 (±0.32)	0.51 (±0.25)	0.58 (±0.27)
RICE10	0.36 (±0.17)	0.34 (±0.20)	0.44 (±0.16)	0.38 (±0.16)	0.46 (±0.19)	0.33 (±0.14)	0.28 (±0.12)	0.30 (±0.18)	0.32 (±0.15)	0.38 (±0.11)
RICE15	0.30 (±0.14)	0.30 (±0.19)	0.39 (±0.13)	0.36 (±0.17)	0.43 (±0.15)	0.28 (±0.13)	0.21 (±0.11)	0.26 (±0.17)	0.29 (±0.17)	0.37 (±0.12)
RICE20	0.25 (±0.11)	0.26 (±0.15)	0.35 (±0.12)	0.35 (±0.15)	0.41 (±0.15)	0.23 (±0.13)	0.17 (±0.10)	0.24 (±0.14)	0.27 (±0.16)	0.34 (±0.14)
RICE25	0.21 (±0.08)	0.23 (±0.14)	0.33 (±0.12)	0.34 (±0.15)	0.40 (±0.15)	0.20 (±0.12)	0.16 (±0.10)	0.23 (±0.12)	0.26 (±0.14)	0.33 (±0.14)
RICE30	0.19 (±0.08)	0.21 (±0.12)	0.30 (±0.13)	0.32 (±0.14)	0.40 (±0.15)	0.19 (±0.10)	0.15 (±0.10)	0.22 (±0.12)	0.26 (±0.12)	0.32 (±0.14)
FOR0	0.05 (±0.13)	0.06 (±0.15)	0.01 (±0.04)	0 (±0)	0.01 (±0.02)	0.07 (±0.18)	0.06 (±0.15)	0 (±0)	0 (±0)	0 (±0)
FOR10	0.07 (±0.08)	0.08 (±0.11)	0.01 (±0.02)	0.01 (±0.02)	0.01 (±0.12)	0.08 (±0.09)	0.06 (±0.10)	0.01 (±0.02)	0.01 (±0.02)	0.00 (±0.01)
FOR15	0.12 (±0.09)	0.10 (±0.11)	0.01 (±0.01)	0.01 (±0.03)	0.01 (±0.02)	0.13 (±0.10)	0.08 (±0.10)	0.03 (±0.04)	0.01 (±0.01)	0.00 (±0.00)
FOR20	0.16 (±0.09)	0.13 (±0.12)	0.01 (±0.01)	0.03 (±0.05)	0.01 (±0.01)	0.20 (±0.10)	0.11 (±0.11)	0.03 (±0.04)	0.03 (±0.04)	0.00 (±0.00)
FOR25	0.21 (±0.09)	0.14 (±0.12)	0.02 (±0.02)	0.03 (±0.05)	0.01 (±0.02)	0.24 (±0.08)	0.14 (±0.11)	0.03 (±0.04)	0.04 (±0.06)	0.01 (±0.01)
FOR30	0.24 (±0.10)	0.15 (±0.13)	0.03 (±0.04)	0.03 (±0.05)	0.01 (±0.02)	0.28 (±0.08)	0.16 (±0.12)	0.04 (±0.04)	0.04 (±0.06)	0.01 (±0.02)

