ASSESSMENT OF SHOREBIRDS AND WADING BIRDS IN GALVESTON BAY USING CONVENTIONAL AND UAV TECHNIQUES

by

Anna Claire Vallery, BS

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Anna Claire Vallery

APPROVED BY

George Guillen, PhD, Chair

Marc Mokrech, PhD, Committee Member

Cynthia Howard, PhD, Committee Member

APPROVED/RECEIVED BY THE COLLEGE OF SCIENCE AND COMPUTER ENGINEERING

Saïd Bettayeb, PhD, Associate Dean

Ju H. Kim, Ph.D., Dean

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ABSTRACT

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Anna Claire Vallery
University of Houston-Clear Lake, 2018

Thesis Chair: George Guillen, PhD
Co-Chair: Marc Mokrech, PhD

Nearly 75% of all U.S. bird species utilize Galveston Bay as either a permanent or seasonal habitat (Galveston Bay Foundation, 1996). Critical coastal bird habitat, including Galveston Bay, is at risk from continued loss due to various factors, including anthropogenic influences (Atkinson, 2003). One of the first steps in conserving and protecting this habitat is to understand the relationship among coastal bird population sizes, density and various intertidal habitats by establishing effective monitoring programs. Collecting data on intertidal and non-tidal habitat use by waterbirds using traditional survey methods can be difficult, though. New emerging technology in the form of Unmanned Aerial Vehicles (UAV) may, however, facilitate large-scale aerial surveys of these areas with less risk, expense, effort, and disturbance (McEvoy et al., 2016). Waterbodies such as Bastrop Bayou and Bastrop Bay provide the ideal setting to test UAV technology for population surveys and habitat selection by wading birds. Conventional boat surveys were conducted in Bastrop Bay bi-monthly from August 2016 to July 2017. These surveys collected base-line information on species abundance and composition for the Bastrop Bay system. Water level was observed to affect which species were observed. Substrate was found to direct patterns of species diversity and abundance more than seasonality for shorebird and wading birds in Bastrop Bay. Two UAVs were used to survey areas around Bastrop Bay as well. The fixed-wing UAV was found to cause more disturbance than the quadcopter UAV. The footage collected with the quadcopter was provided images of more birds than were observed during the concurrent field surveys. Of these birds, 11 of 15 species were able to be identified using the footage. The fixed-wing footage, however, only provided enough detail to identify three species. Though the results collected using the UAVs during this study are promising, further research needs to be conducted to continue to outline standard operating procedures for using UAV technology for surveying shorebirds and wading birds in intertidal habitats.

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CHAPTER I:

INTRODUCTION

Understanding the distribution and habitat use of organisms is one of the primary goals of ecology. The coastal wetlands, however, are often overlooked in this regard despite the fact that their fauna includes a large diversity of species that have an incredibly high socioeconomic and ecological value (Pickens and King, 2013). Wetlands represent an ecotone between terrestrial ecosystems and aquatic ecosystems (Bernard and Tuttle, 1998). As such, they support a unique assemblage of plants and animals adapted to periodic inundation by water. Intertidal wetlands, like many of those found around Galveston Bay, occur where saltwater from the ocean mixes with freshwater running off from land. Consequently organisms living in these tidal wetlands are also adapted to living in a range of salinities. These wetlands provide multiple ecosystem services including nursery and foraging habitat, flood mitigation, erosion control, water pollutant removal and groundwater recharge (Guo et al., 2017). Galveston Bay's wetlands serve as a nursery ground for around 95% of the fish species found in the nearshore Gulf of Mexico, and close to 75% of the U.S. bird species utilize this area as either a permanent or seasonal habitat (Galveston Bay Foundation, 1996). The Galveston Bay intertidal zone is utilized by 23 species of herons, egret, gull, tern, and skimmer along with 31 species of migrant waterfowl and ten different species of loon, grebe, cormorant, frigatebird and pelican (GBF and USFWS, 1995). Wetlands not only provide critical ecological services, but also support various human uses and provide economic benefits that are directly associated with the bird populations that inhabit wetlands.

