LIVING ON THE EDGE: AN ASSESSMENT OF THE HABITAT USE OF WATERBIRDS IN ESTUARINE WETLANDS OF BARATARIA BASIN, LA

A Thesis

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by
Brett Ashley Patton
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This is dedicated to the one that enriched my curious mind at a young age with countless hours of perusing hard-bound encyclopedias, assembling impossible jigsaw puzzles, rousing games of Chinese checkers and Scrabble, tickling piano ivories, and observing nature in her backyard. To the one whose passion for life, learning, and family inspire me every day. I dedicate this to the greatest person I know, Marie Anthony (Grandma Toot). Grandma Toot, I hope to make you proud in all that I do and I dedicate this work to you.

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ABSTRACT

The wetlands of Louisiana are losing area at the rapid rate of 42.9 km^2 yr^{-1} and the trend is expected to continue. This combined with expected sea-level rise will likely cause large shifts in vegetation and salinity regimes that will affect the wildlife species reliant on these ecosystems. Waterbirds serve as indicator species of ecosystem health in estuarine wetland habitats; therefore, these species are often the targets of wetland management goals in Louisiana. However, many proposed wetland restoration projects are focused primarily on social impacts with only a few specific waterbird species designated for management. The majority of these waterbird habitat-use studies in Louisiana wetlands have focused on waterfowl species and their abundance in wetland habitats during migration and winter. My overall objective was to compare habitat use of all waterbird taxa in fresh and saline estuarine wetland habitats. Additionally, I examined habitat use at finer spatial scales to assess a possible preference for marsh edge microhabitats when compared to open water and interior emergent vegetation. I also investigated waterbird associations with the environmental parameters of emergent and aquatic species composition, percentage of open water, and salinity. From July 2014 to December 2015, I compared waterbird density and species richness both spatially and temporally to assess habitat use.

I found that species richness differed between fresh and saline habitats depending on the month, with the month of April having the greatest species richness. Waterbird density was greatest among edge microhabitat regardless of salinity type, and birds utilized this habitat up to 15 m from the edge. Density did not vary in open water plots in relation to salinity type. The relationships between environmental variables and species were significant ($p=0.002$) as well as relationships between guilds and environmental variables ($p=0.002$). These data will be useful in attempts to simulate the effects of wetland loss and salinity changes on habitat quality for waterbirds in coastal Louisiana, and will inform habitat restoration and management decisions for optimal waterbird use.

CHAPTER 1: INTRODUCTION

Waterbirds serve a very important role in ecological systems and are often used as indicator species of ecosystem vigor. Waterbirds often quickly respond to changes in their habitat and can provide valuable insights into habitat health and stability (Rajpar and Zakaria 2011). Monitoring waterbird species density, richness, and associations with habitat and environmental variables can help inform management and restoration decisions (Pierce and Gawlik 2010, Rajpar and Zakaria 2011). Thus, waterbirds are often used as a metric for assessing habitat health and restoration success (Pierce and Gawlik 2010). Within the United States, wetlands have been greatly reduced (Dahl 1990) and Louisiana in particular has experienced the greatest loss (Field et al. 1988).

Louisiana contains the majority of coastal saline and freshwater marshes in the conterminous United States with an estimated 39% and 44% respectively (Field et al. 1988); however, the wetlands of Louisiana are losing area at a rate of 42.9 km^2 yr^{-1} and the trend is expected to continue (Couvillion et al. 2011). Combined with expected sea-level rise, there will likely be large shifts in vegetation and salinity regimes (Couvillion et al. 2013, Visser et al. 2013) that affect wildlife species.

Over 400 species of birds use habitat in Louisiana with many using wetland habitat during some part of the year (Gosselink et al. 1998). Waterfowl in particular have been the focus of much of the research in Louisiana wetlands (Palmisano 1973, Lowey 1974, Esters 1986, Chabreck et al. 1989). Historically, Louisiana wetlands provided a plethora of habitat for waterfowl but with continued wetland loss, populations within Louisiana may decline due to increased competition for waning resources (Chabreck et al. 1989). Additionally, there are 34 waterbird species—including wading birds, shorebirds, and passerines—of conservation concern within Louisiana (USFWS 2008, Rosenberg et al. 2014).

The loss of wetland habitat in Louisiana has triggered the state to propose restoration projects to curb wetland loss, most notably through the Coastal Master Plan, last revised in 2012 (CPRA 2012). However, these restoration projects focus primarily on the social impacts in Louisiana and only consider the habitat needs for a few key waterbirds species: Mottled Duck (*Anas fulvigula*), Green-winged Teal (*Anas crecca*), Roseate Spoonbill (*Platalea ajaja*), Gadwall (*Anas strepera*), and the collectively grouped Neotropical Migrant Songbirds (CPRA 2012). The habitat suitability indices for these birds do not always include all the salinity regimes (CPRA 2012), and ignore the potentially valuable role of edge habitat. This interface between emergent vegetation and open water (Browder et al. 1989, Rozas and Minellos 2001) has been shown to be highly productive in fisheries (Baltz and Rakocinski 1993). In 1993, Baltz and Rakocinski found that 97% of fishes in Barataria Basin, LA were concentrated near the marsh edge (0-1.25 m). Habitat quality for the American Alligator (*Alligator mississippiensis*) and Northern River Otter (*Lutra canadensis)* is also assumed to increase with edge perimeter habitat, up to 10 meters from the emergent vegetation, but positive edge association in waterbirds are ignored in most habitat restoration models (CPRA 2012).

The edge is often preferred by many species of waterbirds (Weller and Spatcher 1965, O'Connell and Nyman 2011, and Sullivan 2015). Weller and Spatcher (1965) found the edge to be significant for breeding waterbirds species in the mid-western pothole region of the United States. O'Connell and Nyman (2011) and Sullivan (2015) examined the difference in bird densities and richness between open water and edge, and also compared natural and restored edges in Louisiana. However, they did not assess the waterbird use in interior emergent wetlands, which precludes using their data to estimate the effects of wetland loss on waterbirds. Through continued degradation of estuarine wetlands and loss of emergent wetlands, marsh vegetation communities become fragmented and in initial stages of degradation may provide more edge (Browder et al. 1985) and transiently provide preferred habitat for species that use shallow open water communities for foraging (Nyman et al. 2013). However, in the latter stages of wetland conversion these wetlands reach a point of no return, and become permanently inundated to deep open water communities (Browder et al. 1985). If wetland degradation continues, it is likely that shallow open water areas will deepen over time and thus reduce habitat availability for waterbirds dependent on shallow water (Bancroft et al. 2002, Lantz et al. 2010, Rajpar et al. 2011).

As wetland loss occurs, waterbirds may also use shallow open water communities dominated by submerged aquatic vegetation (SAV), but it is not well known whether SAV provides benefits comparable to emergent marsh edge habitat (Bancroft et al. 2002). Waterbirds tend to select habitat based on water depth and SAV density, because these factors increase the density of nekton (Kanouse et al. 2006) and may also affect the vulnerability of aquatic prey (Lantz et al. 2010). Therefore, submerged aquatic vegetation likely provides beneficial foraging habitat for waterbirds (Ester 1986, Rajpar 2011). SAV is limited by a water depth threshold, further reinforcing the concept that these deepening open water communities may only remain desirable habitat for waterbirds for short periods of time (Bancroft et al. 2002).

Most bird species tend to select habitat progressively from coarser to finer spatial scales (Johnson 1980, Battin 2006). While some fine scale habitat factors that influence waterbirds—such as water level—have been well studied, the importance of other factors such as vegetative structure, is only known in specific groups of waterbirds, based on short term studies during peak use (Bancroft et al. 2002, Lantz et al. 2010, Rajpar et al. 2011, Zakaria 2013). Focusing study efforts on fine spatial scales, across all seasons, may provide further insight into waterbird habitat use across changing landscapes throughout the year (Pickens and King 2013). Additionally, examining waterbird use in a hierarchical manner can help determine why some birds choose certain habitats but avoid others.

Understanding the mechanisms by which wetland ecosystem drivers such as salinity, water depth, and vegetation richness and structure affect waterbird habitat use is essential for understanding why waterbirds select some habitats and avoid others. Palmisano (1973) found that waterfowl prefer freshwater habitats to saline, yet there are few studies comparing how other waterbirds respond to salinity in coastal Louisiana. To date, I am unaware of any studies that compare waterbird use of edge habitats with emergent vegetation habitats. This is a key knowledge gap in waterbird conservation and management because it is not currently possible to predict effects of habitat conversion from emergent wetland to open water on waterbirds.

My overall objective was to compare waterbird habitat use between fresh and saline estuarine wetland habitats. Additionally, I examined habitat use at finer spatial scales to assess preference for marsh edge microhabitats when compared to open water microhabitats and emergent vegetation microhabitats. Specifically, I evaluated three research questions: 1) Does waterbird density and species richness vary significantly with salinity type in Louisiana wetlands? 2) Is waterbird density and species richness greater in marsh edge habitat when compared to both open water and emergent vegetation habitat? 3) What environmental parameters significantly affect waterbird habitat use in estuarine wetlands?

CHAPTER 2: METHODS

Study Area:

The Barataria Basin is located in southeastern Louisiana and is bounded on the east by the active Mississippi River and on the west by the abandoned Bayou Lafourche distributary (Conner and Day 1987) (Figure 1). At present, the Basin is comprised of 6,333 km^2 of coastal marshes and associated open water habitats that span the entire range of salinity regimes. Roughly 701.40 km^2 is comprised of fresh wetland habitat and 540.66 km^2 is comprised of saline wetland habitat (Sasser et al. 2014).

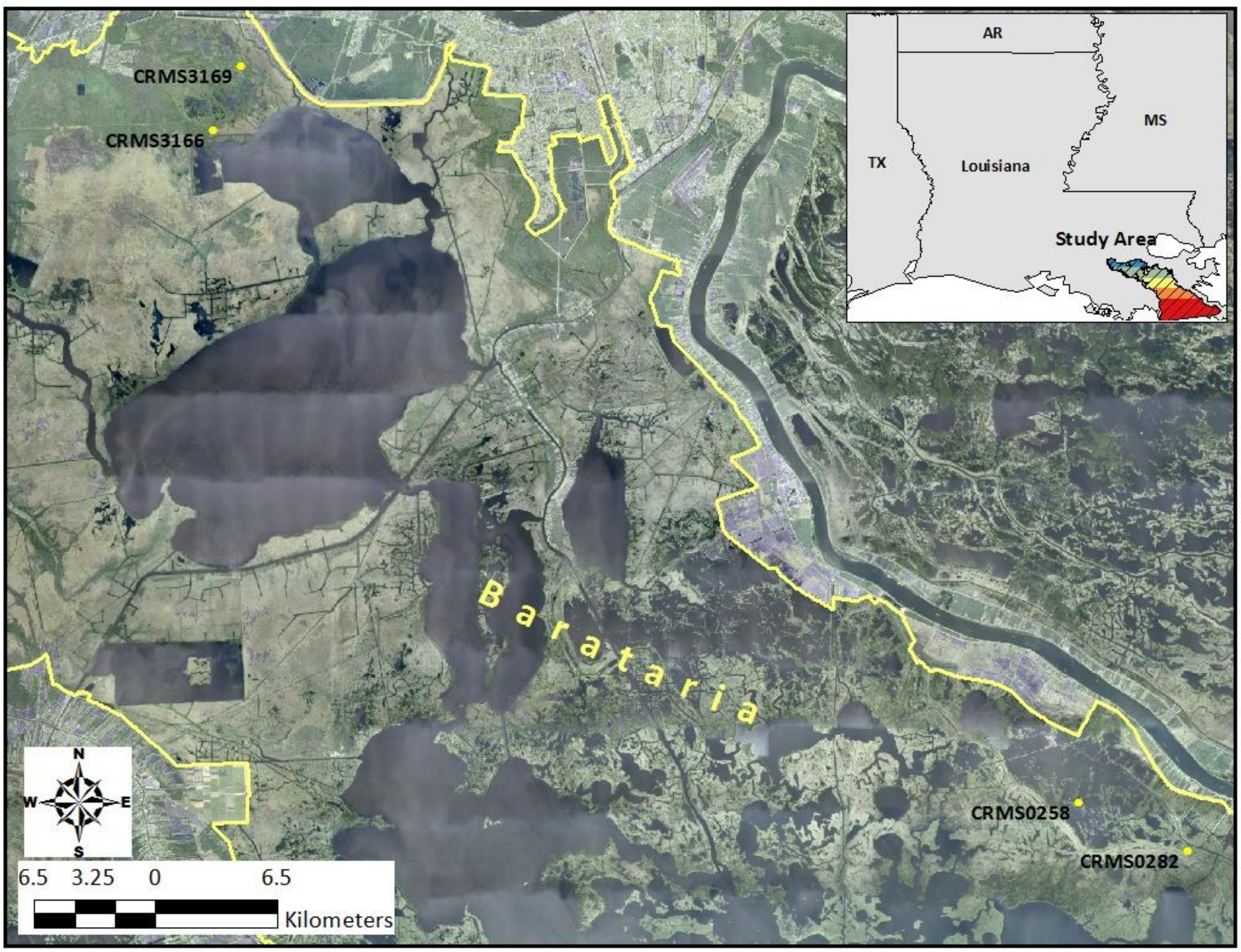


Figure 1: Map of study sites located within Barataria Basin, Louisiana, USA.

Site Selection:

Study sites were selected by identifying sites located within Coastwide Reference Monitoring Stations (CRMS) (lacoast.gov/crms2) that were classified as either fresh or saline marsh by indicator vegetation species (Visser et al. 2011, Sasser et al. 2014). Establishing sites located at a CRMS site allowed for sites that were independent of one another, and allowed for easily obtaining ancillary ecological data, such as salinity and water level data. I then chose Barataria Basin due to its abundance of both fresh and saline marshes (Visser et al. 2011). Finally, I randomly selected among eight potential sites for a site visit to further narrow down site selection. Upon a site visit, I determined whether the following habitat factors were met: 1) presence of open water (ponding) habitat over 25 m from marsh edge; 2) presence of some continuous marsh edge; 3) presence of interior marsh over 25 m from marsh edge. After this evaluation, I selected four sites, two freshwater sites located within the Davis Pond area, and two saline marshes located within the Myrtle Grove area of Barataria Basin. The freshwater study sites were located at CRMS 3166 and CRMS 3169 within the Davis Pond ponding area of Barataria Basin (Figures 1-3), and were comprised of marsh dominated by *Sagittaria lancifolia*, *Colocasia esculenta*, or *Zizaniopsis milacea*. The saline sites, CRMS 0258 and CRMS 0282, were located in the Myrtle Grove area of Barataria Basin (Figures 1,4, and 5) and were dominated by the saline tolerant species of *Spartina alterniflora* and *Distichlis spicata.* Within each site, I evaluated three study plots (emergent marsh, marsh edge, and open water) for a total of 12 study plots.

Figure 2. Overflight photo of CRMS 3166 within the Davis Pond area of Barataria Basin, LA, USA,2015. Picture provided by Gregg Snedden.

Figure 3. Overflight photo of CRMS 3169 within the Davis Pond area of Barataria Basin, LA, USA, 2015. Picture provided by Gregg Snedden.

Figure 4. Google Earth aerial image of CRMS 0258 within the Myrtle Grove area of Barataria Basin, LA, USA, 2015.

Figure 5. Google Earth aerial image of CRMS 0282 within the Myrtle Grove area of Barataria Basin, LA, USA, 2015.

Sample Design:

Within each study site, three study plots were established (Figure 6): an emergent marsh plot, an edge plot, and an open water plot. All study plots were $1200 m^2$, measuring 60 m in length and 20 m in depth (Figure 6). The plots containing marsh edge started 5 m in from the marsh edge and continued out 15 m from marsh edge (Figures 6). This allowed evaluation of edge use up to 15 m out from the emergent vegetation, 5 m further than previous studies (Sullivan 2015, O'Connell and Nyman 2011), while also examining use at a 5 m emergent vegetation perimeter. Edge plots were subdivided into 5 m sections.

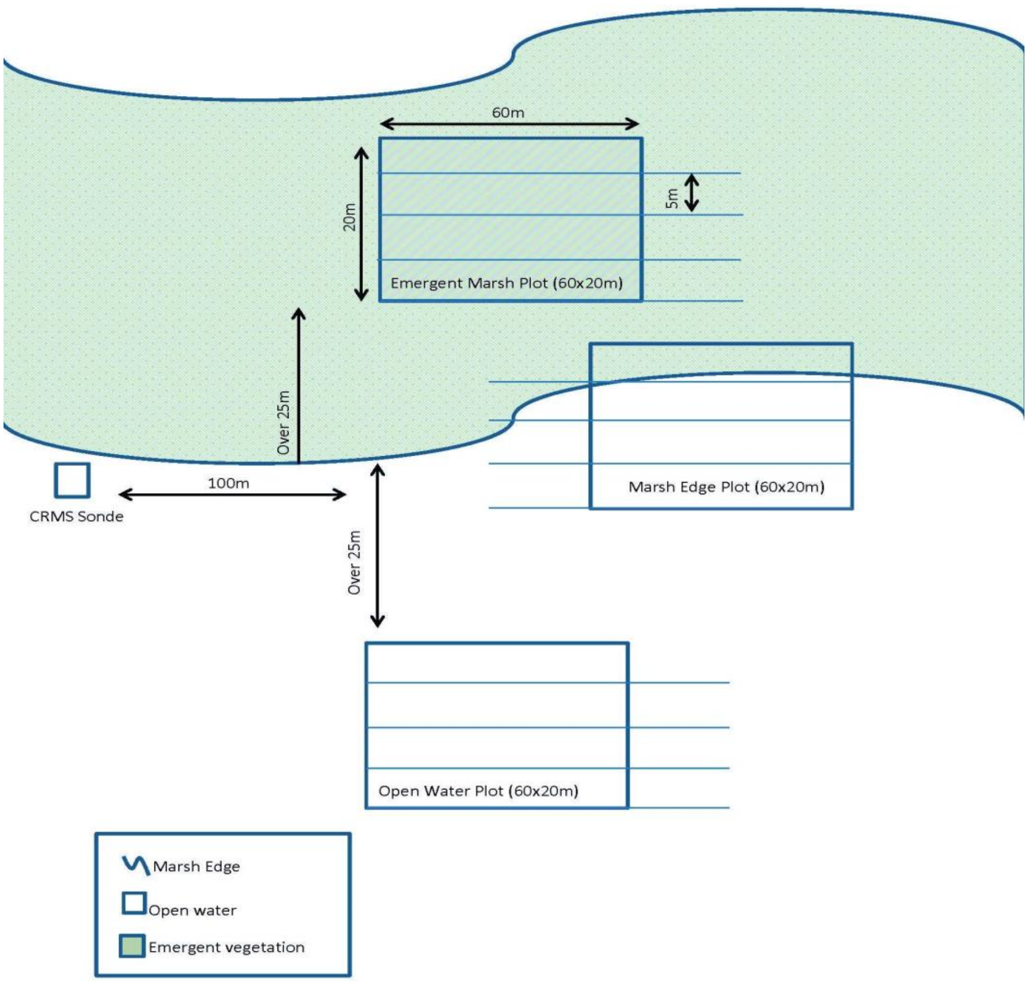


Figure 6. Schematic of study plot design in Barataria Basin, LA, USA, 2014-2015.