APPENDIX H: CONTINUED

	2008					2009				
	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5
DEVEL0	0.03 (±0.08)	0.00 (±0.00)	0.02 (±0.03)	0.03 (±0.06)	0.02 (±0.03)	0.03 (±0.11)	0.00 (±0.01)	0.02 (±004)	0.03 (±0.04)	0.01 (±0.02)
DEVEL10	0.04 (±0.03)	0.06 (±0.09)	0.05 (±0.04)	0.03 (±0.02)	0.04 (±0.03)	0.04 (±0.03)	0.03 (±0.02)	0.05 (±0.05)	0.03 (±0.02)	0.03 (±0.02)
DEVEL15	0.04 (±0.02)	0.06 (±0.09)	0.05 (±0.06)	0.03 (±0.02)	0.03 (±0.03)	0.04 (±0.02)	0.03 (±0.03)	0.06 (±0.06)	0.03 (±0.01)	0.03 (±0.02)
DEVEL20	0.05 (±0.03)	0.06 (±0.07)	0.06 (±0.06)	0.03 (±0.02)	0.04 (±0.02)	0.04 (±0.03)	0.04 (±0.03)	0.06 (±0.06)	0.03 (±0.01)	0.03 (±0.02)
DEVEL25	0.05 (±0.04)	0.06 (±0.07)	0.06 (±0.06)	0.03 (±0.02)	0.04 (±0.02)	0.05 (±0.03)	0.04 (±0.04)	0.06 (±0.05)	0.03 (±0.01)	0.04 (±0.02)
DEVEL30	0.05 (±0.04)	0.07 (±0.07)	0.06 (±0.05)	0.04 (±0.03)	0.04 (±0.02)	0.05 (±0.04)	0.04 (±0.05)	0.06 (±0.05)	0.03 (±0.02)	0.04 (±0.02)
NRC0	0.11 (±0.18)	0.05 (±0.13)	0.08 (±0.17)	0.07 (±0.15)	0.09 (±0.20)	0.02 (±0.07)	0.02 (±0.05)	0.09 (±0.18)	0 (±0)	0.04 (±0.09)
NRC10	0.12 (±0.13)	0.05 (±0.10)	0.06 (±0.08)	0.08 (±0.09)	0.08 (±0.09)	0.03 (±0.05)	0.02 (±0.05)	0.08 (±0.13)	0.03 (±0.06)	0.04 (±0.07)
NRC15	0.10 (±0.11)	0.05 (±0.09)	0.08 (±0.08)	0.09 (±0.10)	0.10 (±0.09)	0.05 (±0.06)	0.02 (±0.04)	0.07 (±0.11)	0.06 (±0.10)	0.04 (±0.06)
NRC20	0.09 (±0.09)	0.06 (±0.09)	0.09 (±0.08)	0.08 (±0.08)	0.10 (±0.08)	0.05 (±0..06)	0.01 (±0.03)	0.07 (±0.10)	0.07 (±0.12)	0.05 (±0.06)
NRC25	0.09 (±0.09)	0.06 (±0.09)	0.09 (±0.08)	0.08 (±0.07)	0.10 (±0.07)	0.04 (±0.05)	0.02 (±0.03)	0.06 (±0.07)	0.07 (±0.12)	0.05 (±0.06)
NRC30	0.08 (±0.08)	0.06 (±0.09)	0.08 (±0.07)	0.08 (±0.07)	0.10 (±0.06)	0.04 (±0.06)	0.02 (±0.03)	0.07 (±0.08)	0.07 (±0.11)	0.05 (±0.05)

APPENDIX H: CONTINUED

	2008					2009				
	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5	HSZ1	HSZ2	HSZ3	HSZ4	HSZ5
CRAW0	0.01 (±0.04)	0.09 (±0.16)	0.10 (±0.24)	0.11 (±0.22)	0.10 (±0.25)	0.04 (±0.14)	0.09 (±0.15)	0.08 (±0.21)	0.04 (±0.11)	0.07 (±0.15)
CRAW10	0.05 (±0.11)	0.07 (±0.10)	0.10 (±0.14)	0.08 (±0.10)	0.11 (±0.13)	0.07 (±0.12)	0.14 (±0.13)	0.11 (±0.15)	0.08 (±0.08)	0.13 (±0.13)
CRAW15	0.07 (±0.13)	0.06 (±0.08)	0.09 (±0.10)	0.07 (±0.08)	0.11 (±0.10)	0.06 (±0.08)	0.11 (±0.11)	0.10 (±0.11)	0.07 (±0.06)	0.14 (±0.12)
CRAW20	0.08 (±0.10)	0.05 (±0.07)	0.09 (±0.08)	0.06 (±0.06)	0.11 (±0.08)	0.06 (±0.07)	0.10 (±0.09)	0.09 (±0.10)	0.07 (±0.05)	0.15 (±0.11)
CRAW25	0.07 (±0.08)	0.04 (±0.06)	0.08 (±0.08)	0.06 (±0.06)	0.10 (±0.08)	0.06 (±0.06)	0.08 (±0.08)	0.09 (±0.08)	0.07 (±0.05)	0.15 (±0.10)
CRAW30	0.07 (±0.07)	0.03 (±0.06)	0.07 (±0.08)	0.05 (±0.05)	0.10 (±0.07)	0.06 (±0.05)	0.08 (±0.08)	0.08 (±0.07)	0.07 (±0.06)	0.14 (±0.10)
FALL0	0.25 (±0.24)	0.24 (±0.23)	0.18 (±0.25)	0.23 (±0.26)	0.20 (±0.26)	0.36 (±0.34)	0.30 (±0.20)	0.31 (±0.28)	0.35 (±0.26)	0.28 (±0.29)
FALL10	0.31 (±0.20)	0.33 (±0.23)	0.28 (±0.16)	0.39 (±0.20)	0.27 (±0.18)	0.40 (±0.13)	0.42 (±0.12)	0.42 (±0.21)	0.49 (±0.20)	0.40 (±0.20)
FALL15	.032 (±0.17)	0.34 (±0.20)	0.29 (±0.14)	0.40 (±0.18)	0.30 (±0.19)	0.40 (±0.12)	0.47 (±0.14)	0.45 (±0.20)	0.49 (±0.23)	0.40 (±0.20)
FALL20	0.32 (±0.15)	0.34 (±0.17)	0.31 (±0.14)	0.40 (±0.16)	0.32 (±0.20)	0.38 (±0.12)	0.48 (±0.15)	0.47 (±0.17)	0.49 (±0.22)	0.40 (±0.20)
FALL25	.032 (±0.12)	0.34 (±0.15)	0.32 (±0.13)	0.40 (±0.16)	0.32 (±0.20)	0.36 (±0.12)	0.47 (±0.14)	0.48 (±0.15)	0.48 (±0.20)	0.41 (±0.20)
FALL30	0.30 (±0.10)	0.34 (±0.13)	0.33 (±0.14)	0.41 (±0.16)	0.32 (±0.20)	0.34 (±0.11)	0.44 (±0.13)	0.48 (±0.14)	0.48 (±0.19)	0.42 (±0.20)