Wetlands provide critical habitat for many bird species which support bird watching and waterfowl hunting, both significant recreational activities in the United States and worldwide (USGS, 1996). Woodward and Wui (2001) conducted an analysis of the economic benefits associated with wetlands and found that bird watching ranked as one of the highest valued attributes of wetlands. Birds also provide other services, such as natural pest control, pollination, and nutrient cycling (Wenny et al. 2011). A survey conducted by Godown et al. (2000) found that the Texas coastline supported has an overall predicted species richness for endangered bird species of 8-9 species, placing it as one of the highest in the nation. Houston and Galveston's positions along the central flyway make it an important habitat for migrating birds. In fact, Galveston Bay supports over five percent of all the migratory shorebird populations from the mid-continental United States. The number of birds using Galveston Bay make it a popular location for both recreational birding and waterfowl hunting (Lester and Gonzalez, 2002).

Critical coastal bird habitat including Galveston Bay is at risk from continued loss due to various factors, including anthropogenic influences (Atkinson, 2003). Between 20 to 70 percent loss of habitat used by shoreline-dependent birds has been suggested to occur along various coastal areas of the United States by 2100 (Galbriath et al., 2002). Changes in weather patterns and increased intensity of severe weather due to continued climate change are expected to significantly alter coastal and intertidal habitats (Convertino et al., 2010). Recently, Hurricane Harvey, caused considerable erosion and changes to coastal habitats around the Texas coastline and Galveston Bay in August of 2017 (USGS, 2017). Continued human use and development represents additional threats to these areas. In Texas, emergent wetlands have also been lost as a result of dredging, bulk heading, and shrimp trawling (USFWS, 2015). The area around Galveston Bay has also experienced wetland loss due to the pumping of groundwater for industrial, commercial and residential use (USFWS, 2015). In addition to these past stressors there are plans for continued beach nourishment, addition of a coastal barrier system, continued channelization and other similar projects that will continue to threaten coastal habitat that support waterfowl and waterbirds using this area. There are numerous examples of federal and state endangered and threatened bird species that will potentially face additional threats if critical wetland habitats continue to disappear (TPWD, 2011). For example, the Snowy and Piping Plovers, which utilize Gulf beaches and back-bay tidal flats face continued habitat loss as a result of climate change, land development, and increased human activity in areas they rely on for wintering, breeding, nesting and brooding (Convertino et al. 2011). And these plovers are only one of many coastal species at risk.

One of the first steps in conserving and protecting these species and their habitat is to understand the relationship of population sizes, density and various intertidal habitats by establishing effective monitoring programs. Monitoring is considered an integral part of an effective wildlife management and conservation program. However, accurate, statistically powerful monitoring programs can be difficult to implement due to their time consuming, logistically difficult, and costly nature. Specifically data on interspecific differences in habitat use is needed for development of best conservation management practices (Isola et al., 2000). Monitoring data is also important for predicting and understanding how changes in water levels may impact substrate types available for foraging and nesting habitat. A number of factors, including prey density, substrate properties, and human activities, effect foraging behaviors of wading and shorebirds (Piersma 1986). However, little is known about the preferred substrates by various species of waterbirds in the Galveston Bay area. A study conducted by Evans and Harris (1994) found that it is possible to determine preferred foraging microhabitats for the wading bird American Avocet in a tidal flat by comparing the relative frequency that these birds use the substrate type compared to the relative amount of area composed of the specific substrate type.

Collecting data on intertidal and non-tidal habitat use by waterbirds using traditional survey methods can be difficult. Traditional monitoring studies of waterbird populations have been conducted on by boat or by small, manned aircraft. These surveys require the proper equipment, good weather and experienced observes to be successful. The results of these surveys, therefore, depend on the experience of all observers, how detectable the species of interest are, and any disturbance caused by either the aircraft or boat in use (Fleming and Tracey, 2008). This makes it difficult to accurately and precisely estimate population sizes, substrate preference, or tidal preference. Many migratory waterbirds are often found at remote locations in the estuary that are difficult to reach without shallow-draft boats. The noise created during both aerial and boat surveys can disturb foraging birds, causing a negative surveyor bias during data collection (Conway, 2005). Determination of intertidal areas also poses an additional logistical constraint while submerged under water. Aerial studies are preferred to survey larger areas. In these cases, small airplanes are used to fly at low altitude while observers on board conduct surveys of the species of interest. In the past, aircraft and boating accidents have been found to be the number one cause of mortality and injury among biologists in the field (Sasse, 2003). Not only can aerial surveys prove dangerous, but they are cost prohibitive. New emerging technology in the form of Unmanned Aerial Vehicles (UAV), may however, facilitate large-scale aerial surveys of these areas with less risk, expense, effort, and disturbance (McEvoy et al., 2016).