From July 2014 to December 2015, I conducted bird surveys, habitat surveys, and recorded environmental conditions at all study plots. Surveys were conducted at least bi-monthly (except December 2014) to observe both resident and migratory birds, and evaluate seasonal variation in waterbird use. I sampled 3 microhabitats within 4 sites over 10 sample dates, resulting in 120 successful surveys. I considered a sampling survey successful if both the waterbird and habitat surveys were completed on the same day. For each bi-monthly survey, all plots were sampled within the same week.

Waterbird Surveys:

Bird survey methods were modified from similar studies by O'Connell (2006) and Sullivan (2015) in southwestern Louisiana and the Bird's Foot Delta, respectively. All observations were made either from a boat next to marsh with a camouflage blind material draped over, or preferentially, the observer was dropped off and hiked to an area of emergent marsh that allowed for inconspicuous observation over the observation interval. For all surveys, I allowed a 15-minute settling period after disturbance caused by boat noise and other anthropogenic disturbance. Ideally, all surveys would have occurred in the early morning, to capture the maximum number of birds; however, this was not always logistically feasible. Therefore, bird surveys were conducted at varying daylight times and the order of site sampling was rotated to mitigate time-of-day effects (O'Connell 2006, Pickens and King 2013). Due to the inherit patchiness of birds in interior marshes, we conducted three consecutive 30 minute counts over a 90-minute time span (three replicated counts for each sampling trip). This differed slightly from O'Connell (2006) and Sullivan (2015), who both used 15-minute counts, but 30-minute surveys allowed us to minimize counts of zero. Visual observations were made using binoculars and spotting scopes. Additionally, small passerines and secretive marsh birds were often confirmed by their calls.

A walk-through bird survey was conducted at the interior marsh edge plots and emergent plots in an effort to increase detection of secretive marsh birds. These surveys were conducted after the initial bird survey. The survey began at the first plot pole and then the observer walked a diagonal transect to the last plot pole on the opposite side. This was then repeated starting from the plot pole opposite the original transect. During the walk-through, any birds that flushed or called were recorded and their location within the plot subdivision was estimated.

In addition to count data, behavior of the waterbirds was classified and subdivision within the overall plot was recorded. Bird behavior was categorized as flush, flyover, forage, loaf, perch, swim, territorial, or vocal. For flyovers, only birds that showed interest in the plot were counted. For example, if a bird simply just flew over the plot it was not counted; however, a bird that circled the plot multiple times or dipped down to the plot but then flew off was counted and categorized as "flyover".

Vocal callbacks were used for five focal secretive marsh bird species: King Rail (*Rallus elegans*), Clapper Rail (*Rallus longirostrus*), Sora (*Porzana carolina*), American Bittern (*Botaurus lentiginosus*), and Common Gallinule (*Gallinula galeata*) (Conway 2008, Conway 2011). The callback surveys were conducted at the emergent and marsh edge plots after the initial bird count surveys were completed. By waiting until survey completion, I minimized calling birds into study plots, thereby skewing results by inadvertently increasing bird numbers. At each plot, prior to broadcasting bird calls, an initial 5-minute passive survey was conducted in which marsh birds calling prior to call-broadcasts were recorded. After the passive survey segment, marsh calls for focal bird species were broadcast (Sibley's bird call app) for 30 seconds at a time, with a 5-second pause between each broadcast call (Conway 2011). For maximum efficacy of the broadcast calls, the speaker was placed upright on the ground and facing center of the marsh when the marsh was not flooded (or just above the water when flooded). The surveyor then stood 2 m to one side of the speaker for the optimal audible range of call backs (Conway 2011).

Habitat and environmental variables:

After bird surveys were completed, I collected data on eleven habitat and environmental variables for each sampling survey: 1) water level, 2) water temperature, 3) salinity, 4) emergent vegetation species richness and percent cover, 5) submerged aquatic vegetation (SAV) species richness and percent cover, 6) floating aquatic vegetation (FAV) richness and percent cover, 7) emergent vegetation structure, and 8) depth at the marsh edge (emergent/open water interface).

Hydrologic variables (salinity, water temperature, conductivity) recorded were measured with a handheld YSI 63 (Yellow Spring Instruments Inc., Yellow Springs, OH). On three days when the YSI was not functioning, hydrologic data gaps were filled using the CRMS hourly hydrologic data for that site.

Water level was measured using a meter stick at 12 random points across all zones in open water and marsh edge plots. At every water level point, SAV presence was measured by dipping a rake to the water bottom and then pulling up; any SAV located on the rake was identified to species and noted as "present" within the plot (Kenow et al. 2006) (Figure 7). Floating aquatic vegetation (FAV) species were also recorded at each water level point. Emergent vegetation surveys were conducted using a 4-m^2 quadrat placed at a randomly selected plot pole. Following CRMS protocol, within the quadrat, total cover, individual vegetation species, percent cover of each species, dominant species, and the average height were estimated (Folse et al 2012). Average plant height was estimated by measuring the height (as the plant stood in plot) of 5 random plants within the plot and then taking the average. We used an average of Robel measurements taken from the cardinal directions to estimate vegetation structure and visual occlusion (Robel 1970 and Smith 2008) at each point.

Figure 7. Picture of SAV rake method data collection Barataria Basin, LA, December 2015.

Statistical Analyses:

For all analyses, a statistical significance level of alpha=0.05 was used. Unless otherwise indicated, a Laplacian approximation was used for estimations of maximum likelihood to counter smaller sample sizes (Zar 2010). I used the maximum number of birds of a particular species for any one count interval (30-minute interval) as the estimate of bird abundance for that species for each survey period (O'Connell 2006). Species (and guild) richness was defined as the total number of species observed during the entire 90-minute survey period for a given study plot. I calculated bird density by dividing bird abundance by the total plot area (1200 m^2) (O'Connell 2006, Sullivan 2015).

Waterbirds are often grouped into foraging guilds when analyzing their habitat use. Grouping them into their foraging guilds can help predict the use of similar species not directly observed. I opted to follow the foraging guild classification used by Sullivan (2015) which closely followed De Graaf's (1985) classification but was not as complex and yielded fewer total guilds (Table 1). Furthermore, I preferred this classification scheme because it separated Ibises from Egrets and Herons. These birds are often all grouped together because they are long-legged wading birds even though their foraging techniques and preferred prey are different. Therefore, it is likely that their fine-scale habitat needs also differ.

Due to the difficulty in distinguishing the Clapper Rail and King Rail through field observation alone, I classified them according to the salinity type in which they were found. For all observations, the Clapper Rail was classified for saline habitat, and the King Rail was classified for fresh habitat (Meanley 1992). The White-faced Ibis (*Plegadis chihi*) and Glossy Ibis (*Plegadis falcinellus*) are also species that are very difficult to discern in the field. It was not possible to distinguish between these two species with binoculars alone, especially when either was in juvenile plumage; therefore, I grouped them together as Dark Ibis (Pickens and King 2013).

Table 1. Foraging guild designation for avian species observed in all study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Foraging guild	Guild code	Included species
Aerial Insectivores	AI	Barn Swallow, Eastern Kingbird, Northern Rough-winged Swallow, Purple Martin, Tree Swallow, Yellow-billed Cuckoo
Carnivorous Hawkers and plungers	CHP	Loggerhead Shrike, Mississippi Kite, Northern Harrier
Dabblers and Grubbers	DG	American Coot, Black-bellied Whistling Duck, Blue-winged Teal, Gadwall, Green-winged Teal, Mottled Duck
Marsh foragers and gleaners	MFG	Black-necked Stilt, Boat-tailed Grackle, Carolina Wren, Clapper Rail, Common Gallinule, King Rail, Marsh Wren, Purple Gallinule, Red-winged Blackbird, Savannah Sparrow, Seaside Sparrow, Sora, Swamp Sparrow, Virginia Rail, White-throated Sparrow
Mudflat probers and gleaners	MPG	Dunlin, Glossy Ibis, Killdeer, Lesser Yellowlegs, Roseate Spoonbill, White-faced Ibis, White Ibis, Willet
Piscivirous plungers and divers	PPD	Anhinga, Belted Kingfisher, Brown Pelican, Common Tern, Double-crested Cormorant, Forster’s Tern, Least Tern, Neotropic Cormorant, Osprey, Royal Tern, Sandwich Tern
Scavengers, food pirates, and generalists	SFPG	Bald Eagle, Black Vulture, Herring Gull, Laughing Gull, Turkey Vulture
Upper canopy gleaner	UCG	Cedar Waxwing
Wading ambusher	WA	Black-crowned Night Heron, Great Blue Heron, Great Egret, Green Heron, Little Blue Heron, Least Bittern, Snowy Egret, Tricolored Heron, Yellow-crowned Night Heron
Water bottom foragers and divers	WBFD	Pied-billed Grebe
Water surface gleaner	WSG	American White Pelican

Waterbird Abundance:

I used count data to create frequency tables (PROC FREQ, SAS version 9.3, SAS, Inc., Cary, NC) to evaluate relative abundances of species and guilds within salinity types (fresh and saline) and among microhabitats (edge, emergent, and open water). All frequency tables can be referenced in appendix B.

Waterbird richness:

To test the null hypothesis that there was no difference in species or guild richness among salinity type or microhabitats, I ran an analysis of covariance (ANCOVA) (PROC GLIMMIX, SAS version 9.3, SAS, Inc., Cary, NC). Models were run to examine the interaction between salinity type and microhabitat, and then with the two covariates month and year. For all models, I used the log link function and compared fit statistics from the Poisson, Gaussian, and negative binomial distributions. The best fit model (distribution) was chosen by comparing the Akaike's Information Criterion (AIC) and the Pearson Chi-Square/Degrees of Freedom fit statistics, the preferred model being one with the lowest AIC score and Pearson statistic closest to one (Zar 2010). The Poisson and negative binomial are generally the most common distributions for species count data (Zar 2010). However, the best fit model for guild richness among salinity type had a Gaussian distribution. The results indicated that for species richness comparison among salinity type, the negative binomial distribution and log link function were the best choice.

Waterbird density:

Similarly, an ANCOVA (PROC GLIMMIX, SAS version 9.3, SAS, Inc., Cary, NC) using waterbird densities was run to test the null hypothesis that there is no difference in density among salinity type or microhabitats. These models had a negative binomial distribution and log link function.

Waterbird Environmental Associations:

Canonical correspondence analysis (CCA) is a powerful tool for analysis of multiple ecological variables (Legendre and Legendre 1998). I ran a CCA (CANOCO vers. 4.5, Microcomputer Power, Ithaca, NY) to identify species (guild) associations with environmental variables (Table 2). Depth at marsh edge was not used in the analysis because it was only measured at marsh edge plots. Rare (observed <1%) waterbird species were not included in this CCA. Prior to running the CCA, I ran a multiple regression (PROC REG, PROC FACTOR, SAS version 9.3, SAS, Inc., Cary, NC), to check for multicollinearity among the environmental variables. I used the correlation factors (>0.75) and variance inflation factors (>5) to identify variables that were problematic due to collinearity. For variables that demonstrated high collinearity and for which one variable could explain the variation, I reduced them to one proxy variable. For example, the variables floating aquatic vegetation (FAV) percent cover, submerged aquatic vegetation (SAV) percent cover, FAV species richness, and SAV species richness were all highly correlated, so I reduced them to the new proxy variable “aquatic vegetation (AQU_VEG)”. After I eliminated the correlated terms, I ran a principal component analysis (PCA) (CANOCO vers. 4.5, Microcomputer Power, Ithaca, NY; PROC FACTOR, SAS version 9.3, SAS, Inc., Cary, NC) to identify environmental variables that explained the greatest variance. I used the communality estimates from the PCA to identify and eliminate variables (backward selection) that indicated little variance.

Table 2. Environmental variables used in PCA and multiple regression analysis.

Environmental variable code	Environmental variable	Description
BARE %	Bare ground percentage	Percent of bare ground at marsh edge and emergent plots.
EMG %	Emergent vegetation percentage	Percent of emergent vegetation at marsh edge and emergent plots.
EMG SR	Emergent vegetation species richness	Number of emergent vegetation species present at marsh edge and emergent plots.
EMG STR	Emergent vegetation structure	Robel pole mean score at marsh edge and emergent plots.
FAV %	Floating aquatic vegetation percentage	Percent of floating aquatic vegetation located in study plots.
FAV SR	Floating aquatic vegetation species richness	Number of floating aquatic species present in study plots.
MEAN DEPTH	Mean water depth	Mean water depth within study plots.
OPEN %	Open water percentage	Percent of open water present within study plots.
SALINITY	Water salinity in ppt	Mean water salinity measured in parts per thousand within study plots.
SAV %	Submerged aquatic vegetation percentage	Percentage of submerged aquatic vegetation within study plots.
SAV SR	Submerged aquatic vegetation species richness	Number of submerged aquatic vegetation species present within study plots.

Table 3. Environmental variables used in CCA and guild response curve analysis.

Environmental variable code	Environmental variable	Description
AQU_VEG	Aquatic vegetation	Reduced from highly correlated variables SAV%, SAV_SR, FAV%, FAV_SR
EMG_VEG	Emergent vegetation	Reduced from highly correlated variables EMG %, EMG_SR, EMG_STR
OPEN %	Open water percentage	Percent of open water present within study plots
SALINITY	Water salinity in ppt	Mean water salinity measured in parts per thousand within study plots

Guild response curves:

Using the output from the CCA, I used CANOCO (vers. 4.5, Microcomputer Power) to create guild response curves in relation to each constrained axis in the CCA. A separate run was used for each guild (response variable) against each dominant environmental (predictor) variable. For each run, I used the log link function and Poisson distribution (Leps and Smilauer 2003). I then graphed guild use as a function of each of the environmental variables (Table 3) to more easily visualize guild response.

Species of concern:

Due to low numbers, I was unable to conduct a reliable comparative analysis for species of conservation concern. I created an abundance table using count data (PROC FREQ, SAS version 9.3, SAS, Inc., Cary, NC).

CHAPTER 3: RESULTS

Site Characterization:

The water depths at edge plots did not vary by salinity type (Table 4): fresh (36.5 cm±4.9), saline (36.5 cm ±3.4); but depth at emergent plots did vary by salinity type: fresh (9.0 cm±1.7), saline (2.4 cm±2.4). Emergent vegetation species richness did not vary between fresh sites (2.1±0.3) and saline sites (2.7±0.2). Submerged aquatic vegetation (SAV) (34%±4) and floating aquatic vegetation (FAV) (36%±6) percent cover were greater at freshwater sites than saline sites with 9% (±3) SAV cover and no FAV cover. Emergent vegetation percent cover was less in fresh emergent plots (70%±7) than in saline emergent plots (84%±5). Detailed hydrological, environmental, and vegetation data for each site can be referenced in appendix C.

Table 4. Summary of mean habitat and environmental data (±standard error) for all habitat types within Barataria Basin, LA, 2014-2015.

	Fresh							
	Overall		Emergent		Edge		Open	
water temp (°C)	21.5	±2.1	21.5	±2.1	21.5	±2.1	21.5	±2.1
salinity (ppt)	0.2	±0.01	0.2	±0.01	0.2	±0.01	0.2	±0.01
water depth (cm)	33.6	±4.9	9.0	±1.7	36.5	±4.9	55.4	±5.3
depth at edge	21.9	±3.2	------	------	21.9	±3.2	------	------
open %	52	±6	0	±0	54	±5	100	±0
bare %	12	±2	29	±4	11	±4	0	±0
EMG[1] %	39	±4	70	±7	38	±6	0	±0
EMG richness	2.1	±0.3	3.1	±0.4	3.2	±0.7	0.0	±0.0
EMG structure	20.6	±2.4	33.7	±3.4	28.2	±3.6	0.0	±0.0
SAV[2] %	34	±4	0	±0	51	±5	52	±7
SAV richness	1.7	±0.3	0.0	±0.0	2.6	±0.5	2.5	±0.3
FAV[3] %	36	±6	0	±0	63	±8	46	±7
FAV richness	1.9	±0.2	1.9	±0.2	3.20	±0.3	2.50	±0.3

	Saline							
	Overall		Emergent		Edge		Open	
water temp (°C)	24.5	±1.3	24.5	±1.3	24.5	±1.3	23.96	±2.1
salinity (ppt)	10.6	±0.7	10.6	±0.7	10.6	±0.7	10.63	±0.7
water depth (cm)	30.3	±3.4	2.4	±2.4	36.5	±3.4	52.1	±5.3
depth at edge	25.4	±3.3	------	------	25.4	±3.3	------	------
open %	54	±6	0	±0	53	±6	100	±0
bare %	17	±4	16	±4	14	±4	0	±0
EMG %	64	±5	84	±5	37	±3	0	±0
EMG richness	2.7	±0.2	3.1	±0.9	2.1	±0.3	0.0	±0.0
EMG structure	35.4	±0.7	36.2	±0.6	25.8	±0.4	0.0	±0.0
SAV %	9	±3	0	±0	12	±2	6	±1
SAV richness	0.4	±0.07	0.0	±0.0	0.5	±0.05	0.3	±0.03
FAV %	0	±0	0	±0	0	±0	0	±0
FAV richness	0.00	±0.00	0.0	±0.0	0.0	±0.0	0.0	±0.0

[1]emergent vegetation

[2]submersed aquatic vegetation

[3]floating aquatic vegetation

Bird Results:

During the study, I conducted 120 successful surveys and identified 1105 waterbirds. Over the course of the study, I identified 69 waterbird species comprising 11 guilds. Detailed waterbird abundance data can be referenced in Appendix B.

Summary abundance/count data by salinity type:

More waterbirds were observed in freshwater sites, with a cumulative bird count of 768, than in the saline sites, which had a cumulative count of 337 (Figure 8). The freshwater sites also had greater species richness with 46 species observed using the sites over the study period, while the saline sites had 41 species. For both fresh and saline sites, the Red-winged Blackbird was the most frequent bird observed.

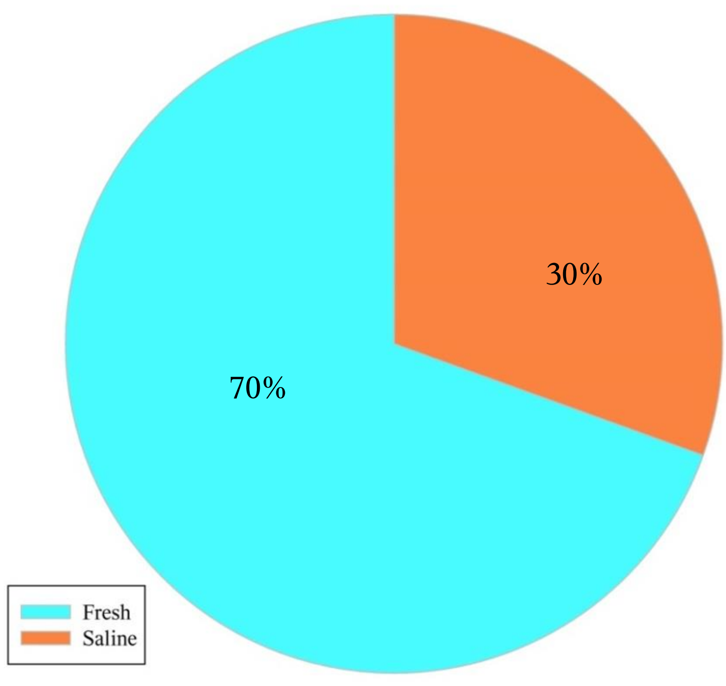


Figure 8. Pie chart showing proportion of cumulative waterbird counts at fresh versus saline sites in Barataria Basin, LA, USA, 2014-2015.