APPENDIX I. 2008 MEAN ABUNDANCE OF EACH SPECIES AND NUMBER OF SITES OBSERVED AT BY SURVEY PERIOD (Mean = Mean abundance of each species, N = Number of sites each species was observed at in a survey period).

SPECIES	SP1		SP2		SP3		SP4		SP5		SP6		SP7		SP8	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
YELL	28.20	5	43.27	11	4.86	7	16.56	23	9.91	23	4.00	1	1.5	2	0	0
BNST	13.00	1	40.00	2	2.00	2	3.00	7	2.57	7	4.42	12	3.83	18	2.88	8
KILL	2.91	11	1.88	8	1.54	13	1.88	8	1.43	7	1.80	5	1.00	4	1.50	4
LEYE	54.38	8	49.09	11	28.11	18	9.22	23	4.67	9	4.00	1	1.33	3	0	0
PEEP	15.00	1	38.50	4	6.00	1	68.5	2	3.00	1	20.00	3	71.20	5	3.00	1
AGBBPL	30.50	4	31.33	3	2.00	4	4.00	5	6.20	5	6.00	2	15.50	4	0	0
PESA	10.50	2	15.25	4	55.00	2	18.00	3	1.00	1	2.00	1	23.67	3	7.00	1
DUNL	143.00	1	4.00	1	2.50	2	55.25	4	2.00	1	41.00	1	14.00	1	0	0
GRYE	6.80	5	13.75	4	3.00	10	1.57	7	3.00	1	0	0	1.00	1	0	0
LESA	65.00	3	6.00	1	23.00	5	34.00	3	0	0	5.00	1	0	0	0	0
DOWI	144.60	5	127.14	7	43.67	3	22.14	7	376.67	3	16.00	1	1.00	1	0	0
GODWIT	0	0	0	0	0	0	6.00	1	1.00	1	0	0	0	0	0	0
STSA	0	0	0	0	0	0	93.67	3	20.50	2	33.00	1	11.50	2	0	0
UNK	0	0	2.00	1	15.00	1	4.00	1	4.00	1	27.50	2	5.50	2	0	0
SEPL	0	0	6.00	1	1.50	2	21.75	4	5.00	3	7.00	1	3.50	2	0	0
BBPL	0	0	0	0	0	0	0	0	2.00	1	0	0	0	0	0	0
WISN	1.50	2	0	0	1.00	1	0	0	0	0	0	0	0	0	0	0
BBSA	0	0	1.00	1	3.00	1	0	0	0	0	22.00	1	9.00	2	0	0
WESA	5.00	1	0	0	7.00	1	100	1	0	0	7.00	1	7.00	1	0	0
SESA	0	0	0	0	0	0	234.00	2	0	0	0	0	0	0	0	0
HUGO	0	0	0	0	0	0	2.00	1	0	0	0	0	0	0	0	0
WIPH	0	0	0	0	0	0	1.00	1	0	0	0	0	0	0	0	0
RUTU	0	0	0	0	0	0	0	0	0	0	57.00	1	37.00	2	0	0
WHIM	0	0	0	0	0	0	0	0	50.50	2	48.00	1	0	0	0	0
AGPL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UPSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WRSA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX J. 2009 MEAN ABUNDANCE OF EACH SPECIES AND NUMBER OF SITES OBSERVED AT BY SURVEY PERIOD (Mean = Mean abundance of each species, N = Number of sites each species was observed at in a survey period).