UAVs, otherwise known as drones, have been on the market for several years now. These instruments have been used for a variety of purposes including commercial, recreational and in military operations. The missions that UAVs are used for have been expanded to include other applications such as precision agriculture, hydrology, and archaeology (Sugiura et al, 2005)). Most recently UAVs are now being evaluated as a useful tool in the wildlife management and monitoring (Yong-Gu et al., 2017). UAV technology allows researchers to remain safe on the ground while they fly survey transects, gathering data on bird populations and species composition and associated habitat. It also enables biologists to safely survey areas of interest with less cost and during weather conditions that would have prevented conventional manned aerial surveys (Watts et al., 2010). With advances in camera technology, it is now possible to acquire aerial images at resolutions of a few centimeters. This technology can be used to not only gather information on bird numbers and concentrations but also in support of behavioral studies. In studies where UAV technology has been applied, the use of UAVs produced more precise abundance estimates in comparison to traditional, ground surveys (Hodgson et al., 2017). Furthermore visual data collected from UAVs, both in the form of photos and videos, can be archived and used later on for additional analyses and incorporated into larger temporal or spatial monitoring programs.

UAVs are manufactured in a variety of sizes and styles. Lee (2004) classified drones into multiple categories based on size and weight. The categories included micro, small, medium, or large. Small UAVs, for example, have a wingspan of only a few meters and weigh less than 10 kg. Another popular method of classifying UAVs is by mode of propulsion, that is whether it is fixed wing or multi-rotor. Current wildlife survey applications utilize a combination of small fixed-wing and multi-rotor units. The two types of UAV have different benefits and drawbacks. Fixed-wing UAVs can cover large areas in a single survey and typically have a larger payload capacity. Fixed-wing UAVs, however, are typically more expensive and require more complicated launch and landing procedures. They also require ideal conditions for flight. Multirotor UAVs, however, are often much lower cost. They can only cover small areas per flight, though, and have limited payload capacities. The ability for a multi-rotor to “hover” makes them better suited for obtaining clear images (Chapman, 2016). UAVs are typically fitted with a camera and/or video camera that can either record in the visual color range, infrared or thermal infrared, depending on the goals of the study. UAVs are controlled either by autopilot using a programmed flight route, manually, or a combination of both. The most commonly used UAV employs autopilot technology, which utilizes a pre-programmed flight plan based on GPS coordinates. Transects of an area can be decided beforehand and programmed in to ensure full coverage of the survey area. Currently UAV units used in wildlife surveys range in cost from $2000 for a small "do-it-yourself" UAV to complex manufactured "special mission" models that have many options that can range over $100,000. So far, UAV technology has been primarily used to survey large terrestrial mammals, aquatic animals, and waterbird colonies. However, as the technology matures, more opportunities and applications in conservation biology and ecology will evolve.

Although UAVs provide new approaches and opportunities to expand the ability to survey organisms over a large geographic area, they also have the potential to alter the target species behavior. Several studies have utilized UAVs to survey species of colonial nesting birds or large flocks of a single species. Canada geese, Snow geese, Black-headed gulls, and colonies of common gulls have been successfully counted using UAVs (Chabot and Bird, 2012, 2012; Sarda-Palomera et al., 2012; Grenzdorffer, 2012). For these studies, the UAV can fly at a high altitude, allowing the surveyor to count the number of individuals at locations beyond the line of sight of the observer. The UAV can fly at a high enough altitude to avoid causing disturbance to the colony because the species has already been identified. UAVs aimed at identifying flocks of multiple species, however, will have to fly at a lower altitude to gain enough detail for species identification of individual birds. This lower flight altitude has the potential to cause disturbance to the birds of interest. In order to successfully survey and identify areas of mixed species of birds, including smaller species, a UAV needs an exceptionally good camera, to fly at a lower altitude, or, ideally, both. McEvoy et al. (2016), for example, conducted a study on waterfowl in New South Wales, Australia testing different UAV types and cameras to determine which system provided detailed enough and caused the smallest amount of disturbance. They found that a fixed-wing UAV with a camera of at least 36 megapixels was ideal for surveying wetland birds. This setup allowed for the most area to be covered with the smallest amount of disturbance. They used the standard disturbance scale for waterbirds that includes three levels; no disturbance, alert distance, and flight-initiation distance. Alert distance is the point at which a bird ceases foraging and is visibly aware of the presence of a "threat". Flight-initiation distance is the point at which a bird flushes the area as a result of the "threat" presence (Ruddock and Whitfield, 2007). The camera systems that yielded the best results were a Sony A7R (priced at US$1900) and a Phase-1 medium format camera (about US$40,000), which may both be cost prohibitive for the majority of investigators (McEvoy et al. 2016). Based on their limited research of waterfowl, McEvoy et al. (2016) found that each bird species exhibits a different reaction to the presence of the varying types of UAVs.