At the freshwater sites, the five most abundant waterbird species (Figure 9) were Red-winged Blackbird (n=204), Boat-tailed Grackle (n=77), Common Gallinule (n=62), Barn Swallow (n=54), and White Ibis (n=46). Within freshwater sites, there were nine foraging guilds observed. The marsh foragers and gleaners was the most abundant foraging guild (n=406) seen using the study plots and making up 53% of the foraging guild use. The other prominent foraging guilds included aerial insectivores (n=115), mudflat probers and gleaners (n=81), dabblers and grubbers (n=61), wading ambushers (n=51), carnivorous hawker and plungers (n=30), scavengers, food pirates, and generalists (n=11), piscivorous plungers and divers (n=9), upper canopy gleaners (n=4). Twenty-one species were only observed using fresh sites: Black-bellied Whistling Duck (n=6), Gadwall (n=1), Anhinga (n=1), Green Heron (n=5), Glossy Ibis (n=3), White-faced Ibis (n=19), Osprey (n=2), Mississippi Kite (n=26), Bald Eagle (n=9), Northern Harrier (n=4), King Rail (n=4), Common Gallinule(n=62), Purple Gallinule (n=3), Killdeer (n=1), Black-necked Stilt (n=37), Lesser Yellowlegs (n=4),Yellow-billed Cuckoo (n=3), Marsh Wren (n=4), Northern Rough-winged Swallow (n=20), Swamp Sparrow (n=4), and White-throated Sparrow (n=2).

Although the Red-winged Blackbird (n=54) was also the most frequent bird species identified using plots within the saline sites, the other top users differed from those at the freshwater sites (Figure 9). The remaining four most frequent species were Seaside Sparrow (n=35), Great Egret (n=28), Blue-winged Teal (n=23), and Clapper Rail (n=14). Within saline sites, there were ten foraging guilds observed. Similar to the freshwater sites, the marsh foragers and gleaners was the most prominent foraging guild with 115 waterbirds represented and comprising 34 percent. The other most prominent foraging guilds were wading ambushers (n=60), piscivorous plungers and divers (n=56), dabblers and grubbers (n=33), scavengers, food pirates and generalists (n=28), aerial insectivores (n=21), mudflat probers and gleaners (n=13), water surface gleaners (n=6), carnivorous hawkers and plungers (n=2), and water bottom foragers and divers (n=2). Twenty-one species were only observed using saline sites: Pied-billed Grebe (n=2), Neotropic Cormorant (n=1), American

White Pelican (n=6), Brown Pelican (n=6), Yellow-crowned Night Heron (n=3), Roseate Spoonbill (n=6), Black Vulture (n=4), Clapper Rail (n=14), Willet (n=6), Dunlin (n=1), Herring Gull (n=1), Laughing Gull (n=12), Least Tern (n=12), Common Tern (n=2), Royal Tern (n=3), Sandwich Tern (n=6), Belted Kingfisher (n=1), Eastern Kingbird (n=1), Purple Martin (n=3), Savannah Sparrow (n=2), Seaside Sparrow (n=35).

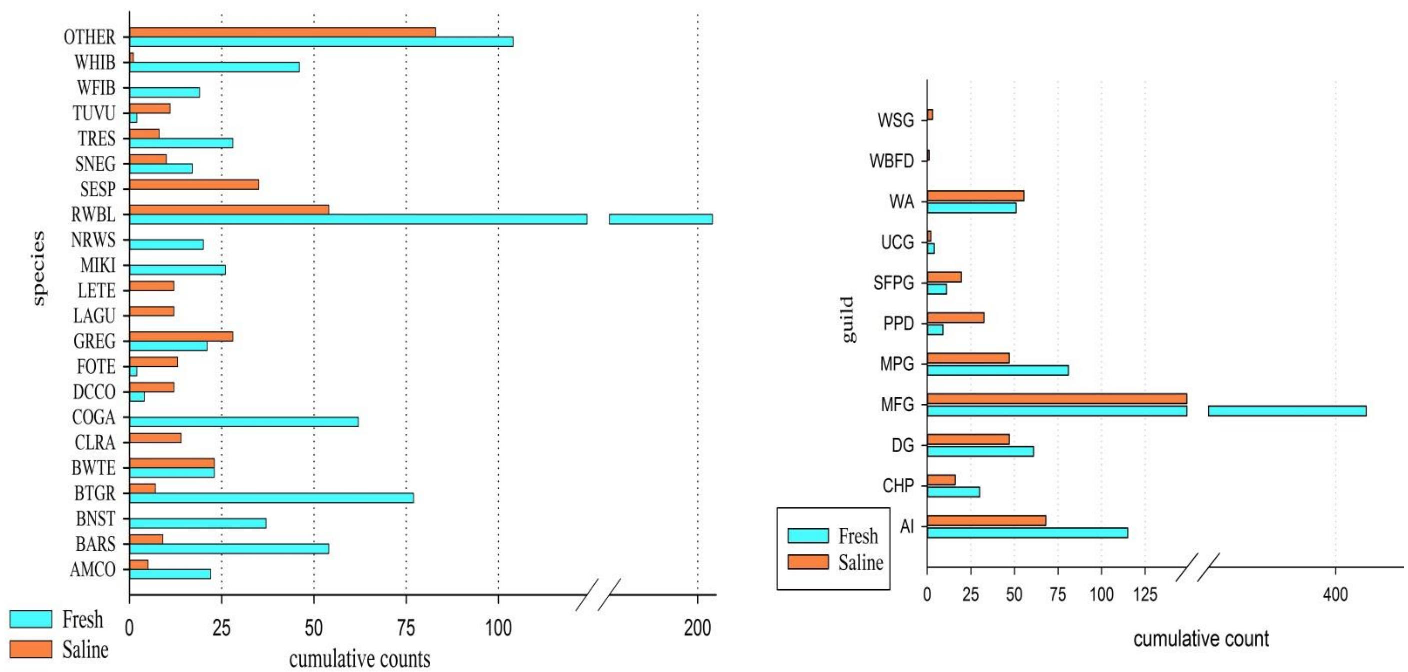


Figure 9. Waterbird species and guild counts by salinity type within Barataria Basin, LA, USA, 2014-2015. Rare species (<1%) were placed in the group “OTHER”.

Summary abundance/count data by microhabitat type:

Combining both fresh and saline sites, the marsh edge plots supported more species than emergent and open water plots (Figure 10). There were 61 species observed using the edge plots out of 613 waterbirds observed using these plots. The emergent plots had 34 species and an abundance of 276. Abundance was lowest in open water plots (n=216), but open water had a greater species richness (n=38) than the emergent plots (n=34).

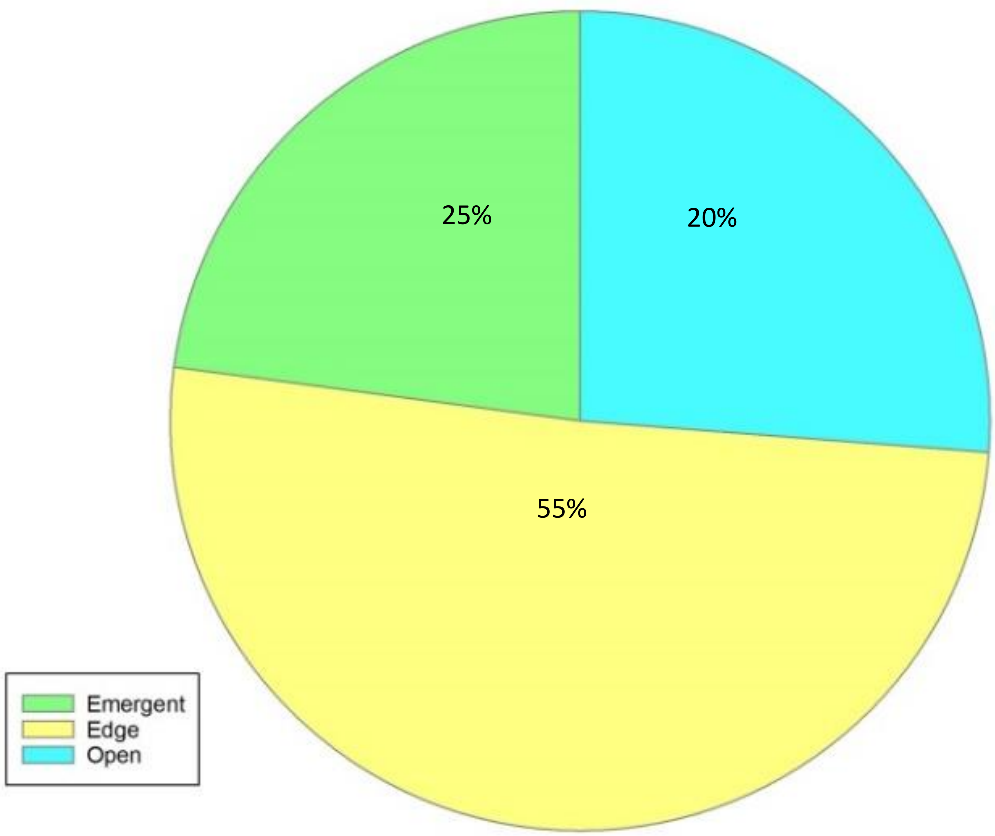


Figure 10. Pie chart showing proportion of cumulative waterbird counts among microhabitats in Barataria Basin, LA, USA, 2014-2015.

At the edge plots, the five most abundant waterbird species (Figure 11) were Red-winged Blackbird (n=144), Boat-tailed Grackle (n=49), Common Gallinule (n=40), Barn Swallow (n=39), and Great Egret (n=29). The marsh foragers and gleaners was the most abundant foraging guild (n=301) seen using these study plots and making up 49% of the foraging guild use. The other foraging guilds included aerial insectivores (n=88), mudflat probers and gleaners (n=52), wading ambushers (n=51), dabblers and grubbers (n=36), piscivorous plungers and divers (n=35), carnivorous hawker and plungers (n=28), scavengers, food pirates, and generalists (n=15), under canopy gleaners (n=3), water surface gleaners (n=3), water bottom foragers and divers (n=1). The Black-bellied Whistling Duck (n=6), Gadwall (n=1), Anhinga (n=1), Glossy Ibis (n=3), Dunlin (n=1), Common Tern (n=2), Belted Kingfisher (n=1), Loggerhead Shrike (n=2), Purple Martin (n=3), Savannah Sparrow (n=2), and White-throated Sparrow (n=2) were only observed at edge plots.

At emergent plots, the species composition was very similar to edge plots (Figure 11). The Red-winged Blackbird (n=92) was the most frequent bird species identified using the plots followed by the Boat-tailed Grackle (n=24), Barn Swallow (n=20), Common Gallinule (n=19), and Seaside Sparrow (n=15). Similar to the edge plots, the marsh foragers and gleaners was the most prominent foraging guild with 177 waterbirds represented and comprising 64 %. The other most prominent foraging guilds were aerial insectivores (n=39), mudflat probers and gleaners (n=31), wading ambushers (n=12), scavengers, food pirates and generalists (n=9), carnivorous hawkers and plungers (n=3), dabblers and grubbers (n=2), piscivorous plungers and divers (n=2), under canopy gleaners (n=1). The Lesser Yellowlegs (n=4), Eastern Kingbird (n=1), and Carolina Wren (n=1) were only observed using emergent plots.

At open water plots, the Blue-winged Teal (n=25) was the most abundant species followed by the Red-winged Blackbird (n=22), American Coot (n=21), Great Egret (n=17), and Snowy Egret (n=13). The dabblers and grubbers was the most prominent foraging guild with 56 waterbirds and comprising 26% of observed birds. The other foraging guilds observed using open water plots were wading ambushers (n=48), marsh foragers and gleaners (n=43), piscivorous plungers and divers (n=28), scavengers, food pirates and generalists (n=15), mudflat probers and gleaners (n=12), aerial insectivores (n=9), water surface gleaners (n=3), carnivorous hawkers and plungers (n=1), and water bottom foragers and divers (n=1). The Neotropic Cormorant (n=1), Killdeer (n=1), and Herring Gull (n=1), and were only observed using the open water plots.

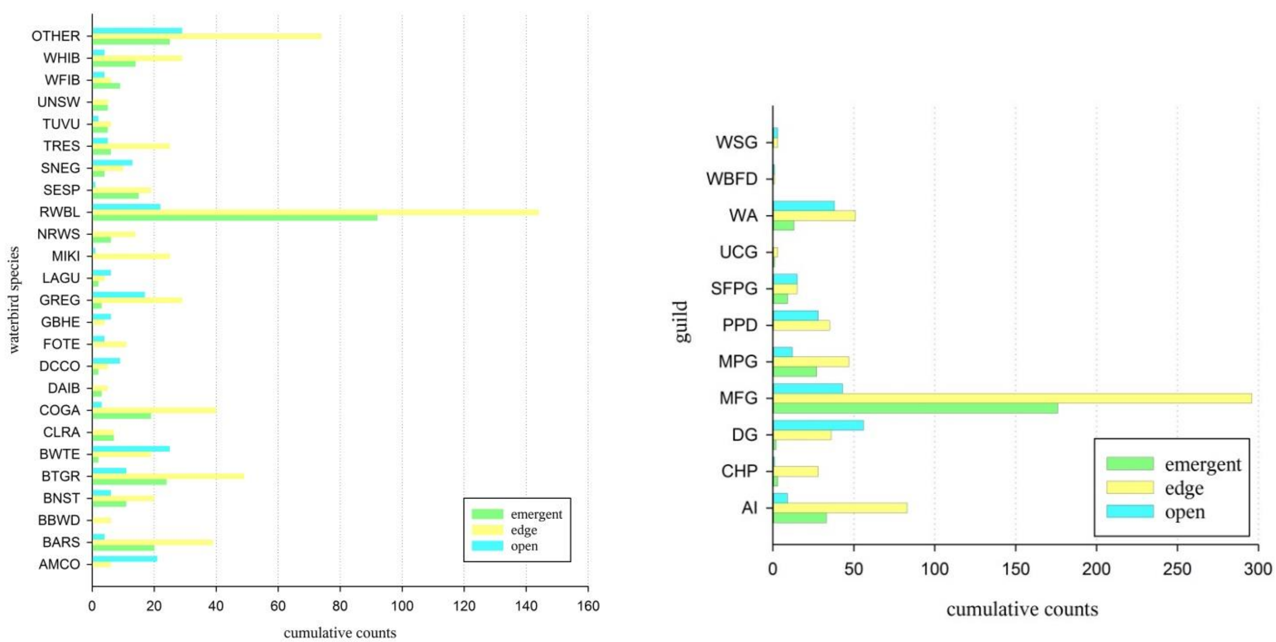


Figure 11. Waterbird species and guild counts by microhabitat within Barataria Basin, LA, USA, 2014-2015. Rare species (<1%) were placed in the group "OTHER".

Species and guild richness:

Species richness averaged 3.9 (±0.4) in fresh sites and 2.9 (± 0.3) in saline sites, but changed over time differently in fresh and saline marsh as indicated by a significant interaction between salinity type and month ($F_{8,100}$=3.18, p=0.005) (Figure 12). The greatest species richness was observed in the month of April at the freshwater sites (mu=2.2±0.1) and it was statistically significant from all other salinity and month combinations (Figure 13). Species richness differed by salinity type during the months of January (fresh:mu=0.9±0.3, saline:mu=1.3±0.2), March (fresh: mu=1.0±0.2, saline:mu=1.4±0.2), October (fresh: mu=1.5±0.2, saline:mu=1.15±0.2), and December (fresh:mu=1.6±0.2, saline:mu=1.0±0.2). Species richness did not vary by salinity type during the summer months of July, August, and September (Figure 12).

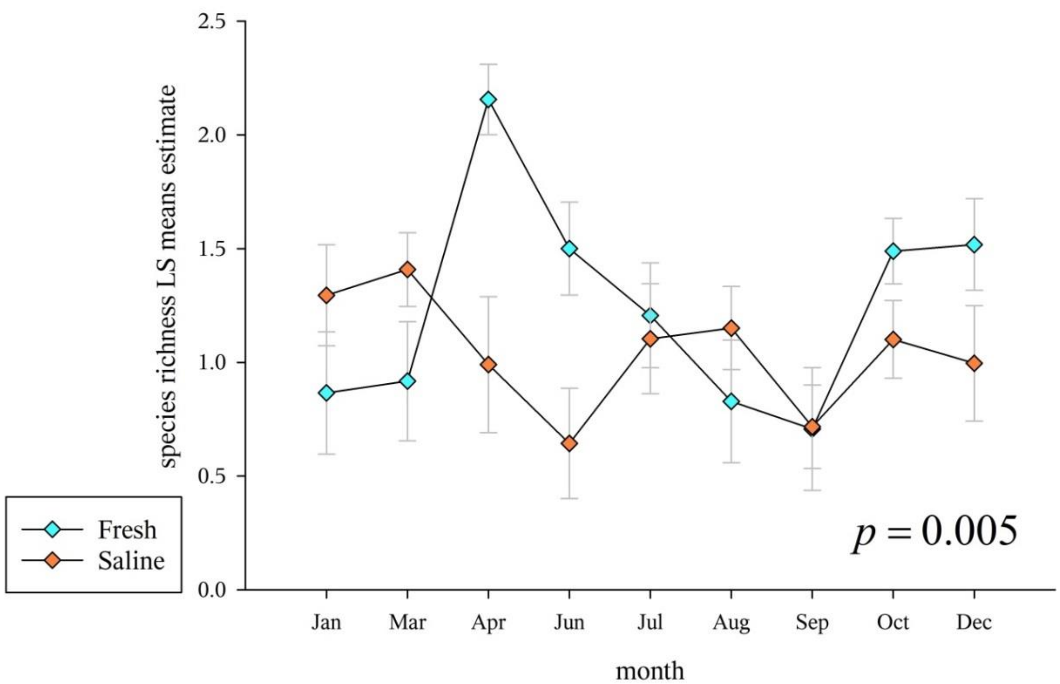


Figure 12. Mean species richness (±standard error) at fresh and saline sites over time (alpha=0.05) in Barataria Basin, LA, USA, 2014 and 2015.

For species richness, there was a strong effect due to the categories of microhabitat ($F_{2,113}$=10.06, p<0.0001) with the marsh edge having the greatest richness (mu=5.3±0.5) (Table 5). The interaction between microhabitat and month was not significant ($F_{16,93}$=1.03, p=0.4). For guild richness, edge plots had the greatest richness (mu=3.3 ±0.3). There was no significant interaction for guild richness observed overall (Table 6).