SPECIES	SP1		SP2		SP3		SP4		SP5		SP6		SP7		SP8	
	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N
YELL	0	0	21.86	7	11.82	11	33.38	13	120.73	11	6.75	4	0	0	0	0
BNST	3.50	2	3.80	5	8.25	4	2.25	4	6.71	7	3.20	5	2.33	3	2.25	8
KILL	3.00	5	2.00	3	1.50	8	1.69	13	1.60	5	1.00	3	1.50	4	1.00	3
LEYE	7.33	3	10.33	6	12.33	21	21.00	24	40.77	22	3.00	2	0	0	0	0
PEEP	0	0	9.00	3	41.67	3	141.33	3	203.80	5	12.00	3	0	0	0	0
AGBBPL	0	0	116.00	1	5.00	1	7.67	3	0	0	0	0	0	0	0	0
PESA	0	0	18.00	2	12.25	8	18.89	9	7.13	8	6.00	2	0	0	0	0
DUNL	0	0	1.00	1	2.50	2	8.33	3	5.17	6	24.50	2	0	0	0	0
GRYE	1.00	2	13.50	2	3.00	10	2.36	11	2.00	15	1.33	6	0	0	0	0
LESA	50.00	2	0	0	23.00	5	30.67	3	128.50	2	2.00	1	0	0	0	0
DOWI	9.00	1	53.00	3	43.67	3	172.00	11	92.89	9	2.00	1	0	0	0	0
GODWIT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STSA	11.00	1	23.00	1	0	0	98.67	6	109.00	5	24.00	2	0	0	0	0
UNK	0	0	100.00	1	15.00	1	165.00	4	64.00	4	6.00	2	0	0	0	0
SEPL	0	0	1.00	1	1.50	2	4.75	4	29.67	3	0	0	0	0	0	0
BBPL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WISN	0	0	0	0	1.00	1	0	0	0	0	0	0	0	0	0	0
BBSA	0	0	0	0	3.00	1	2.00	1	4.00	1	0	0	0	0	0	0
WESA	0	0	0	0	7.00	1	0	0	3.00	1	0	0	0	0	0	0
SESA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HUGO	0	0	0	0	1.00	1	0	0	3.00	1	0	0	0	0	0	0
WIPH	0	0	0	0	0	0	0	0	3.00	1	0	0	0	0	0	0
RUTU	0	0	0	0	0	0	0	0	2.00	1	0	0	0	0	0	0
WHIM	0	0	0	0	1.00	1	0	0	0	0	0	0	0	0	0	0
AGPL	2.00	1	8.00	3	0	0	4.00	2	1.50	2	0	0	0	0	0	0
UPSA	0	0	0	0	0	0	2.50	2	0	0	0	0	0	0	0	0
WRSA	0	0	0	0	0	0	0	0	8.00	1	0	0	0	0	0	0

APPENDIX K. MEAN ABUNDANCE AND DENSITY (BIRDS/HA) OF SHOREBIRDS BY SURVEY POINT AND YEAR, WITH RICE AND FOREST DENSITY WITHIN 3 KM AND HABITAT SUITABILITY ZONE.