Galveston Bay is about 600 square miles with a contributing watershed that covers over 33,000 square miles of land and water. Found in the southwestern portion of this vast estuary is Bastrop Bay, a 217 square mile watershed. The Bastrop Bay watershed contains agricultural land, woodlands, and an expanse of intertidal wetlands in its lower reaches. The primary tributary of Bastrop Bay, Bastrop Bayou, runs through portions of Brazoria National Wildlife Refuge. The bayou contains seagrass meadows, oyster reefs and salt marsh and serves as extremely important habitat for both migratory and nesting birds (Lester and Gonzalez, 2002).

Despite its relatively rural setting, it is forecasted that the human population around the watershed will experience significant growth by 2025 (Bastrop Bayou Watershed Protection Plan, 2014). The increased population may increase the probability of disturbance in the form of recreational activities such as fishing, boating, and construction of coastal communities. This bay is also facing risks similar to those faced by the greater Galveston Bay region. Erosion problems are one of the current issues as a result of human activities such as bulk-heading, dredging, and shipping traffic associated with recreational boating and the Intracoastal Waterway (ICWW) (Lester and Gonzalez, 2002). Christmas Bay, located adjacent to Bastrop Bay, has undergone subsidence due to groundwater withdrawals at nearby Pearland (Lester and Gonzalez, 2002). These activities, along with the projected increases in apparent sea levels will potentially reduce the carrying capacity and ability of coastal areas to support avian populations.

Little research has been done on the use of intertidal and adjacent habitats within Gulf of Mexico estuaries by wading and shorebirds. These areas are known to be key sites used for foraging and nesting. However, there is a lack of quantifiable data on the exact relationship between the distribution of intertidal habitats and the distribution and abundance of shorebirds and wading birds (Withers and Chapman, 1993). This lack of quantifiable data is even more acute in the remote back bays and lagoons found along the Texas coast due to lack of access and the shallow depths that are encountered during meteorologically induced low water conditions. Bastrop is a very shallow bay system with extensive intertidal habitat including saltmarsh, seagrasses, mudflats, and oyster reef (Bastrop Bayou Watershed Protection Plan, 2014). Based on projected sea-level scenarios the amount of suitable intertidal habitat used by wading birds may decline (Galbraith et al., 2001). Goss-Custard (1980) reported that when the amount of foraging area in a given intertidal zone is decreased, wading bird populations typically decline rapidly. The wading bird populations exhibit density dependent responses including a reduction in individuals caused by high mortality rates. The actual amount of exposed intertidal substrate has been found to be one of the best predictors of shorebird population size and abundance (Recher, 1996). Several studies have documented this relationship, including past investigations on the European Oystercatcher, a species very similar to the American Oystercatcher that utilizes supratidal oyster shell islands and intertidal reef habitat in in Galveston Bay for foraging and nesting (Anderson, 2014). In his study, Meire (1991) found that a 30% reduction of an intertidal foraging habitat in The Netherlands resulted in a reduced number of European Oystercatchers. With the current projection anticipating a sea level rise of between 45 and 82 cm centimeters over the next century (IPCC, 2013), populations of American Oystercatchers would face increased risks.

Galveston Bay has also been hit by several large storms in recent years, impacting water levels, nesting habitat, and the availability of certain substrates that wading and shorebirds in the area are dependent on. Oysters, for example, have been hit hard during storms such as Hurricane Ike and Hurricane Harvey due to the extreme amounts of freshwater inflow into the bay systems. These events cause large die-offs of the bivalves, taking away important foraging habitat for species such as American Oystercatchers, Long-billed Curlew, and various Plover species. As these weather events become more common, intertidal habitat, and the birds that rely on it, are at more risk.