Table 5. Mean species richness at microhabitats (alpha=0.05) in Barataria Basin, LA, USA, 2014 and 2015.

category	estimate	standard error
edge	5.3	0.5
emergent	2.9	0.4
open	2.8	0.3

Table 6. Mean guild richness at microhabitats (alpha=0.05) in Barataria Basin, LA, USA, 2014 and 2015.

category	estimate	standard error
edge	3.2	0.3
open	2.1	0.3
emergent	1.8	0.2

Waterbird density:

For waterbird density, there was a significant interaction between microhabitat and salinity type ($F_{7,101}$=2.82, p=0.030) (Figure 13). Waterbird density was greater in fresh edge (mu=5.1±0.2) and fresh emergent (mu=4.3±0.2) microhabitats, when compared to saline edge (mu=4.3±0.2) and saline emergent microhabitats (3.3±0.2). Within open water microhabitat, waterbird density did not vary significantly between open water fresh (mu=3.8±0.2) and open water saline (mu=3.6±0.2) habitats.

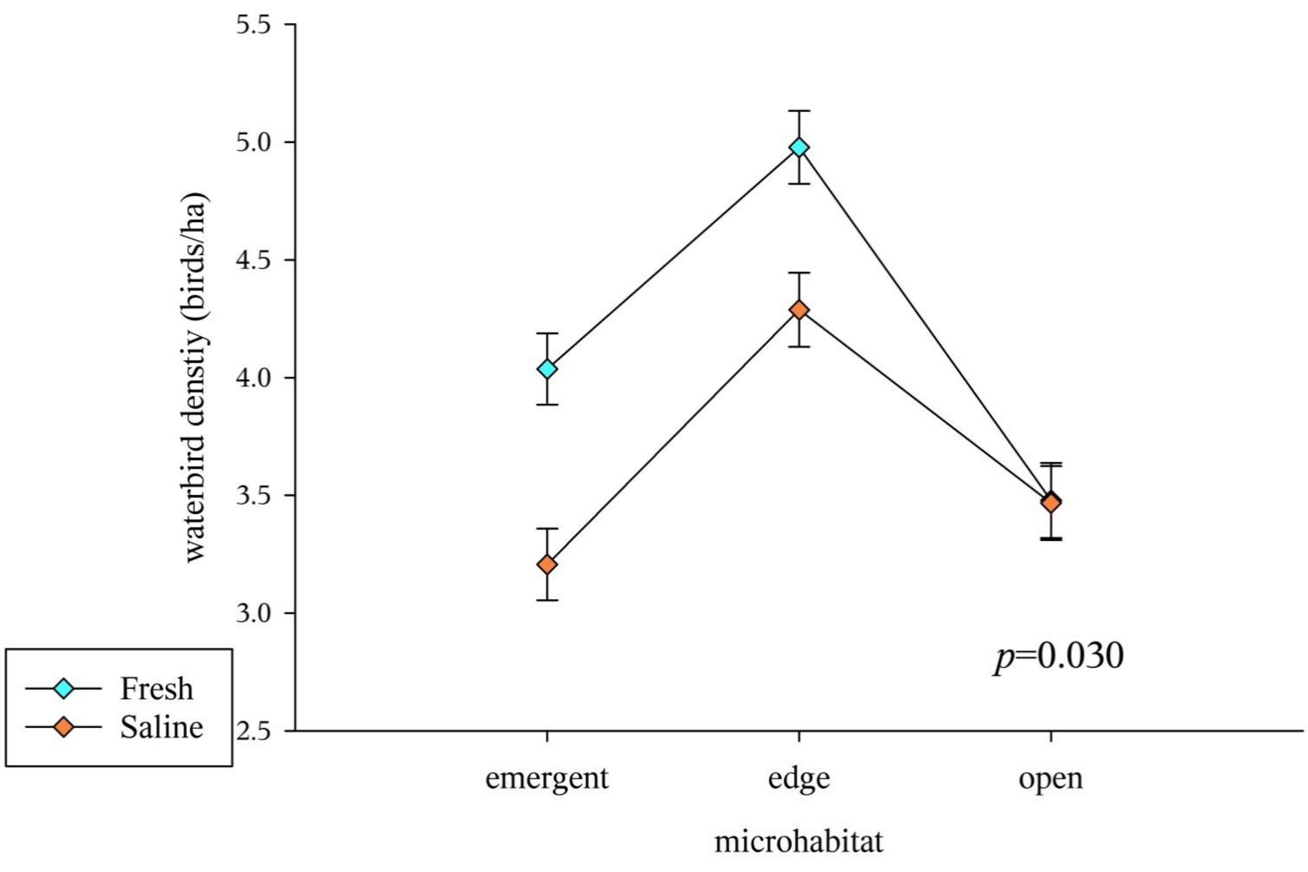


Figure 13. Mean species density for microhabitat*salinity type (alpha=0.05) in Barataria Basin, LA, USA, 2014 and 2015.

Edge Effects:

For edge analysis, there was a strong effect due to plot subdivisions ($F_{9,70}$=5.97, p<0.0001). The interactions between edge subdivision, month, and salinity were not significant. Waterbirds utilized each area of the marsh edge plots equally (Figure 14, Table 7). The only exception was across all subdivisions (-5-15 m range) (mu=2.5±0.3), where waterbird abundance differed significantly from other subdivisions. Waterbird abundance did not drop to zero for any one plot subdivision or combination of subdivisions; therefore, waterbirds utilized the edge habitat to at least 15 m out from the emergent/open water interface (edge).

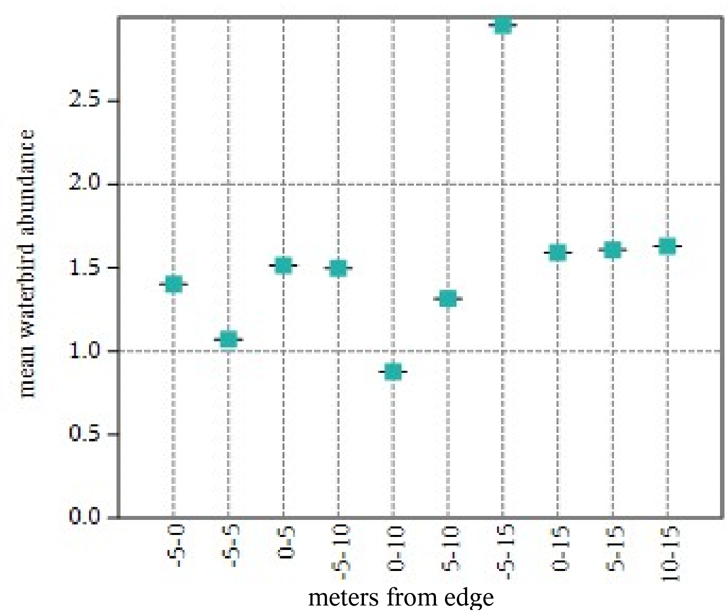


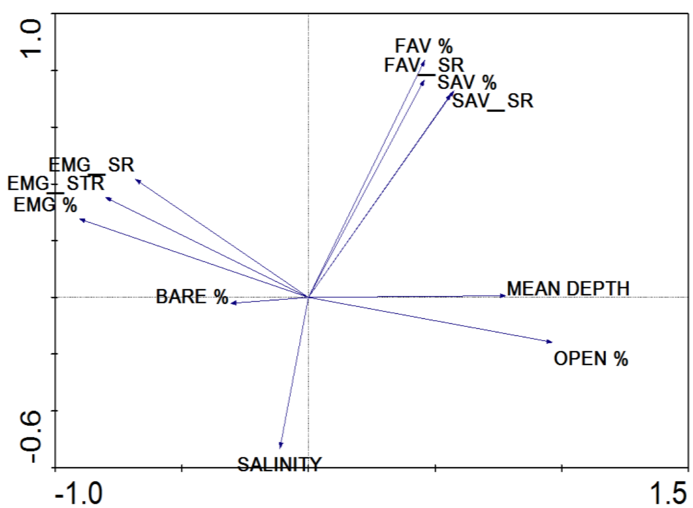
Figure 14. Mean bird count at edge plot subdivisions in Barataria Basin, LA, USA 2014-2015.

Table 7. Mean bird count at edge plot subdivisions in Barataria basin, LA, 2014-2015.

Edge subdivision	Mean waterbird count	Standard error
I,II,III,IV	2.4	0.3
I,II,III	1.9	0.3
II,III,IV	1.6	0.2
I,II	1.5	0.3
I	1.3	0.2
III, IV	1.3	0.3
IV	1.3	0.2
II	1.1	0.2
III	0.9	0.3
II,III	0.7	0.2

Habitat and Environmental Variables:

I ran a principal component analysis (PCA) to identify environmental variables that explained the greatest variance among sites (Figure 15). I reduced the original eleven environmental variables down to four (Tables 2 and 3). FAV percent cover was highly correlated with submerged aquatic (SAV) percent cover (R=0.88), SAV species richness (R=0.83), and FAV species richness (R=0.92). These four were reduced to one variable, aquatic vegetation (AQU_VEG; VIF reduced to 1.50). Emergent vegetation structure was highly correlated with emergent vegetation percent cover (R=0.89) and emergent vegetation species richness (R=0.83). These three variables were reduced to one variable, emergent vegetation (EMG_VEG; VIF reduced to 4.87). Bare ground and mean water depth were removed due to low factor loading (communality estimates) statistics.



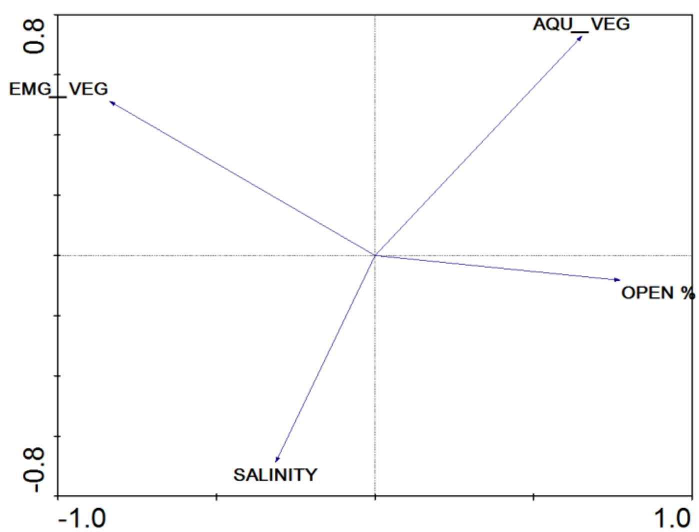


Figure 15. Principal component ordination plots of original set of environmental variables (left) and reduced set of variables (right) in Barataria Basin, LA, USA, 2014-2015. The orientation of each variable in relation to the axes 1 and 2 is represented by the blue arrow, the length indicates the degree of correlation to the axes.

Post PCA, I used canonical correspondence analysis (CCA) to test for correlations between species and the four dominant environmental variables (Figure 16): salinity, emergent vegetation, aquatic vegetation, and open water percent cover. Monte Carlo models using 499 permutations showed a significant relationship between environmental variables and species abundance (p=0.002). The first two canonical axes explained 88% of the species-environmental variation. Axis 1 explained 58% of variation in species abundance, and represented the gradient from open water to emergent marsh vegetation. Axis 2 explained 30% of the variation in species abundance, and represented the gradient from highly saline habitats devoid of aquatic vegetation to habitats with more aquatic vegetation. Both axes were related to vegetation but different bird species were associated with different kinds of vegetation.

Many species were associated with more complex vegetation communities (i.e., emergent and aquatic vegetation) (Figure 16). The Northern Rough-winged Swallow and Red-Winged Blackbird were associated with emergent vegetation community structure. The Clapper Rail and Seaside Sparrow were also associated with emergent vegetation but at higher salinities. The White Ibis, White-faced Ibis, Boat-tailed Grackle, Common Gallinule, Barn Swallow, Mississippi Kite, and Black-necked Stilt all showed an association with aquatic vegetation. Conversely, there were species that showed strong associations with less complex vegetation communities and a higher availability of open water. The American Coot, Least Tern, Blue-winged Teal, Great Blue Heron, Snowy Egret, and Laughing Gull were all associated with areas of greater open water.

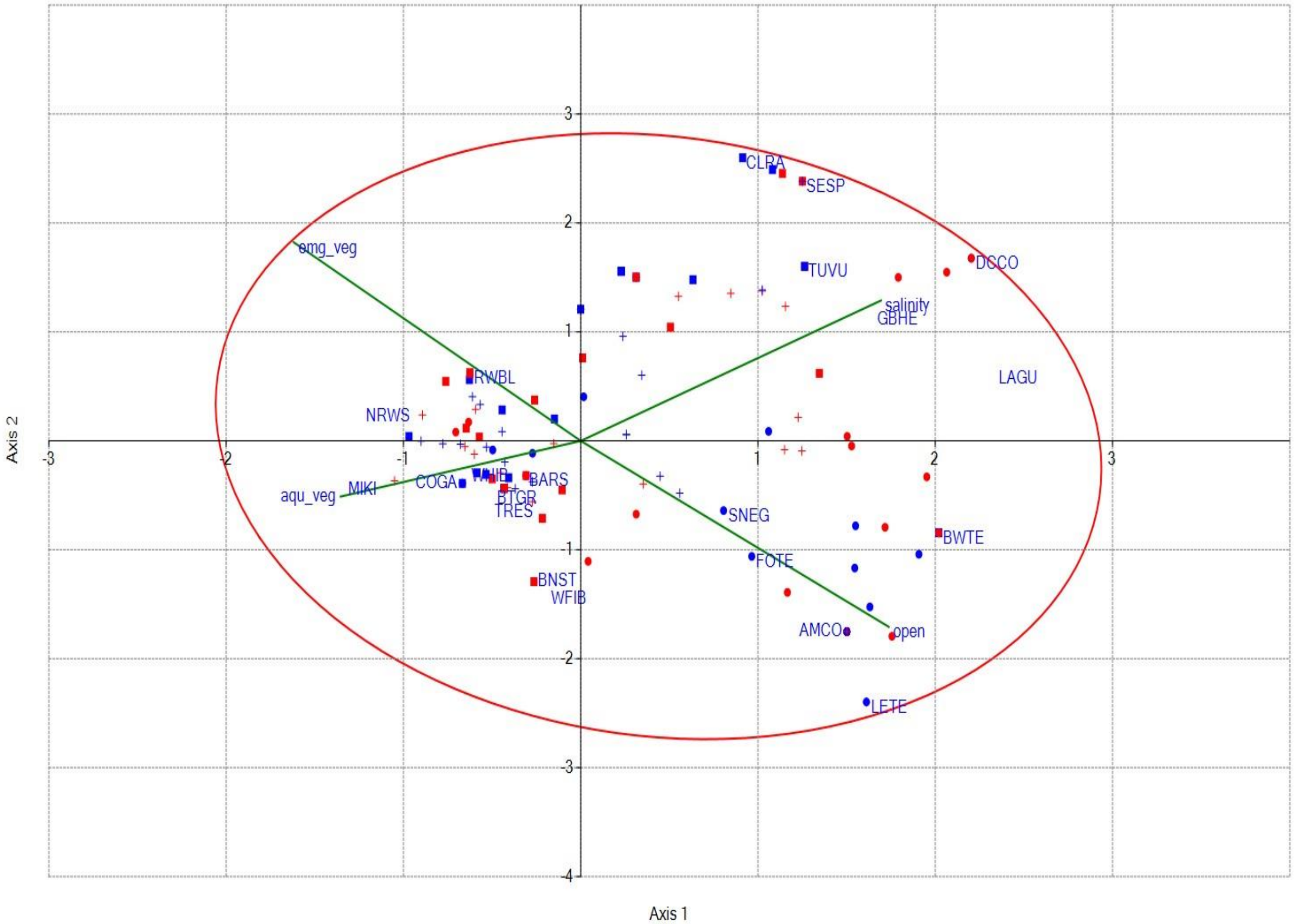


Figure 16. Canonical correspondence tri-plot relating waterbird species to environmental variables in Barataria Basin, LA, USA, 2014-2015. The orientation of each variable in relation to the axes 1 and 2 is represented by the green line; the length indicates the degree of correlation to the axes. Symbols: plus sign=edge plot, square=emergent plot, circle=open water plot; red points=saline sites, blues points=fresh sites. The red circle represents the 95% confidence ellipses.

Post PCA, I used canonical correlation analysis (CCA) to test for correlations between guilds and the four dominant environmental variables (Figure 17): salinity, emergent vegetation, aquatic vegetation, and open water percent cover. Monte Carlo models using 499 permutations resulted in a significant relationship between environmental variables and species abundance ($p=0.002$). The first two canonical axes explained 97% of the guild-environmental variation. Axis 1 explained 91% of variation in guild abundance, and represented the gradient from open water to emergent marsh vegetation. Axis 2 explained 6% of the variation in guild abundance, and represented the gradient from highly saline habitats devoid of aquatic vegetation to habitats with more aquatic vegetation.

Because foraging guilds were grouped by ecological niche, they show little overlap in environmental variable associations (Figure 17). The marsh foragers and gleaners were associated with emergent vegetation. Aerial insectivores and mudflat probers and gleaners were associated with aquatic vegetation. Dabblers and grubbers were associated with increasing open water. Piscivorous plungers and divers, and wading ambushers were associated with higher salinities. Carnivorous hawkers and plungers; scavengers, food pirates, and generalists; upper canopy gleaners; water bottom foragers and divers; and water surface gleaners are not shown in Figure 17 because they landed as outliers in the original CCA run.