Rice Field	Year	HSZ	Mean Abundance	Mean Density	RICE30	FOR30
3	2008	1	0.63	0.35	0.19	0.30
4	2008	4	5.57	0.99	0.48	0.02
5	2008	1	2.00	0.73	0.20	0.23
8	2008	4	37.75	6.90	0.46	0.09
9	2008	3	35.25	10.02	0.20	0.02
11	2008	2	25.00	4.85	0.41	0.07
13	2008	4	13.63	2.44	0.02	0.00
14	2008	1	0	0	0.19	0.42
16	2008	4	1.38	0.43	0.39	0.02
19	2008	5	0.38	1.04	0.11	0.04
20	2008	3	8.14	0.80	0.39	0.03
22	2008	5	9.75	1.33	0.44	0.01
23	2008	3	1.86	0.42	0.17	0.01
26	2008	3	0.25	0.02	0.59	0.06
28	2008	5	27.75	2.32	0.56	0
31	2008	2	1.38	0.85	0.09	0.07
32	2008	5	50.56	14.19	0.44	0.04
35	2008	3	1.63	0.11	0.31	0
36	2008	4	3.38	1.90	0.46	0.01
38	2008	2	2.25	0.47	0.41	0.08
40	2008	3	32.125	9.20	0.50	0.01
42	2008	5	96.38	9.24	0.35	0
43	2008	4	0	0	0.39	0.04
45	2008	5	3.43	0.97	0.35	0.01
46	2008	1	0.14	0.01	0.32	0.24
49	2008	3	0.13	0.05	0.30	0.01
53	2008	2	1.63	1.89	0.20	0.19
54	2008	3	110.43	48.74	0.32	0
56	2008	4	174.71	32.35	0.04	0.04
58	2008	1	0	0	0.15	0.27
60	2008	5	0.88	0.23	0.25	0
61	2008	1	0.38	0.07	0.16	0.26
65	2008	5	10.75	1.96	0.45	0
66	2008	5	33.25	21.76	0.57	0.01
67	2008	3	54.13	5.80	0.26	0.01
70	2008	2	0	0	0.07	0.42
71	2008	3	6.50	0.87	0.29	0.02
72	2008	4	17.88	1.05	0.27	0.01

APPENDIX K: CONTINUED

Rice Field	Year	HSZ	Mean Abundance	Mean Density	RICE30	FOR30
75	2008	4	26.75	1.61	0.50	0.00
76	2008	1	1.14	1.18	0.19	0.08
77	2008	2	12.63	5.94	0.23	0.16
88	2008	2	24.25	1.61	0.06	0.03
91	2008	1	1.25	0.06	0.14	0.34
93	2008	1	0	0	0.38	0.12
98	2008	4	1.14	0.32	0.40	0.03
103	2008	4	0.50	0.17	0.33	0.01
104	2008	4	2.75	2.20	0.21	0.20
110	2008	5	0	0	0.67	0
111	2008	5	18.88	2.86	0.52	0
114	2008	5	3.71	1.42	0.38	0
116	2008	5	20.43	3.13	0.34	0.01
117	2008	5	0.13	0.02	0.34	0.08
120	2008	5	1.88	0.25	0.10	0
121	2008	1	0	0	0.23	0.34
131	2008	5	54.63	23.46	0.50	0.08
133	2008	1	0	0	0.28	0.22
134	2008	4	0	0	0.40	0
135	2008	3	4.25	1.63	0.21	0.12
138	2008	2	0	0	0.17	0.04
139	2008	3	65.00	20.13	0.14	0.05
141	2008	2	18.17	14.22	0.29	0.20
142	2008	4	183.67	29.84	0.28	0
143	2008	5	10.00	3.20	0.48	0
144	2008	1	0	0	0.12	0.36
145	2008	2	0	0	0.23	0.14
147	2008	1	0	0	0.11	0.03
148	2008	3	1.29	0.94	0.45	0.06
149	2008	5	0	0	0.34	0.00
150	2008	1	0	0	0.23	0.13
151	2008	1	3.14	0.47	0.17	0.28
152	2008	1	1.14	0.11	0.05	0.16
154	2008	4	1.29	0.85	0.43	0
155	2008	4	0	0	0.27	0.01
156	2008	5	1.17	0.18	0.48	0
157	2008	2	0.40	0.09	0.33	0.08
158	2008	1	0	0	0.19	0.23
159	2008	2	17.00	2.97	0.08	0.37
160	2008	4	0.83	0.49	0.40	0.00
161	2008	3	3.33	0.77	0.33	0.11