Waterbodies such as Bastrop Bayou and Bastrop Bay provide the ideal setting to test UAV technology for population surveys and habitat selection by wading birds. The use of UAVs will enable researchers to more easily access and conduct surveys of waterbirds and wading birds in the intertidal zone of remote waterbodies such as Bastrop Bay. Being able to survey these areas and understand how different species of shorebird utilize this habitat at different tide and water levels will help scientists understand the impacts of sea level rise. The use of UAVs may also assist biologists attempting to learn about wading bird foraging behaviors, including preferences for specific substrates and tidal conditions. By testing and possibly implementing new UAV technology, we can develop better monitoring to track changes in wading and waterbird populations and the factors that may influence their survival. This information will help direct and focus future management strategies and conservation efforts.

There is need to both test and develop UAV protocol that will yield accurate data while reducing avoidance behavior of birds, particularly waterbirds. The Ornithological Council is currently working to get changes to regulations on the use of UAVs for research. As the regulations currently stand, Federal permits list the use of UAVs for research on avian species under the Airborne Hunting Act. A critical literature review of the disturbance on bird species will be conducted when making these regulatory changes (Ornithological Council, 2018). Therefore, new study protocol must take into account the potential behavioral impacts on the target species, which, in this case are wading birds, shorebirds, and waterfowl. Determining the appropriate type of UAV, camera, and flying methods is the first step in the process. Comparing the accuracy and cost effectiveness of these methods to conventional methods is also important for developing protocol that can be used into the future.

This study is aimed at determining the important foraging habitat for water-dependent birds in the study area through the use of conventional survey methods. The second aim of this study is to determine the appropriate protocol for utilizing UAV technology by expanding and improving survey methodology in the future. It is also aimed at comparing two types of UAV, fixed-wing and multi-rotor, thereby identifying which method works the best for capturing data on the species of interest with the least amount of disturbance. The final aim is to compare the findings from concurrent conventional visual survey methodology to those collected with UAVs. By accomplishing these objectives, future studies can be conducted utilizing this technology in the most effective manner possible.

CHAPTER II:

MATERIALS AND METHODS

Study Area

The area of focus for this study was Bastrop Bayou and Bastrop Bay, a 562 km (217 mi2) watershed about fifty miles south of Houston, adjacent to Brazoria National Wildlife Refuge (Figure 1). Several small subdivisions located along lower portion of Bastrop Bayou are regularly used for both recreation and agriculture. Most of Bastrop Bay encompasses rural landscapes and includes relatively pristine habitats that are used for foraging by a number of wading and shorebirds (HGAC, 2015). Within Bastrop Bay, there are several oyster reefs, salt marshes, and seagrass beds that are commonly used for foraging by the many species of birds found in this area (HGAC, 2015). Intertidal oyster reefs are abundant in this bay. Sediment types within this area include live oyster reef, dead oyster shell, shell hash, sand, silt, clay, and seagrass.