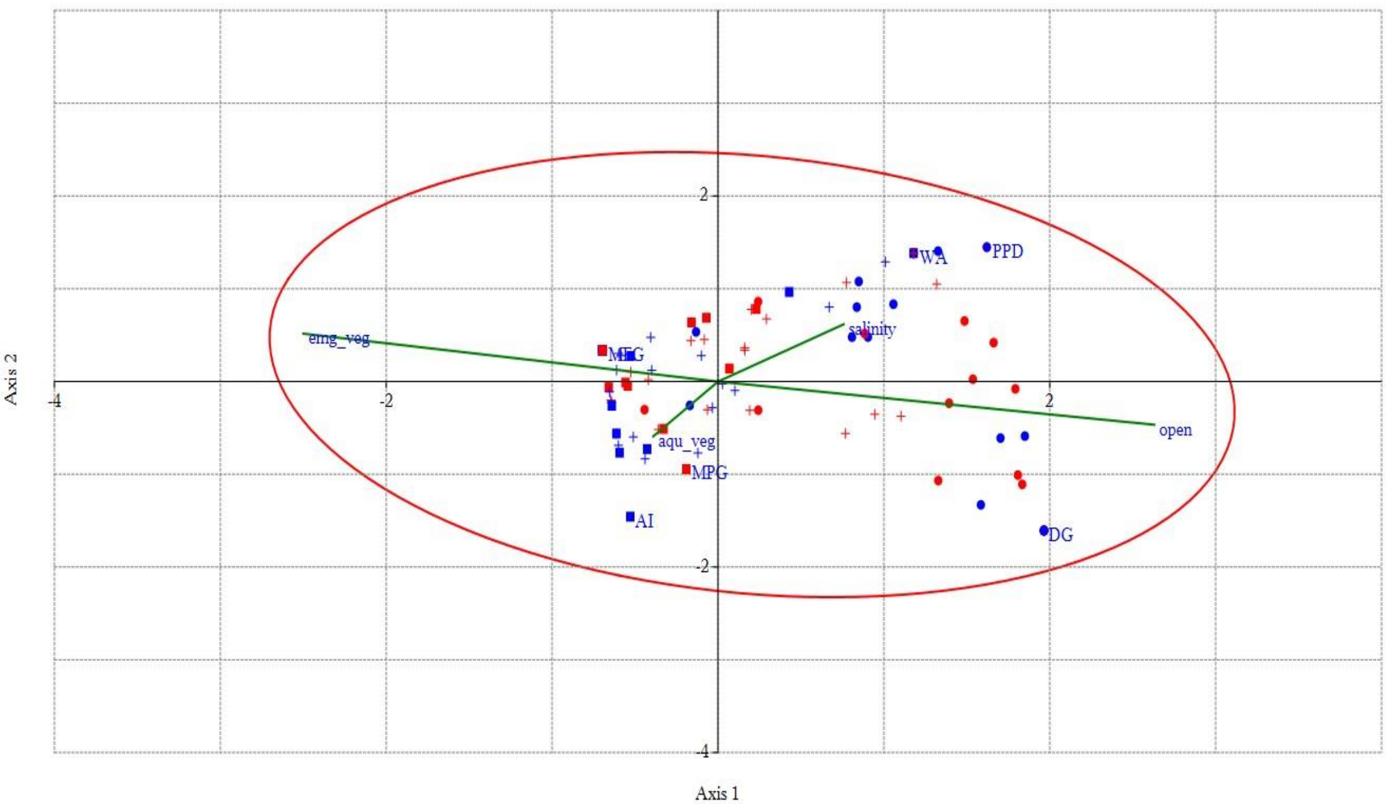


Figure 17. Canonical correspondence tri-plot relating waterbird guilds to environmental variables in Barataria Basin, LA, USA, 2014-2015. The orientation of each variable in relation to the axes 1 and 2 is represented by the green line, the length indicates the degree of correlation to the axes. Symbols: plus sign=edge plot, square=emergent plot, circle=open water plot; red points=saline site, blues points=fresh site. The red circle represents the 95% confidence ellipses.

Response curves help visualize how strongly each guild responded to changes in particular environmental conditions (Figure 18). Marsh foragers and gleaners were sensitive to changes in most variables. They showed strong positive responses to increasing aquatic and emergent vegetation but negative responses to increased open water and salinity. Aerial insectivores and mudflat probers and gleaners responded in a similar way for all variables. They responded positively to increases in aquatic and emergent vegetation but negatively to increases in salinity and open water.

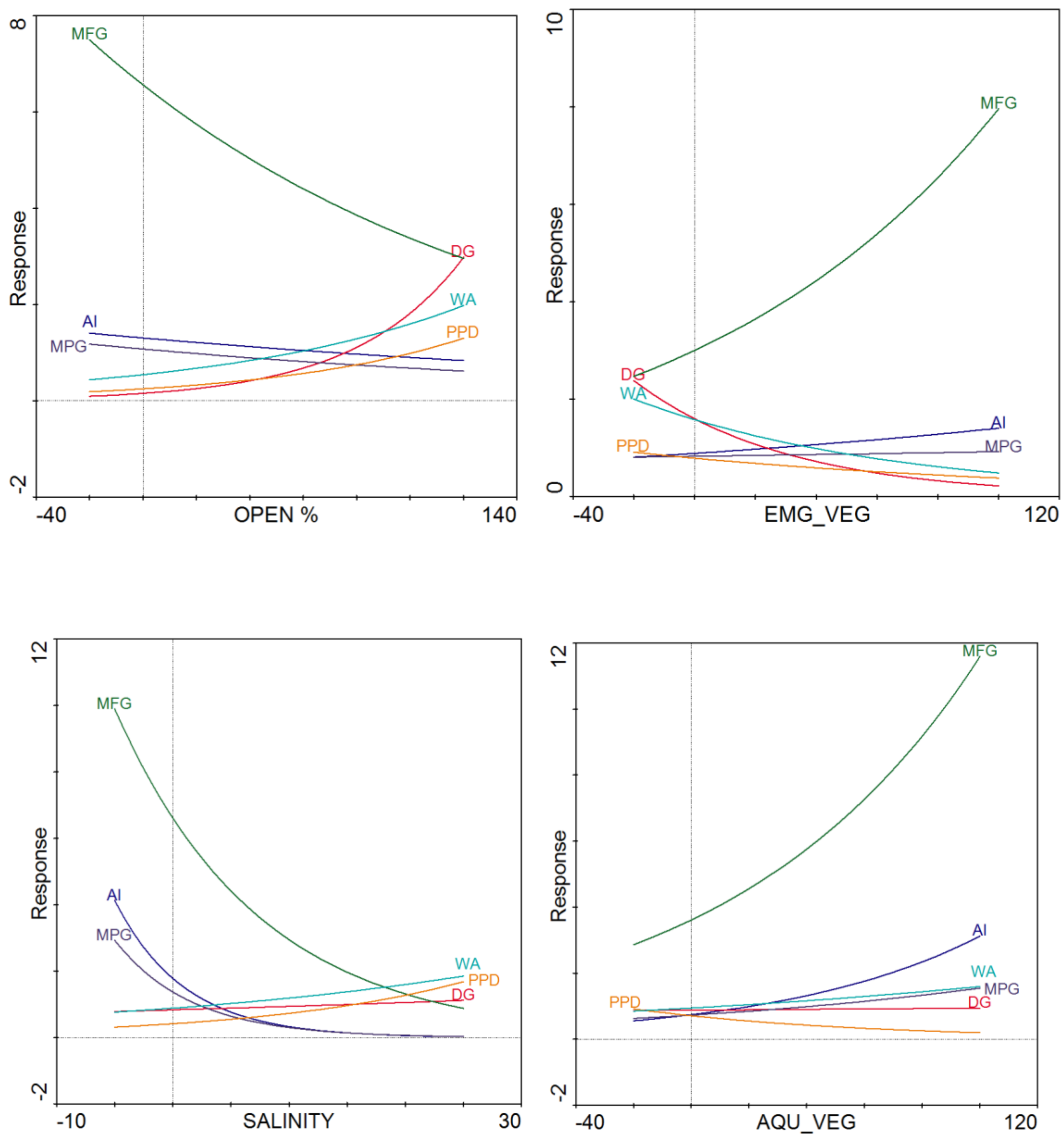


Figure 18. Guild response curves in relation to environmental variables in Barataria Basin, LA, USA 2014-2015

Species of Concern:

I observed nine species of concern from the 2014 The State of the Birds Watch List (Rosenberg et al. 2014). The Mottled Duck (n=10) was the only species observed from the Red Watch List (Table 7). Species from the Yellow Watch List included the King Rail (n=4), Lesser Yellowlegs (n=4), Willet (n=6), and Dunlin (n=1). Additionally, common species in steep decline included the Purple Gallinule (n=3), Herring Gull (n=1), Yellow-Billed Cuckoo (n=3), and Loggerhead Shrike (n=2). The total number of birds (n=34) that belonged to the species of concern, or species in steep decline, was too low for statistical analysis.

Table 8. Waterbird species of concern counted in Barataria Basin, LA, 2014-2015.

Species	Marsh Type	Emergent	Edge	Open Water
Dunlin	Fresh	0	0	0
	Saline	0	1	0
Herring Gull	Fresh	0	0	0
	Saline	0	0	1
King Rail	Fresh	3	1	0
	Saline	0	0	0
Lesser Yellowlegs	Fresh	0	0	0
	Saline	0	2	0
Loggerhead Shrike	Fresh	0	0	0
	Saline	0	2	0
Mottled Duck	Fresh	0	3	2
	Saline	0	1	4
Purple Gallinule	Fresh	1	2	0
	Saline	0	0	0
Willet	Fresh	0	0	0
	Saline	1	4	1
Yellow-billed Cuckoo	Fresh	1	2	0
	Saline	0	0	0

CHAPTER 4: DISCUSSION

My study supported the hypothesis that salinity, microhabitats, and finer environmental factors significantly affect waterbird use. I found that edge habitat, vegetation, salinity, and open water availability were the parameters that best explained waterbird habitat use in Louisiana wetlands. Few studies have examined these parameters on waterbirds in Louisiana and this study is the first to compare edge use to both open water and interior emergent habitat across multiple salinity regimes. These parameters aid in explaining why certain groups of waterbirds use a particular habitat and will help biologists and managers predict effects of habitat conversion from emergent wetland to open water on waterbirds in Louisiana. Parameters that I estimated may also be useful to restoration planners wanting to compare the effects of potential wetland restoration projects on waterbirds.

I found that edge microhabitats supported greater waterbird species and guild richness compared to open water and emergent plots; I also found that this edge effect differed between fresh and saline marsh. These differences in waterbird abundance and species are best explained by the presence of a more complex vegetation community that increased niche availability. Emergent and submerged aquatic vegetation (SAV) were both present at edge plots, and floating aquatic vegetation (FAV) was found in fresh edge habitat. Open water microhabitats lacked emergent vegetation, and emergent microhabitats lacked both SAV and FAV. The presence of a diversity of habitat types in edge plots likely provided an increase in refuge and foraging potential for waterbirds. I found that species richness was lowest in saline emergent vegetation plots and this was likely due to the absence of aquatic vegetation that resulted in a less complex community. These explanations were reinforced through the canonical correspondence, where I demonstrated that most waterbirds are associated with both emergent and aquatic vegetation.

O'Connell and Nyman (2011) and Sullivan (2015) compared waterbird use at marsh edge to open water habitat, but O'Connell and Nyman worked only in brackish marsh dominated by *Spartina patens* and Sullivan worked only in fresh marshes. They both found that edge (emergent/open water interface) hosted greater species richness and greater density during most seasons. Weller and Spatcher (1965) also found that edge supported maximum species diversity and abundance for most species. Similarly, my edge plots had the greatest density and species richness when compared to other microhabitats. Furthermore, concordant with my study, Weller and Spatcher (1965) found that species richness and abundance generally decrease with increasing open water, but some swimming species may increase. I found that edge habitat supported 1.9 times more waterbird species richness and 1.8 times more guild richness than emergent and open water habitat regardless of salinity type. Weller and Spatcher (1965) modeled the habitat cycle of semi-permanent marshes in the midwestern glacial pothole region, which closely mimics the succession of wetland degradation of Louisiana wetlands. If wetland degradation continues at its anticipated rate, the shifts in wetland communities will cause some species to increase while others will decrease. Species that associate with open water (e.g., dabblers and grubbers, wading ambushers, piscivorous plungers and divers) would likely increase, while most other species (e.g., marsh foragers and gleaners, aerial insectivores, mudflat probers and gleaners) associated with emergent vegetation would decrease.

Species richness varied throughout the year, likely due to changing habitat conditions and the arrival and departure of migratory species in southeastern Louisiana. Species richness did not differ between fresh and saline areas in the summer months, when environmental conditions were relatively stable. I found that the most species-rich month for waterbirds, regardless of salinity type or microhabitat, was the spring month of April. This differs from Sullivan (2015), who found greater species richness in the winter and summer seasons for most sites.

Waterbird density was greater in fresh habitat for both emergent and edge microhabitats when compared to saline emergent and edge habitat regardless of time of year (month). This differs from O'Connell and Nyman (2011) who found that waterbird densities differed seasonally depending on their foraging guild based on the time of year the birds migrate. Saline open water microhabitats had greater waterbird densities when compared to saline emergent habitat. However, I did find that waterbird density did not vary by salinity for open water microhabitats, instead densities in open water were equal regardless of salinity type. The consistency of waterbird density at open water plots regardless of salinity is most likely attributed to the fact that both salinity types similarly provided no refuge for waterbirds, but did provide beneficial foraging for certain waterbird species (e.g., dabblers and grubbers; piscivorous plungers and divers; and wading ambushers). Within both emergent and edge microhabitats, the amount and diversity of refuge and foraging habitat varied between salinity types. I found that the effects of edge on density differed between fresh and saline areas. Assuming that the edge effect is defined as the ratio of waterbirds in edge habitat compared to open water, then the edge effect was 1.4:1.0 in fresh marsh but 1.2:1.0 in saline marsh. Similarly, Palmisano (1973) found greater waterfowl abundance in fresh marshes than saline within Louisiana wetlands.

Perhaps the most surprising finding was that beneficial edge effects extended to at least 15 meters out from the marsh edge. This differs from past studies in south Louisiana that assumed that the edge effects is limited to open water within 0-10 m of emergent vegetation (Sullivan 2015, O'Connell and Nyman 2010). In fresh habitat, this large edge effect might partially be explained by waterbirds often using thick floating mats of *Eichhornia crassipes* to extend their foraging range. Within saline communities this large edge effect may be that because these areas are more tidally influenced, trapping more prey items for waterbirds. Piscivorous plungers and divers were often seen foraging in the open water area of the marsh edge. However, Baltz and Rakocinski (1993) concluded that for nekton, the edge effect was limited to within seven meters of marsh edge. Perhaps foraging waterbirds are more indicative of their nekton prey than researchers using throw-traps.

Also surprising was that mean water depth was a weak predictor of species and guilds associations. Water depth is often cited as one of the main drivers and limiting factors in waterbird use (Bancroft et al. 2002, Lantz et al. 2010, Rajpar et al. 2011). Rather, my results were similar to Esters (1986) who found significant correlations between Mottled Duck use and areas of open water habitat in Louisiana wetlands, but did not find significant relationships between their use and overall water depth. I found that availability of open water habitat, not water depth, was a better predictor of waterfowl use. I also found that emergent and aquatic vegetation structures were strong predictors of species and guild use. It may be that water depth was confounded with the emergent and aquatic vegetation communities, and thus indirectly driving waterbird use. In Louisiana wetlands, where much work has been done modeling the hydrologic drivers of wetland plant productivity and richness (Snedden and Steyer 2013, CPRA 2012), these wetland plant models could be used jointly to simulate the effects of different wetland restoration techniques on waterbirds. These models would allow predicting optimal vegetation and water depth ranges for waterbirds.

It is important to note that much of the analyses were driven by the 18 waterbird species that made up 99% of all the waterbirds observed. Additionally, the marsh foragers and gleaners guild made up roughly 56% of the guild use and were the major guild driving analysis. While our findings suggest that greater attention should paid toward understanding the use of waterbird at finer scales, it should also be noted that our study took place on a rather small scale; therefore, a similar study on a larger scale would bring more insight into the best means of managing waterbirds across the landscape. For instance, a study extending across all salinity regimes in coastal Louisiana would increase the understanding of waterbird habitat use in the transitional area of intermediate and brackish marsh when compared to saline and fresh marsh types. Investigating use across multiple hydrologic basins would allow for making predictions coastwide in Louisiana. Also, examining the extent of marsh edge use past the 15 m range could quantify the threshold of bird use from the edge.

Particularly in saline habitat, examining the influence of tides on the edge use (which I was unable to survey) would bring more understanding into waterbird use at varying water levels.

Anticipating and modeling the manner in which wetland ecology governs waterbird use is essential. By investigating the effects of a comprehensive set of spatial, temporal, and environmental parameters on waterbird habitat use within Louisiana estuarine wetlands, I found that the associations between waterbirds and these parameters were complex. I showed that factors such as edge, salinity, aquatic and emergent plants, and open water availability were all strongly related to habitat use by waterbirds. Overall, fresh edge habitats supported the highest density of birds, but both fresh and saline habitats provided beneficial habitat for waterbirds and there were species that were unique to each salinity type. Maximizing edge habitat, especially fresh edge habitat, is essential for providing beneficial habitat for both waterbird species richness and density. As the sea level rises, freshwater flows change, and managers seek to respond and adapt to these shifts, understanding waterbird habitat associations will be useful in attempts to simulate the effects of wetland loss, salinity changes, and restoration effects on habitat quality for waterbirds in coastal Louisiana and other coastal areas.

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APPENDIX A: STANDARD AVIAN SPECIES ALPHA CODES

Table A.1. Standard alpha codes (Pyle and DeSantes 2014) and scientific names for all identified bird species observed in all study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Alpha Code	Common Name	Scientific Name
AMCO	American Coot	*Fulica americana*
ANHI	Anhinga	*Anhinga anhinga*
AWPE	American White Pelican	*Pelecanus erythrorhynchos*
BAEA	Bald Eagle	*Haliaeetus leucocephalus*
BARS	Barn Swallow	*Hirundo rustica*
BBWD	Black-bellied Whistling-Duck	*Dendrocygna autumnalis*
BCNH	Black-crowned Night Heron	*Nycticorax nycticorax*
BEKI	Belted Kingfisher	*Megaceryle alcyon*
BLVU	Black Vulture	*Coragyps atratus*
BNST	Black-necked Stilt	*Himantopus mexicanus*
BRPE	Brown Pelican	*Pelcanus occidentalis*
BTGR	Boat-tailed Grackle	*Quiscalus major*
BWTE	Blue-winged Teal	*Anas discors*
CARW	Carolina Wren	*Thryothorus ludovicianus*
CEDW	Cedar Waxwing	*Bombycilla cedrorum*
CLRA	Clapper Rail	*Rallus longirostis*
COGA	Common Gallinule	*Gallinula galeata*
COTE	Common Tern	*Sterna hirundo*
DAIB	Dark Ibis[a]	*Plegadis* sp.
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*
DUNL	Dunlin	*Calidris alpina*
EAKI	Eastern Kingbird	*Tyrannus tyrannus*
FOTE	Forster's Tern	*Sterna forsteri*
GADW	Gadwall	*Anas strepera*
GBHE	Great Blue Heron	*Ardea herodias*
GLIB	Glossy Ibis	*Plegadis falcinellus*
GREG	Great Egret	*Ardea alba*
GRHE	Green Heron	*Butorides virescens*
GWTE	Green-winged Teal	*Anas carolinensis*
HERG	Herring Gull	*Larus argentatus*
KILL	Killdeer	*Charadrius vociferus*
KIRA	King Rail	*Rallus elegans*
LAGU	Laughing Gull	*Leucophaeus atricilla*
LBHE	Little Blue Heron	*Egretta caerulea*
LETE	Least Tern	*Sternula antillarum*
LEYE	Lesser Yellowlegs	*Tringa flavipes*
LIBI	Least Bittern	*Ixobrychus exilis*

(Table A.1 continued)

Alpha Code	Common Name	Scientific Name
LOSH	Loggerhead Shrike	*Lanius ludovicianus*
MAWR	Marsh Wren	*Cistothorus palustris*
NECO	Neotropic Cormorant	*Phalacrocorax brasilianus*
NOHA	Northern Harrier	*Circus cyaneus*
NRWS	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
OSPR	Osprey	*Pandion haliaetus*
PBGR	Pied-billed Grebe	*Podilymbus podiceps*
PUGA	Purple Gallinule	*Porphyrio martinicus*
PUMA	Purple Martin	*Progne subis*
ROSP	Roseate Spoonbill	*Platalea ajaja*
ROYT	Royal Tern	*Thalasseus maximus*
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*
SATE	Sandwich Tern	*Thalasseus sandvicensis*
SAVS	Savannah Sparrow	*Passerculus sandwichensis*
SESP	Seaside Sparrow	*Ammodramus maritimus*
SNEG	Snowy Egret	*Egretta thula*
SORA	Sora	*Porzana carolina*
SWSP	Swamp Sparrow	*Melospiza georgiana*
TRES	Tree Swallow	*Tachycineta bicolor*
TRHE	Tricolored Heron	*Egretta tricolor*
TUVU	Turkey Vulture	*Carthartes aura*
UNSP	Unidentified Sparrow	Family: Emberizidae
UNSW	Unidentified Swallow	Family: Hirundinidae
UNWR	Unidentified Wren	Family: *Troglodytidae*
VIRA	Virginia Rail	*Rallus limicola*
WFIB	White-faced Ibis	*Plegadis chihi*
WHIB	White Ibis	*Eudocimus albus*
WILL	Willet	*Tringa semipalmata*
WTSP	White-throated Sparrow	*Zonotrichia albicollis*
YBCU	Yellow-billed Cuckoo	*Coccyzus americanus*
YCNH	Yellow-crowned Night Heron	*Nyctanassa violacea*

[a]Non-standard naming and alpha code for *Plegadis* sp. when unable to identify to species (Pickens and King 2014).