APPENDIX K: CONTINUED

Rice Field	Year	HSZ	Mean Abundance	Mean Density	RICE30	FOR30
162	2008	4	26.83	15.83	0.10	0
163	2008	2	0.50	0.21	0.21	0
164	2008	3	3.00	1.63	0.31	0.00
165	2008	4	1.50	1.17	0.32	0.04
166	2008	3	0	0	0.14	0.03
167	2008	2	2.00	0.15	0.05	0.18
168	2008	2	0.75	0.06	0.41	0.37
170	2008	1	0	0	0.13	0.35
171	2008	4	0	0	0.20	0
172	2008	3	0.33	0.05	0.25	0.00
173	2008	5	343.75	40.91	0.20	0.00
174	2008	4	0	0	0.41	0.01
175	2008	3	0	0	0.14	0
176	2008	3	1.50	1.98	0.15	0.00
177	2008	5	4.50	1.36	0.35	0.02
22	2009	5	30.88	4.23	0.15	0.01
26	2009	3	1.00	0.10	0.45	0.06
32	2009	5	0.25	0.07	0.47	0.03
70	2009	2	4.14	0.76	0.03	0.46
76	2009	1	1.86	1.91	0.17	0.18
88	2009	2	14.5	0.96	0.05	0.07
98	2009	4	0.86	0.24	0.40	0.03
133	2009	1	0	0	0.21	0.27
134	2009	4	0.13	0.15	0.37	0.04
143	2009	5	29.63	9.47	0.46	0
144	2009	1	0.50	0.29	0.12	0.38
162	2009	4	0.50	0.29	0.09	0.02
171	2009	4	135.38	29.50	0.27	0.06
201	2009	3	93.86	36.57	0.30	0.07
202	2009	4	0	0	0.41	0.06
203	2009	5	1.29	0.36	0.49	0.09
204	2009	2	6.13	1.08	0.13	0.08
205	2009	5	0	0	0.42	0.01
206	2009	3	37.71	10.97	0.34	0
207	2009	3	7.00	3.32	0.27	0.00
208	2009	2	3.75	0.53	0.33	0.21
209	2009	1	0	0	0.20	0.13
210	2009	3	118.50	22.27	0.09	0.01
211	2009	2	12.86	3.30	0.21	0.08
212	2009	3	4.43	1.26	0.42	0.01
213	2009	3	67.00	19.05	0.29	0.02

APPENDIX K: CONTINUED

Rice Field	Year	HSZ	Mean Abundance	Mean Density	RICE30	FOR30
215	2009	5	13.25	4.64	0.24	0.00
216	2009	5	0.86	0.17	0.37	0.01
217	2009	2	5.75	3.81	0.13	0.18
218	2009	3	0	0	0.12	0.01
219	2009	4	48.00	10.11	0.09	0.00
220	2009	4	0.50	0.08	0.19	0.02
222	2009	5	0.63	0.11	0.40	0.00
223	2009	4	3.25	0.92	0.18	0.01
224	2009	3	178.86	15.59	0.20	0.10
225	2009	4	24.00	10.72	0.46	0.00
226	2009	3	27.29	1.74	0.07	0.02
227	2009	4	0	0	0.10	0.04
228	2009	5	1.71	0.44	0.59	0.01
229	2009	5	5.20	1.86	0.06	0.35
230	2009	1	4.57	6.38	0.17	0.27
231	2009	5	0.67	0.16	0.31	0.02
232	2009	5	0	0	0.34	0.05
233	2009	5	0	0	0.30	0
234	2009	3	17.50	8.84	0.34	0.13
235	2009	2	5.33	5.63	0.13	0.09
237	2009	1	0	0	0.19	0.20
238	2009	3	1.71	0.33	0.17	0.03
239	2009	3	0.57	0.23	0.21	0.00
240	2009	3	1.50	0.60	0.31	0.12
241	2009	3	0	0	0.10	0.02
242	2009	1	0	0	0.20	0.32
243	2009	4	13.00	2.04	0.16	0.01
244	2009	5	5.29	2.95	0.12	0
245	2009	5	20.57	8.66	0.32	0.02
246	2009	5	0.86	0.30	0.14	0
247	2009	3	3.71	1.20	0.08	0.01
248	2009	2	297.33	25.19	0.20	0.10
249	2009	5	0	0	0.26	0.01
250	2009	4	0.17	0.21	0.24	0.02
251	2009	1	2.29	0.34	0.01	0.19
252	2009	1	16.17	9.87	0.12	0.36
253	2009	1	3.00	1.37	0.13	0.29
254	2009	1	0	0	0.19	0.36
255	2009	2	0	0	0.14	0.24
256	2009	3	53.50	3.97	0.11	0.03
258	2009	1	0	0	0.17	0.23

APPENDIX K: CONTINUED

Rice Field	Year	HSZ	Mean Abundance	Mean Density	RICE30	FOR30
259	2009	3	4.71	0.83	0.33	0.12
260	2009	1	20.00	8.01	0.55	0.22
261	2009	4	0	0	0.22	0.25
262	2009	4	3.57	1.13	0.26	0.03
263	2009	4	6.67	8.78	0.37	0.00
264	2009	2	5.83	0.87	0.32	0.18
265	2009	2	0.50	0.24	0.22	0.04
266	2009	1	2.00	0.61	0.21	0.37
267	2009	5	109.86	14.76	0.05	0
268	2009	3	0.50	0.11	0.10	0.01
269	2009	2	0	0	0.05	0.07
270	2009	4	8.17	2.52	0.31	0.04
271	2009	1	4.14	0.59	0.16	0.32
272	2009	5	0	0	0.29	0
273	2009	5	69.67	7.88	0.36	0.00
274	2009	3	0.80	0.43	0.16	0.04
275	2009	1	0	0	0.23	0.42
276	2009	5	324.00	75.16	0.25	0