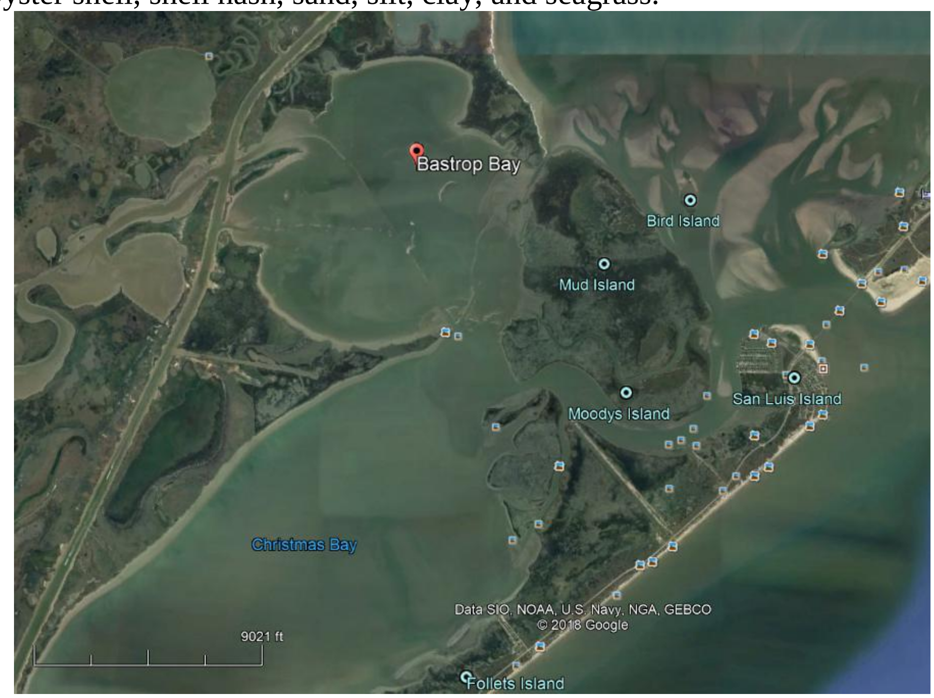

Figure 1.Map of Bastrop Bay with reference to its location hear Christmas Bay and San Luis Pass.

Species of Interest

Based on past studies and amateur bird watching data we anticipated a diverse assemblage of wading bird and shorebird species would be observed in the study area including the American Oystercatcher (*Haematopus palliatus*), Long-billed Curlew (*Numenius americanus*), Marbled Godwit (*Limosa fedoa*), Red Knot (*Calidris canutus*), and Reddish Egret (*Egretta rufescens*), all of which are species of conservation concern in Texas and the United States (Ortego and Ealy, 2010). Additional species that were expected in the study area include the Western Sandpiper (*Calidris mauri*), Laughing and Herring Gull (*Leucophaeus atricilla* & *Larus argentatus*), Brown and White Pelican (*Pelecanus occidentalis* & *Pelecanus erythrorhynchos*) as well as several heron and egret species, plovers, and killdeer (*Charadrius vociferus*). All bird species were reocorded using their four-digit species code (Pyle and DeSante, 2017) (Appendix A).

Any waterbird species observed during surveys, both conventional and UAV, were recorded. Species of interest were determined by the family. There are three orders of interest, Anseriformes, Charadriiformes, and Pelecaniformes. However, within these orders there were some families that were not targetted for monitoring, specifically Laridae, or the gulls terns and skimmers. The species of interest are all within eight families (Table 1).

All birds were then classified into taxonomic group (shorebird, wading bird, waterbird and waterfowl) based their taxonomy and their foraging behaviors. For example, waterfowl are all from the family Anatidae. Wading birds are from the families Ardeidae and Threskiornithidae. The order Charadriiformes includes both shorebirds and seabirds. Seabirds are those evolved for pelagic foraging, while shorebirds are evolved for foraging on the ground in wetland ecosystems. For this study, Shorebirds included the families Charadriidae, Recurvirostridae, Haematopodidae, and Scolopacidae. Waterbirds (or seabirds) included the families Laridae and Pelecanidae. The Laridae family was not included as a family of interest because they typically use the substrates available for only roosting, not foraging. Bird species were, lastly categorized into two potential groups for analyses. “Species of interest” included all species that fall into the seven families of interest. “Indicator species” are those that were seen in both high frequency and abundance, for this study, ten species made up the indicator group.

Table 1. Families of interest for this study listed with their order and description.

Order	**Family**	**Description**
Anseriformes	Anatidae	Ducks and Geese
Pelecaniformes	Ardeidae	Bitterns, Herons, and Allies
Charadriiformes	Charadriidae	Plovers and Lapwings
Charadriiformes	Haematopodidae	Oystercatchers
Pelecaniformes	Pelecanidae	Pelicans
Pelecaniformes	Recurvirostridae	Stilts and Avocets
Charadriiformes	Scolopacidae	Sandpipers, Phalaropes, and Allies
Pelecaniformes	Threskiornithidae	Ibises and Spoonbills

Methods

Conventional Survey Method

Bastrop Bay was split into five sections (4 quadrats around the bay defined by channels, and the central portion of the bay) (Figure 2). These sections were surveyed during spring, summer, and autumn months. Due to the weather patterns during winter and the large number of birds, two quadrats were randomly selected and visited, along with the center of the bay, during winter surveys. A total count of the defined area within Bastrop was completed during each survey. This area is defined by the coastal edge of the quadrats and 400 yards in any direction. It also included any exposed reef or manmade structure within the interior portion of the bay (Figure 2). This distance is used because it is about the furthest distance a species identification can be made on the majority of the birds using the binoculars and/or spotting scope. In addition, these areas cover the majority of shallow and intertidal habitat within the bay system.