APPENDIX B: SPECIES FREQUENCY TABLES

Table B.1. Frequency of all waterbirds observed within all study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Species Alpha Code	Frequency	Percent	Cumulative Frequency	Cumulative Percent
RWBL	258	23.35	258	23.35
BTGR	84	7.60	342	30.95
BARS	63	5.70	405	36.65
COGA	62	5.61	467	42.26
GREG	49	4.43	516	46.7
WHIB	47	4.25	563	50.95
BWTE	46	4.16	609	55.11
BNST	37	3.35	646	58.46
TRES	36	3.26	682	61.72
SESP	35	3.17	717	64.89
AMCO	27	2.44	744	67.33
SNEG	27	2.44	771	69.77
MIKI	26	2.35	797	72.13
NRWS	20	1.81	817	73.94
WFIB	19	1.72	836	75.66
DCCO	16	1.45	852	77.1
FOTE	15	1.36	867	78.46
CLRA	14	1.27	881	79.73
TUVU	13	1.18	894	80.9
LAGU	12	1.09	906	81.99

(Table B.1 continued)

Species Alpha Code	Frequency	Percent	Cumulative Frequency	Cumulative Percent
LETE	12	1.09	918	83.08
MODU	10	0.90	938	84.89
UNSW	10	0.90	948	85.79
BAEA	9	0.81	957	86.61
LBHE	9	0.81	966	87.42
DAIB	8	0.72	974	88.14
TRHE	8	0.72	982	88.87
AWPE	6	0.54	988	89.41
BBWD	6	0.54	994	89.95
BRPE	6	0.54	1000	90.5
ROSP	6	0.54	1006	91.04
SATE	6	0.54	1012	91.58
WILL	6	0.54	1018	92.13
GRHE	5	0.45	1023	92.58
SORA	5	0.45	1028	93.03
BLVU	4	0.36	1032	93.39
CEDW	4	0.36	1036	93.76
GWTE	4	0.36	1040	94.12
KIRA	4	0.36	1044	94.48
LEYE	4	0.36	1048	94.84
MAWR	4	0.36	1052	95.2

(Table B.1 continued)

Species Alpha Code	Frequency	Percent	Cumulative Frequency	Cumulative Percent
NOHA	4	0.36	1056	95.57
SWSP	4	0.36	1060	95.93
GLIB	3	0.27	1063	96.2
PUGA	3	0.27	1066	96.47
PUMA	3	0.27	1069	96.74
ROYT	3	0.27	1072	97.01
UNSP	3	0.27	1075	97.29
YBCU	3	0.27	1078	97.56
YCNH	3	0.27	1081	97.83
COTE	2	0.18	1083	98.01
LOSH	2	0.18	1085	98.19
OSPR	2	0.18	1087	98.37
PBGR	2	0.18	1089	98.55
SAVS	2	0.18	1091	98.73
UNWR	2	0.18	1093	98.91
WTSP	2	0.18	1095	99.1
ANHI	1	0.09	1096	99.19
BEKI	1	0.09	1097	99.28
CARW	1	0.09	1098	99.37
DUNL	1	0.09	1099	99.46
EAKI	1	0.09	1100	99.55

(Table B.1 continued)

Species Alpha Code	Frequency	Percent	Cumulative Frequency	Cumulative Percent
GADW	1	0.09	1101	99.64
HERG	1	0.09	1102	99.73
KILL	1	0.09	1103	99.82
NECO	1	0.09	1104	99.91
VIRA	1	0.09	1105	100

Table B.2. Frequency of all waterbirds observed within all freshwater study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
RWBL	204	26.56	204	26.56
BTGR	77	10.03	281	36.59
COGA	62	8.07	343	44.66
BARS	54	7.03	397	51.69
WHIB	46	5.99	443	57.68
BNST	37	4.82	480	62.5
TRES	28	3.65	508	66.15
MIKI	26	3.39	534	69.53
BWTE	23	2.99	557	72.53
AMCO	22	2.86	579	75.39
GREG	21	2.73	600	78.13
NRWS	20	2.60	620	80.73
WFIB	19	2.47	639	83.2
SNEG	17	2.21	656	85.42
UNSW	10	1.30	666	86.72
BAEA	9	1.17	675	87.89
DAIB	8	1.04	683	88.93
BBWD	6	0.78	689	89.71
MODU	6	0.78	695	90.49
GRHE	5	0.65	700	91.15
CEDW	4	0.52	704	91.67
DCCO	4	0.52	708	92.19
KIRA	4	0.52	712	92.71
LEYE	4	0.52	716	93.23
MAWR	4	0.52	720	93.75
NOHA	4	0.52	724	94.27
SORA	4	0.52	728	94.79
SWSP	4	0.52	732	95.31
GBHE	3	0.39	735	95.7
GLIB	3	0.39	738	96.09
GWTE	3	0.39	741	96.48

(Table B.2 continued)

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
LBHE	3	0.39	744	96.88
PUGA	3	0.39	747	97.27
YBCU	3	0.39	750	97.66
FOTE	2	0.26	752	97.92
OSPR	2	0.26	754	98.18
TRHE	2	0.26	756	98.44
TUVU	2	0.26	758	98.7
UNWR	2	0.26	760	98.96
WTSP	2	0.26	762	99.22
ANHI	1	0.13	763	99.35
CARW	1	0.13	764	99.48
GADW	1	0.13	765	99.61
KILL	1	0.13	766	99.74
UNSP	1	0.13	767	99.87
VIRA	1	0.13	768	100

Table B.3. Frequency of all waterbirds observed within all saline study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
RWBL	54	16.02	54	16.02
SESP	35	10.39	89	26.41
GREG	28	8.31	117	34.72
BWTE	23	6.82	140	41.54
CLRA	14	4.15	154	45.7
FOTE	13	3.86	167	49.55
DCCO	12	3.56	179	53.12
LAGU	12	3.56	191	56.68
LETE	12	3.56	203	60.24
TUVU	11	3.26	214	63.5
SNEG	10	2.97	224	66.47
BARS	9	2.67	233	69.14
TRES	8	2.37	241	71.51
BTGR	7	2.08	248	73.59
GBHE	7	2.08	255	75.67
AWPE	6	1.78	261	77.45
BRPE	6	1.78	267	79.23
LBHE	6	1.78	273	81.01
ROSP	6	1.78	279	82.79
SATE	6	1.78	285	84.57
TRHE	6	1.78	291	86.35
WILL	6	1.78	297	88.13
AMCO	5	1.48	302	89.61
BLVU	4	1.19	306	90.8
MODU	4	1.19	310	91.99
PUMA	3	0.89	313	92.88
ROYT	3	0.89	316	93.77
YCNH	3	0.89	319	94.66
COTE	2	0.59	321	95.25
LOSH	2	0.59	323	95.85
PBGR	2	0.59	325	96.44
SAVS	2	0.59	327	97.03
UNSP	2	0.59	329	97.63

(Table B.3 continued)

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BEKI	1	0.30	330	97.92
DUNL	1	0.30	331	98.22
EAKI	1	0.30	332	98.52
GWTE	1	0.30	333	98.81
HERG	1	0.30	334	99.11
NECO	1	0.30	335	99.41
SORA	1	0.30	336	99.7
WHIB	1	0.30	337	100

Table B.4. Frequency of all waterbirds observed within all edge study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
RWBL	144	23.49	144	23.49
BTGR	49	7.99	193	31.48
COGA	40	6.53	233	38.01
BARS	39	6.36	272	44.37
GREG	29	4.73	301	49.1
WHIB	29	4.73	330	53.83
MIKI	25	4.08	355	57.91
TRES	25	4.08	380	61.99
BNST	20	3.26	400	65.25
BWTE	19	3.10	419	68.35
SESP	19	3.10	438	71.45
NRWS	14	2.28	452	73.74
FOTE	11	1.79	463	75.53
SNEG	10	1.63	473	77.16
CLRA	7	1.14	480	78.3
AMCO	6	0.98	486	79.28
BBWD	6	0.98	492	80.26
LETE	6	0.98	498	81.24
TUVU	6	0.98	504	82.22
WFIB	6	0.98	510	83.2
DAIB	5	0.82	515	84.01
DCCO	5	0.82	520	84.83
UNSW	5	0.82	525	85.64
BRPE	4	0.65	529	86.3
GBHE	4	0.65	533	86.95
LAGU	4	0.65	537	87.6
MODU	4	0.65	541	88.25
ROSP	4	0.65	545	88.91
SWSP	4	0.65	549	89.56
WILL	4	0.65	553	90.21
AWPE	3	0.49	556	90.7
BAEA	3	0.49	559	91.19
CEDW	3	0.49	562	91.68

(Table B.4 continued)

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
GLIB	3	0.49	565	92.17
GRHE	3	0.49	568	92.66
PUMA	3	0.49	571	93.15
SORA	3	0.49	574	93.64
TRHE	3	0.49	577	94.13
UNSP	3	0.49	580	94.62
BLVU	2	0.33	582	94.94
COTE	2	0.33	584	95.27
LOSH	2	0.33	586	95.6
MAWR	2	0.33	588	95.92
PUGA	2	0.33	590	96.25
ROYT	2	0.33	592	96.57
SATE	2	0.33	594	96.9
SAVS	2	0.33	596	97.23
UNWR	2	0.33	598	97.55
WTSP	2	0.33	600	97.88
YBCU	2	0.33	602	98.21
ANHI	1	0.16	603	98.37
BEKI	1	0.16	604	98.53
DUNL	1	0.16	605	98.69
GADW	1	0.16	606	98.86
KIRA	1	0.16	607	99.02
LBHE	1	0.16	608	99.18
NOHA	1	0.16	609	99.35
OSPR	1	0.16	610	99.51
PBGR	1	0.16	611	99.67
VIRA	1	0.16	612	99.84
YCNH	1	0.16	613	100

Table B.5. Frequency of all waterbirds observed within all emergent study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
RWBL	92	33.33	92	33.33
BTGR	24	8.70	116	42.03
BARS	20	7.25	136	49.28
COGA	19	6.88	155	56.16
SESP	15	5.43	170	61.59
WHIB	14	5.07	184	66.67
BNST	11	3.99	195	70.65
WFIB	9	3.26	204	73.91
CLRA	7	2.54	211	76.45
NRWS	6	2.17	217	78.62
TRES	6	2.17	223	80.8
TUVU	5	1.81	228	82.61
UNSW	5	1.81	233	84.42
LEYE	4	1.45	237	85.87
SNEG	4	1.45	241	87.32
DAIB	3	1.09	244	88.41
GREG	3	1.09	247	89.49
KIRA	3	1.09	250	90.58
NOHA	3	1.09	253	91.67
BAEA	2	0.72	255	92.39
BWTE	2	0.72	257	93.12
DCCO	2	0.72	259	93.84
GRHE	2	0.72	261	94.57
LAGU	2	0.72	263	95.29
LBHE	2	0.72	265	96.01
MAWR	2	0.72	267	96.74
SORA	2	0.72	269	97.46
CARW	1	0.36	270	97.83
CEDW	1	0.36	271	98.19
EAKI	1	0.36	272	98.55
PUGA	1	0.36	273	98.91
TRHE	1	0.36	274	99.28
WILL	1	0.36	275	99.64
YBCU	1	0.36	276	100

Table B.6. Frequency of all waterbirds observed within all open water study plots in Barataria Basin, Louisiana, USA, 2014-2015.

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
BWTE	25	11.57	25	11.57
RWBL	22	10.19	47	21.76
AMCO	21	9.72	68	31.48
GREG	17	7.87	85	39.35
SNEG	13	6.02	98	45.37
BTGR	11	5.09	109	50.46
DCCO	9	4.17	118	54.63
BNST	6	2.78	124	57.41
GBHE	6	2.78	130	60.19
LAGU	6	2.78	136	62.96
LBHE	6	2.78	142	65.74
LETE	6	2.78	148	68.52
MODU	6	2.78	154	71.3
TRES	5	2.31	159	73.61
BAEA	4	1.85	163	75.46
BARS	4	1.85	167	77.31
FOTE	4	1.85	171	79.17
GWTE	4	1.85	175	81.02
SATE	4	1.85	179	82.87
TRHE	4	1.85	183	84.72
WFIB	4	1.85	187	86.57
WHIB	4	1.85	191	88.43
AWPE	3	1.39	194	89.81
COGA	3	1.39	197	91.2
BLVU	2	0.93	199	92.13
BRPE	2	0.93	201	93.06
ROSP	2	0.93	203	93.98
TUVU	2	0.93	205	94.91
YCNH	2	0.93	207	95.83
HERG	1	0.46	208	96.3
KILL	1	0.46	209	96.76
MIKI	1	0.46	210	97.22
NECO	1	0.46	211	97.69

(Table B.6 continued)

Species	Frequency	Percent	Cumulative Frequency	Cumulative Percent
OSPR	1	0.46	212	98.15
PBGR	1	0.46	213	98.61
ROYT	1	0.46	214	99.07
SESP	1	0.46	215	99.54
WILL	1	0.46	216	100

APPENDIX C: ENVIRONMENTAL AND HABITAT TABLES

Table C.1. All vegetation species observed within study plots in Barataria Basin, LA, 2014-2015. Listed in order of occurrence.

Site	Emergent vegetation species	SAV species	FAV species
CRMS 0258	*Spartina alterniflora*	*Ruppia maritima*	
	Distichlis spicata		
	Schoenoplectus robustus		
	Ipoemea sagittata		
	Iva frutescens		
	Baccharis halimifolia		
	Amaranthus australis		
	Symphyotrichum subulatum		
	Symphyotrichum tenuifolium		
CRMS 0282	*Spartina alterniflora*	*Ruppia maritima*	
	Distichlis spicata		
	Spartina patens		
	Schoenoplectus robustus		
CRMS 3166	*Sagittaria lancifolia*	*Ceratophyllum demersum*	*Eichhornia crassipes*
	Polygonum punctatum	*Cabomba caroliniana*	*Lemna minor*
	Alternanthera philoxeroides	*Najas guadalupensis*	*Salvinia minima*
	Hydrocotyle umbellata	*Pontamogeton pusillus*	*Nymphoides aquatica*
	Sagittaria lancifolia		
	Symphyotrichum tenuifolium		
	Amaranthus australis		
	Bidens laevis		
	Ludwigia grandiflora		
	Ludwigia spp.		
	Phyla lanceolata		
	Hydrocotyle ranuculoides		
	Kosteletzkya virginica		
	Typha latifolia		
	Sesbania herbacea		

(Table C.1 continued)

Site	Emergent vegetation species	SAV species	FAV species
CRMS 3169	*Sagittaria lancifolia*	*Cabomba caroliniana*	*Eichhornia crassipes*
	Colocasia esculenta	*Ceratophyllum demersum*	*Salvinia minima*
	Zizaniopsis miliacea	*Hydrilla verticullata*	*Lemna minor*
	Alternanthera philoxeroides		*Salvinia molesta*
	Ludwigia grandiflora		*Azolla caroliniana*
	Sesbania herbacea		*Nelumbo lutea**
	Vigna luteola		
	*Nelumbo lutea**		
	Hydrocotyle ranuculoides		
	Mikania scandens		
	Bidens laevis		
	Ludwigia octavalis		
	Ludwigia sp.		
	Sesbania drumondii		
	Kosteletzkya virginica		
	Cirsium muticum		

**Nelumbo* sp. was classified as floating aquatic when plants were floating on surface, and emergent when plant was above water surface.