APPENDIX L. COORDINATES OF ALL SURVEYED RICE FIELDS (LATITUDE AND LONGITUDE) WITH YEARS SURVEYED

Rice Field	Years Surveyed	Latitude	Longitude
3	2008	30.3841	-92.8276
4	2008	30.0853	-92.7229
5	2008	30.4488	-92.4066
8	2008	30.1809	-92.7582
9	2008	30.4534	-92.6818
11	2008	30.0023	-92.7127
13	2008	30.1719	-92.9941
14	2008	30.4157	-92.9029
16	2008	30.3051	-92.7915
19	2008	30.1222	-92.2342
20	2008	30.6405	-92.4317
22	2008, 2009	29.9315	-92.3252
23	2008	30.0568	-92.1608
26	2008, 2009	30.0230	-92.4271
28	2008	29.9793	-92.4780
31	2008	29.9990	-92.7920
32	2008, 2009	30.3422	-92.4472
35	2008	30.0161	-92.9127
36	2008	29.9772	-92.3633
38	2008	30.1239	-92.8548
40	2008	30.1694	-92.6868
42	2008	30.3208	-92.8587
43	2008	30.2604	-92.7092
45	2008	30.2604	-92.7403
46	2008	29.8870	-92.1809
49	2008	30.6183	-92.2617
53	2008	30.2172	-92.8943
54	2008	30.7050	-92.3965
56	2008	30.1398	-93.1372
58	2008	30.1701	-92.6386
60	2008	29.9697	-92.5799
61	2008	30.3874	-92.5687
65	2008	30.0506	-92.2794
66	2008	30.3932	-92.4149
67	2008	30.0964	-92.4248
70	2008, 2009	30.4233	-92.4897
71	2008	29.8559	-92.2652
72	2008	30.0319	-93.0731
75	2008	29.9342	-92.2268
76	2008, 2009	30.7300	-92.2582
77	2008	30.4879	-92.4544
88	2008, 2009	30.4646	-92.1451

APPENDIX L: CONTINUED

Rice Field	Years Surveyed	Latitude	Longitude
91	2008	30.5785	-92.6225
93	2008	30.5893	-92.3895
98	2008, 2009	30.1178	-92.7752
103	2008	30.0205	-92.6387
104	2008	30.1927	-92.8422
110	2008	30.1551	-92.3966
111	2008	30.1399	-92.4785
114	2008	30.3492	-92.3701
116	2008	29.9836	-92.3079
117	2008	30.1784	-92.2257
120	2008	30.0829	-93.1438
121	2008	30.5805	-92.5453
131	2008	30.3486	-92.3259
133	2008, 2009	30.4939	-92.7694
134	2008, 2009	30.5830	-92.4668
135	2008	30.2860	-92.2980
138	2008	30.5378	-92.1691
139	2008	30.4639	-92.2841
141	2008	30.6618	-92.5004
142	2008	30.6568	-92.3427
143	2008, 2009	30.3639	-92.7489
144	2008, 2009	30.4073	-92.6462
145	2008	30.5004	-92.5259
147	2008	30.3997	-92.2530
148	2008	30.2826	-92.4128
149	2008	30.2755	-92.4594
150	2008	30.2522	-92.5168
151	2008	29.8345	-92.1577
152	2008	29.8745	-92.0883
154	2008	30.1832	-92.2934
155	2008	30.0499	-92.3498
156	2008	29.9496	-92.4244
157	2008	30.0595	-92.5942
158	2008	30.1358	-92.5903
159	2008	30.2145	-92.4739
160	2008	30.4044	-92.3466
161	2008	30.3398	-92.2505
162	2008, 2009	30.3357	-92.6828
163	2008	30.4592	-92.8442
164	2008	30.2601	-92.9307
165	2008	30.3355	-92.9313
166	2008	30.4663	-92.2266
167	2008	29.9131	-92.0749
168	2008	30.3787	-92.9760