Table C.2. Summary of hydrological conditions for all sampling periods and sites in Barataria Basin, LA, USA, 2014-2015

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
25-Jul-2014	CRMS3166	fr_edge	0.23	15.6	10	60
25-Jul-2014	CRMS3169	fr_edge	0.2	12.8	9.5	60
7-Sep-2014	CRMS3166	fr_edge	0.24	58.6	43	60
7-Sep-2014	CRMS3169	fr_edge	0.26	46.1	32	30
19-Oct-2014	CRMS3166	fr_edge	0.23	44.7	32	60
28-Oct-2014	CRMS3169	fr_edge	0.23	34.1	26	15
19-Jan-2015	CRMS3166	fr_edge	0.26	43.3	31	100
19-Jan-2015	CRMS3169	fr_edge	0.19	8.9	8	0
29-Mar-2015	CRMS3166	fr_edge	0.25	26.1	21	60
29-Mar-2015	CRMS3169	fr_edge	0.15	28.1	5	40
25-Apr-2015	CRMS3166	fr_edge	0.29	31.5	30	30
25-Apr-2015	CRMS3169	fr_edge	0.29	28.1	5	20
6-Jun-2015	CRMS3166	fr_edge	0.16	90.42	30	60
6-Jun-2015	CRMS3169	fr_edge	0.19	26.16	5	60
28-Aug-2015	CRMS3166	fr_edge	0.19	26.4	14	75
28-Aug-2015	CRMS3169	fr_edge	0.21	13.1	9	80
18-Oct-2015	CRMS3169	fr_edge	0.27	60.96	44	40
22-Oct-2015	CRMS3166	fr_edge	0.24	46.21	37	100
14-Dec-2015	CRMS3166	fr_edge	0.2	74.5	43	60
14-Dec-2015	CRMS3169	fr_edge	0.25	13.3	5	60
25-Jul-2014	CRMS3166	fr_em	0.23	3	.	0
25-Jul-2014	CRMS3169	fr_em	0.2	5	.	0
7-Sep-2014	CRMS3166	fr_em	0.24	32	.	0
7-Sep-2014	CRMS3169	fr_em	0.26	10	.	0

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
19-Oct-2014	CRMS3166	fr_em	0.23	15	.	0
28-Oct-2014	CRMS3169	fr_em	0.23	20	.	0
19-Jan-2015	CRMS3166	fr_em	0.26	12	.	0
19-Jan-2015	CRMS3169	fr_em	0.19	8	.	0
29-Mar-2015	CRMS3166	fr_em	0.25	5	.	0
29-Mar-2015	CRMS3169	fr_em	0.15	2	.	0
25-Apr-2015	CRMS3166	fr_em	0.29	3	.	0
25-Apr-2015	CRMS3169	fr_em	0.29	2	.	0
6-Jun-2015	CRMS3166	fr_em	0.16	0	.	0
6-Jun-2015	CRMS3169	fr_em	0.19	2	.	0
28-Aug-2015	CRMS3166	fr_em	0.19	0	.	0
28-Aug-2015	CRMS3169	fr_em	0.21	0	.	0
18-Oct-2015	CRMS3169	fr_em	0.27	30	.	0
22-Oct-2015	CRMS3166	fr_em	0.24	6	.	0
14-Dec-2015	CRMS3166	fr_em	0.2	20	.	0
14-Dec-2015	CRMS3169	fr_em	0.25	5	.	0
25-Jul-2014	CRMS3166	fr_open	0.23	33.3	.	100
25-Jul-2014	CRMS3169	fr_open	0.2	15.4	.	100
7-Sep-2014	CRMS3166	fr_open	0.24	98.2	.	100
7-Sep-2014	CRMS3169	fr_open	0.26	63.4	.	100
19-Oct-2014	CRMS3166	fr_open	0.23	96	.	100
28-Oct-2014	CRMS3169	fr_open	0.23	52.7	.	100
19-Jan-2015	CRMS3166	fr_open	0.26	63.1	.	100
19-Jan-2015	CRMS3169	fr_open	0.19	43.7	.	100
29-Mar-2015	CRMS3166	fr_open	0.25	55.4	.	100

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
29-Mar-2015	CRMS3169	fr_open	0.15	31.7	.	100
25-Apr-2015	CRMS3166	fr_open	0.29	68.5	.	100
25-Apr-2015	CRMS3169	fr_open	0.29	36.8	.	100
6-Jun-2015	CRMS3166	fr_open	0.16	96.01	.	100
6-Jun-2015	CRMS3169	fr_open	0.19	38.86	.	100
28-Aug-2015	CRMS3166	fr_open	0.19	51.9	.	100
28-Aug-2015	CRMS3169	fr_open	0.21	36.6	.	100
18-Oct-2015	CRMS3169	fr_open	0.27	65.5	.	100
22-Oct-2015	CRMS3166	fr_open	0.24	64.43	.	100
14-Dec-2015	CRMS3166	fr_open	0.2	70.8	.	100
14-Dec-2015	CRMS3169	fr_open	0.25	25.1	.	100
7-Jul-2014	CRMS0258	sal_edge	1.48	16.2	8	60
7-Jul-2014	CRMS0282	sal_edge	5	28.9	30	60
14-Sep-2014	CRMS0258	sal_edge	7.3	51.5	33	60
14-Sep-2014	CRMS0282	sal_edge	8.4	29.6	20	60
28-Oct-2014	CRMS0258	sal_edge	13.32	48.1	25	60
28-Oct-2014	CRMS0282	sal_edge	16.4	32.3	24	85
15-Jan-2015	CRMS0258	sal_edge	14.18	10.2	5	0
15-Jan-2015	CRMS0282	sal_edge	20.6	10	9	100
3-Apr-2015	CRMS0258	sal_edge	7.42	42.1	29	20
3-Apr-2015	CRMS0282	sal_edge	13.9	31.3	15	100
26-Apr-2015	CRMS0258	sal_edge	2.08	47.7	36	95
26-Apr-2015	CRMS0282	sal_edge	5.4	55.6	44	40
7-Jun-2015	CRMS0258	sal_edge	6.03	46	39	60
7-Jun-2015	CRMS0282	sal_edge	6.2	60	60	60

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
1-Sep-2015	CRMS0258	sal_edge	9.1	37.4	21	30
1-Sep-2015	CRMS0282	sal_edge	11.4	39.2	26	0
17-Oct-2015	CRMS0258	sal_edge	12.25	53.1	43	25
17-Oct-2015	CRMS0282	sal_edge	17.7	1	0.5	20
12-Dec-2015	CRMS0258	sal_edge	15.25	54.1	22	60
12-Dec-2015	CRMS0282	sal_edge	19.1	35.31	19	60
7-Jul-2014	CRMS0258	sal_em	1.48	1	.	0
7-Jul-2014	CRMS0282	sal_em	5	1	.	0
14-Sep-2014	CRMS0258	sal_em	7.3	8	.	0
14-Sep-2014	CRMS0282	sal_em	8.4	8	.	0
28-Oct-2014	CRMS0258	sal_em	13.32	9	.	0
28-Oct-2014	CRMS0282	sal_em	16.4	10	.	0
15-Jan-2015	CRMS0258	sal_em	14.18	0	.	0
15-Jan-2015	CRMS0282	sal_em	20.6	2	.	0
3-Apr-2015	CRMS0258	sal_em	7.42	0	.	0
3-Apr-2015	CRMS0282	sal_em	13.9	1	.	0
26-Apr-2015	CRMS0258	sal_em	2.08	0	.	0
26-Apr-2015	CRMS0282	sal_em	5.4	1	.	0
7-Jun-2015	CRMS0258	sal_em	6.03	0	.	0
7-Jun-2015	CRMS0282	sal_em	6.2	0	.	0
1-Sep-2015	CRMS0258	sal_em	9.1	1	.	0
1-Sep-2015	CRMS0282	sal_em	11.4	2	.	0
17-Oct-2015	CRMS0258	sal_em	12.25	2	.	0
17-Oct-2015	CRMS0282	sal_em	17.7	0	.	0
12-Dec-2015	CRMS0258	sal_em	15.25	0	.	0

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
12-Dec-2015	CRMS0282	sal_em	19.1	2	.	0
7-Jul-2014	CRMS0258	sal_open	1.48	27.1	.	100
7-Jul-2014	CRMS0282	sal_open	5	37.9	.	100
14-Sep-2014	CRMS0258	sal_open	7.3	78.5	.	100
14-Sep-2014	CRMS0282	sal_open	8.4	56.7	.	100
28-Oct-2014	CRMS0258	sal_open	13.32	69.6	.	100
28-Oct-2014	CRMS0282	sal_open	16.4	61.7	.	100
15-Jan-2015	CRMS0258	sal_open	14.18	7.8	.	100
15-Jan-2015	CRMS0282	sal_open	20.6	12.7	.	100
3-Apr-2015	CRMS0258	sal_open	7.42	44.3	.	100
3-Apr-2015	CRMS0282	sal_open	13.9	46.7	.	100
26-Apr-2015	CRMS0258	sal_open	2.08	65.8	.	100
26-Apr-2015	CRMS0282	sal_open	5.4	78.5	.	100
7-Jun-2015	CRMS0258	sal_open	6.03	52	.	100
7-Jun-2015	CRMS0282	sal_open	6.2	69	.	100
1-Sep-2015	CRMS0258	sal_open	9.1	63.8	.	100
1-Sep-2015	CRMS0282	sal_open	11.4	53.5	.	100
17-Oct-2015	CRMS0258	sal_open	12.25	62.09	.	100
17-Oct-2015	CRMS0282	sal_open	17.7	20.5	.	100
12-Dec-2015	CRMS0258	sal_open	15.25	81.53	.	100
12-Dec-2015	CRMS0282	sal_open	19.1	53.09	.	100
25-Jul-2014	CRMS3166	fr_edge	0.23	15.6	10	60
25-Jul-2014	CRMS3169	fr_edge	0.2	12.8	9.5	60
7-Sep-2014	CRMS3166	fr_edge	0.24	58.6	43	60
7-Sep-2014	CRMS3169	fr_edge	0.26	46.1	32	30

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
19-Oct-2014	CRMS3166	fr_edge	0.23	44.7	32	60
28-Oct-2014	CRMS3169	fr_edge	0.23	34.1	26	15
19-Jan-2015	CRMS3166	fr_edge	0.26	43.3	31	100
19-Jan-2015	CRMS3169	fr_edge	0.19	8.9	8	0
29-Mar-2015	CRMS3166	fr_edge	0.25	26.1	21	60
29-Mar-2015	CRMS3169	fr_edge	0.15	28.1	5	40
25-Apr-2015	CRMS3166	fr_edge	0.29	31.5	30	30
25-Apr-2015	CRMS3169	fr_edge	0.29	28.1	5	20
6-Jun-2015	CRMS3166	fr_edge	0.16	90.42	30	60
6-Jun-2015	CRMS3169	fr_edge	0.19	26.16	5	60
28-Aug-2015	CRMS3166	fr_edge	0.19	26.4	14	75
28-Aug-2015	CRMS3169	fr_edge	0.21	13.1	9	80
18-Oct-2015	CRMS3169	fr_edge	0.27	60.96	44	40
22-Oct-2015	CRMS3166	fr_edge	0.24	46.21	37	100
14-Dec-2015	CRMS3166	fr_edge	0.2	74.5	43	60
14-Dec-2015	CRMS3169	fr_edge	0.25	13.3	5	60
25-Jul-2014	CRMS3166	fr_em	0.23	3	.	0
25-Jul-2014	CRMS3169	fr_em	0.2	5	.	0
7-Sep-2014	CRMS3166	fr_em	0.24	32	.	0
7-Sep-2014	CRMS3169	fr_em	0.26	10	.	0
19-Oct-2014	CRMS3166	fr_em	0.23	15	.	0
28-Oct-2014	CRMS3169	fr_em	0.23	20	.	0
19-Jan-2015	CRMS3166	fr_em	0.26	12	.	0
19-Jan-2015	CRMS3169	fr_em	0.19	8	.	0
29-Mar-2015	CRMS3166	fr_em	0.25	5	.	0

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
29-Mar-2015	CRMS3169	fr_em	0.15	2	.	0
25-Apr-2015	CRMS3166	fr_em	0.29	3	.	0
25-Apr-2015	CRMS3169	fr_em	0.29	2	.	0
6-Jun-2015	CRMS3166	fr_em	0.16	0	.	0
6-Jun-2015	CRMS3169	fr_em	0.19	2	.	0
28-Aug-2015	CRMS3166	fr_em	0.19	0	.	0
28-Aug-2015	CRMS3169	fr_em	0.21	0	.	0
18-Oct-2015	CRMS3169	fr_em	0.27	30	.	0
22-Oct-2015	CRMS3166	fr_em	0.24	6	.	0
14-Dec-2015	CRMS3166	fr_em	0.2	20	.	0
14-Dec-2015	CRMS3169	fr_em	0.25	5	.	0
25-Jul-2014	CRMS3166	fr_open	0.23	33.3	.	100
25-Jul-2014	CRMS3169	fr_open	0.2	15.4	.	100
7-Sep-2014	CRMS3166	fr_open	0.24	98.2	.	100
7-Sep-2014	CRMS3169	fr_open	0.26	63.4	.	100
19-Oct-2014	CRMS3166	fr_open	0.23	96	.	100
28-Oct-2014	CRMS3169	fr_open	0.23	52.7	.	100
19-Jan-2015	CRMS3166	fr_open	0.26	63.1	.	100
19-Jan-2015	CRMS3169	fr_open	0.19	43.7	.	100
29-Mar-2015	CRMS3166	fr_open	0.25	55.4	.	100
29-Mar-2015	CRMS3169	fr_open	0.15	31.7	.	100
25-Apr-2015	CRMS3166	fr_open	0.29	68.5	.	100
25-Apr-2015	CRMS3169	fr_open	0.29	36.8	.	100
6-Jun-2015	CRMS3166	fr_open	0.16	96.01	.	100
6-Jun-2015	CRMS3169	fr_open	0.19	38.86	.	100

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
28-Aug-2015	CRMS3166	fr_open	0.19	51.9	.	100
28-Aug-2015	CRMS3169	fr_open	0.21	36.6	.	100
18-Oct-2015	CRMS3169	fr_open	0.27	65.5	.	100
22-Oct-2015	CRMS3166	fr_open	0.24	64.43	.	100
14-Dec-2015	CRMS3166	fr_open	0.2	70.8	.	100
14-Dec-2015	CRMS3169	fr_open	0.25	25.1	.	100
7-Jul-2014	CRMS0258	sal_edge	1.48	16.2	8	60
7-Jul-2014	CRMS0282	sal_edge	5	28.9	30	60
14-Sep-2014	CRMS0258	sal_edge	7.3	51.5	33	60
14-Sep-2014	CRMS0282	sal_edge	8.4	29.6	20	60
28-Oct-2014	CRMS0258	sal_edge	13.32	48.1	25	60
28-Oct-2014	CRMS0282	sal_edge	16.4	32.3	24	85
15-Jan-2015	CRMS0258	sal_edge	14.18	10.2	5	0
15-Jan-2015	CRMS0282	sal_edge	20.6	10	9	100
3-Apr-2015	CRMS0258	sal_edge	7.42	42.1	29	20
3-Apr-2015	CRMS0282	sal_edge	13.9	31.3	15	100
26-Apr-2015	CRMS0258	sal_edge	2.08	47.7	36	95
26-Apr-2015	CRMS0282	sal_edge	5.4	55.6	44	40
7-Jun-2015	CRMS0258	sal_edge	6.03	46	39	60
7-Jun-2015	CRMS0282	sal_edge	6.2	60	60	60
1-Sep-2015	CRMS0258	sal_edge	9.1	37.4	21	30
1-Sep-2015	CRMS0282	sal_edge	11.4	39.2	26	0
17-Oct-2015	CRMS0258	sal_edge	12.25	53.1	43	25
17-Oct-2015	CRMS0282	sal_edge	17.7	1	0.5	20
12-Dec-2015	CRMS0258	sal_edge	15.25	54.1	22	60

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
3-Apr-2015	CRMS0258	sal_open	7.42	44.3	.	100
3-Apr-2015	CRMS0282	sal_open	13.9	46.7	.	100
12-Dec-2015	CRMS0282	sal_edge	19.1	35.31	19	60
7-Jul-2014	CRMS0258	sal_em	1.48	1	.	0
7-Jul-2014	CRMS0282	sal_em	5	1	.	0
14-Sep-2014	CRMS0258	sal_em	7.3	8	.	0
14-Sep-2014	CRMS0282	sal_em	8.4	8	.	0
28-Oct-2014	CRMS0258	sal_em	13.32	9	.	0
28-Oct-2014	CRMS0282	sal_em	16.4	10	.	0
15-Jan-2015	CRMS0258	sal_em	14.18	0	.	0
15-Jan-2015	CRMS0282	sal_em	20.6	2	.	0
3-Apr-2015	CRMS0258	sal_em	7.42	0	.	0
3-Apr-2015	CRMS0282	sal_em	13.9	1	.	0
26-Apr-2015	CRMS0258	sal_em	2.08	0	.	0
26-Apr-2015	CRMS0282	sal_em	5.4	1	.	0
7-Jun-2015	CRMS0258	sal_em	6.03	0	.	0
7-Jun-2015	CRMS0282	sal_em	6.2	0	.	0
1-Sep-2015	CRMS0258	sal_em	9.1	1	.	0
1-Sep-2015	CRMS0282	sal_em	11.4	2	.	0
17-Oct-2015	CRMS0258	sal_em	12.25	2	.	0
17-Oct-2015	CRMS0282	sal_em	17.7	0	.	0
12-Dec-2015	CRMS0258	sal_em	15.25	0	.	0
12-Dec-2015	CRMS0282	sal_em	19.1	2	.	0
7-Jul-2014	CRMS0258	sal_open	1.48	27.1	.	100
7-Jul-2014	CRMS0282	sal_open	5	37.9	.	100

(Table C.2 continued)

date	site	habitat	salinity (ppt)	mean depth (cm)	depth at edge (cm)	open %
14-Sep-2014	CRMS0258	sal_open	7.3	78.5	.	100
14-Sep-2014	CRMS0282	sal_open	8.4	56.7	.	100
28-Oct-2014	CRMS0258	sal_open	13.32	69.6	.	100
28-Oct-2014	CRMS0282	sal_open	16.4	61.7	.	100
15-Jan-2015	CRMS0258	sal_open	14.18	7.8	.	100
15-Jan-2015	CRMS0282	sal_open	20.6	12.7	.	100
26-Apr-2015	CRMS0258	sal_open	2.08	65.8	.	100
26-Apr-2015	CRMS0282	sal_open	5.4	78.5	.	100
7-Jun-2015	CRMS0258	sal_open	6.03	52	.	100
7-Jun-2015	CRMS0282	sal_open	6.2	69	.	100
1-Sep-2015	CRMS0258	sal_open	9.1	63.8	.	100
1-Sep-2015	CRMS0282	sal_open	11.4	53.5	.	100
17-Oct-2015	CRMS0258	sal_open	12.25	62.09	.	100
17-Oct-2015	CRMS0282	sal_open	17.7	20.5	.	100
12-Dec-2015	CRMS0258	sal_open	15.25	81.53	.	100
12-Dec-2015	CRMS0282	sal_open	19.1	53.09	.	100

Table C.3. Summary of vegetation conditions for all sampling periods and sites in Barataria Basin, LA, USA, 2014-2015

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
25-Jul-2014	CRMS3166	fr_edge	10	30	6	38	83	2	91	3
25-Jul-2014	CRMS3169	fr_edge	0	40	4	36	50	2	91	5
7-Sep-2014	CRMS3166	fr_edge	5	55	4	44	58	4	91	4
7-Sep-2014	CRMS3169	fr_edge	30	40	4	56	58	2	83	4
19-Oct-2014	CRMS3166	fr_edge	5	35	4	34	58	4	91	4
28-Oct-2014	CRMS3169	fr_edge	0	85	4	16	25	2	83	5
19-Jan-2015	CRMS3166	fr_edge	0	0	.	.	75	2	33	3
19-Jan-2015	CRMS3169	fr_edge	40	60	0	12	75	2	25	3
29-Mar-2015	CRMS3166	fr_edge	15	25	3	24	16	1	33	3
29-Mar-2015	CRMS3169	fr_edge	20	40	4	26	25	1	8	2
25-Apr-2015	CRMS3166	fr_edge	10	60	2	28	50	4	66	3
25-Apr-2015	CRMS3169	fr_edge	10	70	3	26	16	1	0	0
6-Jun-2015	CRMS3166	fr_edge	10	40	4	32	33	4	58	3
6-Jun-2015	CRMS3169	fr_edge	0	40	6	42	58	2	58	4
28-Aug-2015	CRMS3166	fr_edge	25	25	3	50	75	4	66	3
28-Aug-2015	CRMS3169	fr_edge	0	20	4	28	25	2	83	4
18-Oct-2015	CRMS3169	fr_edge	25	35	3	30	25	2	83	2
22-Oct-2015	CRMS3166	fr_edge	0	0	.	.	41	4	91	4
14-Dec-2015	CRMS3166	fr_edge	15	25	3	20	83	4	75	1
14-Dec-2015	CRMS3169	fr_edge	5	35	3	22	83	3	58	4
25-Jul-2014	CRMS3166	fr_em	10	90	3	42	.	.	.	.
25-Jul-2014	CRMS3169	fr_em	5	95	5	42	.	.	.	.
7-Sep-2014	CRMS3166	fr_em	5	95	8	46	.	.	.	.
7-Sep-2014	CRMS3169	fr_em	15	85	3	50	.	.	.	.
19-Oct-2014	CRMS3166	fr_em	15	85	4	34	.	.	.	.