APPENDIX L: CONTINUED

Rice Field	Years Surveyed	Latitude	Longitude
170	2008	30.3329	-92.5178
171	2008, 2009	30.5438	-92.3125
172	2008	30.1708	-92.1640
173	2008	30.0376	-93.0515
174	2008	30.1393	-92.3442
175	2008	30.1136	-92.9873
176	2008	30.0056	-92.2408
177	2008	30.0246	-92.5316
201	2009	30.1767	-92.2236
202	2009	30.1370	-92.3456
203	2009	30.3494	-92.3246
204	2009	30.4602	-92.2924
205	2009	30.3916	-92.4151
206	2009	30.6274	-92.2733
207	2009	30.6554	-92.3441
208	2009	30.6578	-92.5016
209	2009	30.6175	-92.3888
210	2009	30.0699	-92.1671
211	2009	30.0622	-92.5922
212	2009	30.1709	-92.6884
213	2009	30.4534	-92.6818
215	2009	30.3210	-92.8615
216	2009	30.4194	-92.7397
217	2009	30.2175	-92.8893
218	2009	30.2504	-92.9455
219	2009	31.1732	-92.9946
220	2009	30.0313	-93.0699
222	2009	30.0506	-92.2849
223	2009	29.9774	-92.3656
224	2009	30.0943	-92.4251
225	2009	30.1787	-92.2949
226	2009	30.1432	-92.1734
227	2009	30.0905	-92.2155
228	2009	30.1398	-92.4745
229	2009	30.2161	-92.4747
230	2009	30.2606	-92.5157
231	2009	30.2758	-92.4635
232	2009	30.2833	-92.4143
233	2009	30.3492	-92.3726
234	2009	30.3407	-92.2512
235	2009	30.3952	-92.2436
237	2009	30.5271	-92.4063
238	2009	30.6424	-92.4310
239	2009	30.6961	-92.3768

APPENDIX L: CONTINUED

Rice Field	Years Surveyed	Latitude	Longitude
240	2009	30.2890	-92.2950
241	2009	30.0151	-92.2338
242	2009	29.8803	-92.1877
243	2009	29.8881	-92.2592
244	2009	29.9771	-92.4915
245	2009	30.0295	-92.5315
246	2009	29.9740	-92.5814
247	2009	30.0014	-92.3158
248	2009	30.0106	-92.7109
249	2009	29.9786	-92.3098
250	2009	30.0508	-92.3457
251	2009	29.8745	-92.0883
252	2009	30.3331	-92.5188
253	2009	30.3840	-92.5677
254	2009	30.5818	-92.5448
255	2009	30.4824	-92.5267
256	2009	30.4646	-92.2380
258	2009	30.1625	-92.6472
259	2009	30.1804	-92.7560
260	2009	30.1260	-92.8523
261	2009	30.1927	-92.8441
262	2009	30.3354	-92.9269
263	2009	30.3200	-92.7924
264	2009	30.3720	-92.8272
265	2009	30.4382	-92.8402
266	2009	30.3789	-92.9710
267	2009	30.0797	-93.1480
268	2009	30.0130	-92.9125
269	2009	30.0016	-92.7923
270	2009	30.0833	-92.7233
271	2009	30.5729	-92.6242
272	2009	29.9497	-92.4193
273	2009	30.1533	-92.3947
274	2009	30.2613	-92.7108
275	2009	30.1341	-92.5950
276	2009	30.3994	-92.3541

VITA

Rachel Villani was born in October 1984, in Metairie, Louisiana, to Eric and Stephanie Villani. She grew up in the small town of St. Rose and Bush, Louisiana, and graduated from Covington High School in 2003. She received her Bachelor of Science degree in wildlife and fisheries with a concentration in wildlife ecology from Louisiana State University in Baton Rouge, Louisiana, in May 2007. While enrolled at Louisiana State University, Rachel worked as a student worker for the Louisiana Department of Wildlife and Fisheries where she banded songbirds for the Monitoring Avian Productivity and Survivorship (MAPS) stations at Sherburne Wildlife Management Area in Krotz Springs, Louisiana. She was also involved in Henslow's Sparrow research through Louisiana State University for several years while in college. She spent one summer working for the Student Conservation Association and the National Park Service at the St. Croix National Scenic Riverway – Namekagon District in Trego, Wisconsin, where she was involved with exotic plant removal, community outreach, breeding bird surveys, and a dragonfly research project. In the summer of 2007, Rachel began her graduate research in the School of Renewable Natural Resources at Louisiana State University. She completed two research projects during her graduate career, her thesis research and additional research on waterbird use of moist soil units in the Mississippi Alluvial Valley. Rachel will receive her Master of Science degree in wildlife in May 2010.