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
28-Oct-2014	CRMS3169	fr_em	30	70	5	32	.	.	.	.
19-Jan-2015	CRMS3166	fr_em	45	55	3	16	.	.	.	.
19-Jan-2015	CRMS3169	fr_em	80	20	1	18	.	.	.	.
29-Mar-2015	CRMS3166	fr_em	50	50	2	30	.	.	.	.
29-Mar-2015	CRMS3169	fr_em	30	55	2	28	.	.	.	.
25-Apr-2015	CRMS3166	fr_em	30	70	2	34	.	.	.	.
25-Apr-2015	CRMS3169	fr_em	50	50	2	28	.	.	.	.
6-Jun-2015	CRMS3166	fr_em	20	80	3	42	.	.	.	.
6-Jun-2015	CRMS3169	fr_em	10	75	3	22	.	.	.	.
28-Aug-2015	CRMS3166	fr_em	5	90	4	42	.	.	.	.
28-Aug-2015	CRMS3169	fr_em	5	95	2	60	.	.	.	.
18-Oct-2015	CRMS3169	fr_em	30	70	3	32	.	.	.	.
22-Oct-2015	CRMS3166	fr_em	30	70	2	32	.	.	.	.
14-Dec-2015	CRMS3166	fr_em	50	50	3	20	.	.	.	.
14-Dec-2015	CRMS3169	fr_em	60	40	1	24	.	.	.	.
25-Jul-2014	CRMS3166	fr_open	.	.	.	.	83	4	75	3
25-Jul-2014	CRMS3169	fr_open	.	.	.	.	50	2	91	4
7-Sep-2014	CRMS3166	fr_open	.	.	.	.	83	4	41	4
7-Sep-2014	CRMS3169	fr_open	.	.	.	.	75	2	91	4
19-Oct-2014	CRMS3166	fr_open	.	.	.	.	58	4	50	3
28-Oct-2014	CRMS3169	fr_open	.	.	.	.	58	2	66	5
19-Jan-2015	CRMS3166	fr_open	.	.	.	.	50	2	33	3
19-Jan-2015	CRMS3169	fr_open	.	.	.	.	0	0	0	0
29-Mar-2015	CRMS3166	fr_open	.	.	.	.	33	2	16	3
29-Mar-2015	CRMS3169	fr_open	.	.	.	.	0	0	0	0

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
25-Apr-2015	CRMS3166	fr_open	.	.	.	.	16	2	41	3
25-Apr-2015	CRMS3169	fr_open	.	.	.	.	0	0	0	0
6-Jun-2015	CRMS3166	fr_open	.	.	.	.	75	4	66	3
6-Jun-2015	CRMS3169	fr_open	.	.	.	.	66	2	66	3
28-Aug-2015	CRMS3166	fr_open	.	.	.	.	100	4	83	3
28-Aug-2015	CRMS3169	fr_open	.	.	.	.	41	2	58	4
18-Oct-2015	CRMS3169	fr_open	.	.	.	.	66	2	41	2
22-Oct-2015	CRMS3166	fr_open	.	.	.	.	66	4	58	2
14-Dec-2015	CRMS3166	fr_open	.	.	.	.	66	4	41	1
14-Dec-2015	CRMS3169	fr_open	.	.	.	.	58	3	0	0
7-Jul-2014	CRMS0258	sal_edge	10	30	3	32	41	1	0	0
7-Jul-2014	CRMS0282	sal_edge	0	50	2	32	0	0	0	0
14-Sep-2014	CRMS0258	sal_edge	15	85	6	34	16	1	0	0
14-Sep-2014	CRMS0282	sal_edge	5	35	1	40	0	0	0	0
28-Oct-2014	CRMS0258	sal_edge	10	30	2	32	16	1	0	0
28-Oct-2014	CRMS0282	sal_edge	0	15	1	34	0	0	0	0
15-Jan-2015	CRMS0258	sal_edge	20	80	3	34	0	0	0	0
15-Jan-2015	CRMS0282	sal_edge	0	0	.	.	0	0	0	0
3-Apr-2015	CRMS0258	sal_edge	20	60	3	34	8	1	0	0
3-Apr-2015	CRMS0282	sal_edge	0	0	.	.	0	0	0	0
26-Apr-2015	CRMS0258	sal_edge	0	5	1	32	75	1	0	0
26-Apr-2015	CRMS0282	sal_edge	60	0	0	.	0	0	0	0
7-Jun-2015	CRMS0258	sal_edge	0	40	5	36	8	1	0	0
7-Jun-2015	CRMS0282	sal_edge	10	30	2	36	0	0	0	0
1-Sep-2015	CRMS0258	sal_edge	0	70	3	38	33	1	0	0

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
1-Sep-2015	CRMS0282	sal_edge	60	40	0	.	0	0	0	0
17-Oct-2015	CRMS0258	sal_edge	10	65	3	36	25	1	0	0
17-Oct-2015	CRMS0282	sal_edge	40	40	0	.	8	1	0	0
12-Dec-2015	CRMS0258	sal_edge	5	35	4	32	8	1	0	0
12-Dec-2015	CRMS0282	sal_edge	5	35	2	34	0	0	0	0
7-Jul-2014	CRMS0258	sal_em	10	90	3	36	.	.	.	.
7-Jul-2014	CRMS0282	sal_em	20	75	2	38	.	.	.	.
14-Sep-2014	CRMS0258	sal_em	10	90	3	36	.	.	.	.
14-Sep-2014	CRMS0282	sal_em	10	90	2	42	.	.	.	.
28-Oct-2014	CRMS0258	sal_em	15	85	5	32	.	.	.	.
28-Oct-2014	CRMS0282	sal_em	10	90	3	42	.	.	.	.
15-Jan-2015	CRMS0258	sal_em	5	95	3	34	.	.	.	.
15-Jan-2015	CRMS0282	sal_em	30	70	2	36	.	.	.	.
3-Apr-2015	CRMS0258	sal_em	5	95	3	34	.	.	.	.
3-Apr-2015	CRMS0282	sal_em	30	70	2	36	.	.	.	.
26-Apr-2015	CRMS0258	sal_em	25	75	3	32	.	.	.	.
26-Apr-2015	CRMS0282	sal_em	20	80	3	42	.	.	.	.
7-Jun-2015	CRMS0258	sal_em	5	95	5	40	.	.	.	.
7-Jun-2015	CRMS0282	sal_em	10	90	3	38	.	.	.	.
1-Sep-2015	CRMS0258	sal_em	5	95	4	36	.	.	.	.
1-Sep-2015	CRMS0282	sal_em	5	95	3	40	.	.	.	.
17-Oct-2015	CRMS0258	sal_em	10	90	4	38	.	.	.	.
17-Oct-2015	CRMS0282	sal_em	10	90	3	38	.	.	.	.
12-Dec-2015	CRMS0258	sal_em	45	55	3	22	.	.	.	.
12-Dec-2015	CRMS0282	sal_em	30	70	3	32	.	.	.	.

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
7-Jul-2014	CRMS0258	sal_open	.	.	.	.	33	1	0	0
7-Jul-2014	CRMS0282	sal_open	.	.	.	.	0	0	0	0
14-Sep-2014	CRMS0258	sal_open	.	.	.	.	8	1	0	0
14-Sep-2014	CRMS0282	sal_open	.	.	.	.	0	0	0	0
28-Oct-2014	CRMS0258	sal_open	.	.	.	.	8	1	0	0
28-Oct-2014	CRMS0282	sal_open	.	.	.	.	0	0	0	0
15-Jan-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
15-Jan-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
3-Apr-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
3-Apr-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
26-Apr-2015	CRMS0258	sal_open	.	.	.	.	58	1	0	0
26-Apr-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
7-Jun-2015	CRMS0258	sal_open	.	.	.	.	8	1	0	0
7-Jun-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
1-Sep-2015	CRMS0258	sal_open	.	.	.	.	16	1	0	0
1-Sep-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
17-Oct-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
17-Oct-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
12-Dec-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
12-Dec-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
25-Jul-2014	CRMS3166	fr_edge	10	30	6	38	83	2	91	3
25-Jul-2014	CRMS3169	fr_edge	0	40	4	36	50	2	91	5
7-Sep-2014	CRMS3166	fr_edge	5	55	4	44	58	4	91	4
7-Sep-2014	CRMS3169	fr_edge	30	40	4	56	58	2	83	4
19-Oct-2014	CRMS3166	fr_edge	5	35	4	34	58	4	91	4

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
28-Oct-2014	CRMS3169	fr_edge	0	85	4	16	25	2	83	5
19-Jan-2015	CRMS3166	fr_edge	0	0	.	.	75	2	33	3
19-Jan-2015	CRMS3169	fr_edge	40	60	0	12	75	2	25	3
29-Mar-2015	CRMS3166	fr_edge	15	25	3	24	16	1	33	3
29-Mar-2015	CRMS3169	fr_edge	20	40	4	26	25	1	8	2
25-Apr-2015	CRMS3166	fr_edge	10	60	2	28	50	4	66	3
25-Apr-2015	CRMS3169	fr_edge	10	70	3	26	16	1	0	0
6-Jun-2015	CRMS3166	fr_edge	10	40	4	32	33	4	58	3
6-Jun-2015	CRMS3169	fr_edge	0	40	6	42	58	2	58	4
28-Aug-2015	CRMS3166	fr_edge	25	25	3	50	75	4	66	3
28-Aug-2015	CRMS3169	fr_edge	0	20	4	28	25	2	83	4
18-Oct-2015	CRMS3169	fr_edge	25	35	3	30	25	2	83	2
22-Oct-2015	CRMS3166	fr_edge	0	0	.	.	41	4	91	4
14-Dec-2015	CRMS3166	fr_edge	15	25	3	20	83	4	75	1
14-Dec-2015	CRMS3169	fr_edge	5	35	3	22	83	3	58	4
25-Jul-2014	CRMS3166	fr_em	10	90	3	42	.	.	.	.
25-Jul-2014	CRMS3169	fr_em	5	95	5	42	.	.	.	.
7-Sep-2014	CRMS3166	fr_em	5	95	8	46	.	.	.	.
7-Sep-2014	CRMS3169	fr_em	15	85	3	50	.	.	.	.
19-Oct-2014	CRMS3166	fr_em	15	85	4	34	.	.	.	.
28-Oct-2014	CRMS3169	fr_em	30	70	5	32	.	.	.	.
19-Jan-2015	CRMS3166	fr_em	45	55	3	16	.	.	.	.
19-Jan-2015	CRMS3169	fr_em	80	20	1	18	.	.	.	.
29-Mar-2015	CRMS3166	fr_em	50	50	2	30	.	.	.	.
29-Mar-2015	CRMS3169	fr_em	30	55	2	28	.	.	.	.

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
25-Apr-2015	CRMS3166	fr_em	30	70	2	34	.	.	.	.
25-Apr-2015	CRMS3169	fr_em	50	50	2	28	.	.	.	.
6-Jun-2015	CRMS3166	fr_em	20	80	3	42	.	.	.	.
6-Jun-2015	CRMS3169	fr_em	10	75	3	22	.	.	.	.
28-Aug-2015	CRMS3166	fr_em	5	90	4	42	.	.	.	.
28-Aug-2015	CRMS3169	fr_em	5	95	2	60	.	.	.	.
18-Oct-2015	CRMS3169	fr_em	30	70	3	32	.	.	.	.
22-Oct-2015	CRMS3166	fr_em	30	70	2	32	.	.	.	.
14-Dec-2015	CRMS3166	fr_em	50	50	3	20	.	.	.	.
14-Dec-2015	CRMS3169	fr_em	60	40	1	24	.	.	.	.
25-Jul-2014	CRMS3166	fr_open	.	.	.	.	83	4	75	3
25-Jul-2014	CRMS3169	fr_open	.	.	.	.	50	2	91	4
7-Sep-2014	CRMS3166	fr_open	.	.	.	.	83	4	41	4
7-Sep-2014	CRMS3169	fr_open	.	.	.	.	75	2	91	4
19-Oct-2014	CRMS3166	fr_open	.	.	.	.	58	4	50	3
28-Oct-2014	CRMS3169	fr_open	.	.	.	.	58	2	66	5
19-Jan-2015	CRMS3166	fr_open	.	.	.	.	50	2	33	3
19-Jan-2015	CRMS3169	fr_open	.	.	.	.	0	0	0	0
29-Mar-2015	CRMS3166	fr_open	.	.	.	.	33	2	16	3
29-Mar-2015	CRMS3169	fr_open	.	.	.	.	0	0	0	0
25-Apr-2015	CRMS3166	fr_open	.	.	.	.	16	2	41	3
25-Apr-2015	CRMS3169	fr_open	.	.	.	.	0	0	0	0
6-Jun-2015	CRMS3166	fr_open	.	.	.	.	75	4	66	3
6-Jun-2015	CRMS3169	fr_open	.	.	.	.	66	2	66	3
28-Aug-2015	CRMS3166	fr_open	.	.	.	.	100	4	83	3

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
28-Aug-2015	CRMS3169	fr_open	.	.	.	.	41	2	58	4
18-Oct-2015	CRMS3169	fr_open	.	.	.	.	66	2	41	2
22-Oct-2015	CRMS3166	fr_open	.	.	.	.	66	4	58	2
14-Dec-2015	CRMS3166	fr_open	.	.	.	.	66	4	41	1
14-Dec-2015	CRMS3169	fr_open	.	.	.	.	58	3	0	0
7-Jul-2014	CRMS0258	sal_edge	10	30	3	32	41	1	0	0
7-Jul-2014	CRMS0282	sal_edge	0	50	2	32	0	0	0	0
14-Sep-2014	CRMS0258	sal_edge	15	85	6	34	16	1	0	0
14-Sep-2014	CRMS0282	sal_edge	5	35	1	40	0	0	0	0
28-Oct-2014	CRMS0258	sal_edge	10	30	2	32	16	1	0	0
28-Oct-2014	CRMS0282	sal_edge	0	15	1	34	0	0	0	0
15-Jan-2015	CRMS0258	sal_edge	20	80	3	34	0	0	0	0
15-Jan-2015	CRMS0282	sal_edge	0	0	.	.	0	0	0	0
3-Apr-2015	CRMS0258	sal_edge	20	60	3	34	8	1	0	0
3-Apr-2015	CRMS0282	sal_edge	0	0	.	.	0	0	0	0
26-Apr-2015	CRMS0258	sal_edge	0	5	1	32	75	1	0	0
26-Apr-2015	CRMS0282	sal_edge	60	0	0	.	0	0	0	0
7-Jun-2015	CRMS0258	sal_edge	0	40	5	36	8	1	0	0
7-Jun-2015	CRMS0282	sal_edge	10	30	2	36	0	0	0	0
1-Sep-2015	CRMS0258	sal_edge	0	70	3	38	33	1	0	0
1-Sep-2015	CRMS0282	sal_edge	60	40	0	.	0	0	0	0
17-Oct-2015	CRMS0258	sal_edge	10	65	3	36	25	1	0	0
17-Oct-2015	CRMS0282	sal_edge	40	40	0	.	8	1	0	0
12-Dec-2015	CRMS0258	sal_edge	5	35	4	32	8	1	0	0
12-Dec-2015	CRMS0282	sal_edge	5	35	2	34	0	0	0	0

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
7-Jul-2014	CRMS0258	sal_em	10	90	3	36	.	.	.	.
7-Jul-2014	CRMS0282	sal_em	20	75	2	38	.	.	.	.
14-Sep-2014	CRMS0258	sal_em	10	90	3	36	.	.	.	.
14-Sep-2014	CRMS0282	sal_em	10	90	2	42	.	.	.	.
28-Oct-2014	CRMS0258	sal_em	15	85	5	32	.	.	.	.
28-Oct-2014	CRMS0282	sal_em	10	90	3	42	.	.	.	.
15-Jan-2015	CRMS0258	sal_em	5	95	3	34	.	.	.	.
15-Jan-2015	CRMS0282	sal_em	30	70	2	36	.	.	.	.
3-Apr-2015	CRMS0258	sal_em	5	95	3	34	.	.	.	.
3-Apr-2015	CRMS0282	sal_em	30	70	2	36	.	.	.	.
26-Apr-2015	CRMS0258	sal_em	25	75	3	32	.	.	.	.
26-Apr-2015	CRMS0282	sal_em	20	80	3	42	.	.	.	.
7-Jun-2015	CRMS0258	sal_em	5	95	5	40	.	.	.	.
7-Jun-2015	CRMS0282	sal_em	10	90	3	38	.	.	.	.
1-Sep-2015	CRMS0258	sal_em	5	95	4	36	.	.	.	.
1-Sep-2015	CRMS0282	sal_em	5	95	3	40	.	.	.	.
17-Oct-2015	CRMS0258	sal_em	10	90	4	38	.	.	.	.
17-Oct-2015	CRMS0282	sal_em	10	90	3	38	.	.	.	.
12-Dec-2015	CRMS0258	sal_em	45	55	3	22	.	.	.	.
12-Dec-2015	CRMS0282	sal_em	30	70	3	32	.	.	.	.
7-Jul-2014	CRMS0258	sal_open	.	.	.	.	33	1	0	0
7-Jul-2014	CRMS0282	sal_open	.	.	.	.	0	0	0	0
14-Sep-2014	CRMS0258	sal_open	.	.	.	.	8	1	0	0
14-Sep-2014	CRMS0282	sal_open	.	.	.	.	0	0	0	0
28-Oct-2014	CRMS0258	sal_open	.	.	.	.	8	1	0	0

(Table C.3 continued)

date	site	habitat	bare %	EMG %	EMG richness	EMG structure	SAV %	SAV richness	FAV %	FAV richness
28-Oct-2014	CRMS0282	sal_open	.	.	.	.	0	0	0	0
15-Jan-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
15-Jan-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
3-Apr-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
3-Apr-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
26-Apr-2015	CRMS0258	sal_open	.	.	.	.	58	1	0	0
26-Apr-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
7-Jun-2015	CRMS0258	sal_open	.	.	.	.	8	1	0	0
7-Jun-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
1-Sep-2015	CRMS0258	sal_open	.	.	.	.	16	1	0	0
1-Sep-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
17-Oct-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
17-Oct-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0
12-Dec-2015	CRMS0258	sal_open	.	.	.	.	0	0	0	0
12-Dec-2015	CRMS0282	sal_open	.	.	.	.	0	0	0	0

VITA

Brett Ashley Patton was born on March 23, 1985 in the coastal town of Long Beach, Mississippi. Growing up just blocks from the beach sparked her love for coastal nature, which became the focus of her work and studies. She graduated from Long Beach Senior High School in 2003 and then earned a Bachelor of Science in biology from William Carey University in Hattiesburg in 2007. Following graduation, Brett worked as a Field Biologist with the National Park Service on the Mississippi barrier islands and is at present an Ecologist for the U.S. Geological Survey in Baton Rouge, LA. Wanting to develop more as a scientist, and research avian and wetland vegetation ecology, Brett entered the LSU Renewable Natural Resources graduate program as a part-time student in August 2013 under the guidance of Dr. Andrew Nyman. She expects to graduate in summer 2016 and live happily ever after.