Figure 2. Area of interest outlined for surveys in Bastrop Bay.

Bi-monthly surveys of bird populations were collected from August of 2016 to July of 2017 (Table 2). The Christmas Bay NOAA tide station (8772132) water levels for each survey day is saved after each survey. Weather, wind speed and direction, temperature, and cloud cover are recorded at the beginning of each survey. Surveys began around 08:00 each day.

Table 2. Dates for all conventional surveys and the number of minutes each lasted.

Date	**Survey Time (min)**
8/25/2016	335
9/7/2016	397
9/22/2016	387
10/13/2016	351
10/27/2016	275
11/30/2016	201
12/13/2016	165
12/23/2016	180
1/13/2017	173
2/1/2017	69
2/22/2017	259
3/10/2017	147
4/3/2017	224
4/17/2017	242
5/5/2017	294
5/15/2017	277
6/9/2017	296
6/19/2017	288
7/6/2017	248

Surveys were conducted from a surface-drive vessel in order to navigate the shallow terrain characteristic of Bastrop Bay. A 20 ft Diamondback Airboat and a 16 ft Go-Devil Surface Drive boat were used to ferry observers and UAV operators (Figure 3). During each survey we attempted to survey as much of the bay as possible. During most months this covered the entire bay area depicted in figure 4. However, during winter months when we generally observed higher numbers of birds and lower water levels, we frequently were only able to survey 50% of the target area.

Figure 3. 20’ Diamondback Airboat and a 16’ Go-Devil Surface Drive vessels used during study

Conventional visual surveys were conducted using a Vortex Spotting Scope and tripod, Bushnell Fusion 1-mile ARC 12x50 mm magnification binoculars with built-in laser rangefinder, and a magnetic compass. Every bird sighted was recorded, including the surveyor’s location (latitude, longitude), the distance to the bird, bearing of the bird from the observer’s location, bird’s behavior, number of individuals of that species in the group, and the substrate the bird appeared to be using. The birds’ distance from observer was determined using the laser rangefinder built into the binoculars. The direction from the observer location to the recorded bird was determined using a hand-held magnetic compass.

Data was entered into the Excel software package. Distance from observer to bird was converted from yards to meters. Bearing was converted from degrees into radians, and easting and northing coordinate values were determined for each bird sighting. Substrates observed being used were classfified into multiple categories prior to statistical analysis. For example, birds using pilings, docks, and fishing encampments are grouped into the category “manmade”. Table 3 lists all substrates observed during the study that were used by birds for foraging, nesting, or roosting.

Table 3. All substrate categories and which substrates were included in each.

Substrate Category	**Definition**
Air	Flying
Manmade	Docks, houses, pilings, or anything else in the habitat that is manmade
Marsh	Physically in the marsh
Mud	Physically on mostly mud
Open Water	In the water, either floating on the water or diving under the water
Other	Rocks, logs, or other unidentified substrates
Oyster	Oyster reef
Seagrass	Seagrass beds
Shell	Shell hash

Data analyzed included latitude, longitude, species, estimated number, behavior, bottom habitat, salinity, water levels, wind direction, speed, and water levels (obtained from NOAA tide station 877213). The Excel, Minitab, Primer 7, and ArcGIS Pro software packages were used in analyses. Graphical representation of numbers and frequency of birds by taxonomic group versus season were generated including the mean Standard Error. ArcGIS Pro was used to map all bird observations and run Hot Spot Analyses. Both “optimized hotspot” and “emerging hotspot” analyses were run to better understand which parts of the bay were utilized most by wading birds and shorebirds. Optimized hot spot analysis considers the data points and determines the nearest neighbors of each. Areas with many close “neighbors” were designated as a hot spot. This function uses the average and the median nearest neighbor calculations for aggregation and to develop the scale of the analyses (Ord and Getis, 1995). Emerging Hot Spot Analysis is used to identify trends over time. This tool was run to find new, sporadic, or changing hot and cold spots. To run the emerging hot spot analysis, the data was first input into a space-time cube. Like the optimized hot spot analysis, the emerging hot spot analysis then uses nearest neighbors. The hot spots can then be evaluated by time to determine what changes are taking place over the course of the data collection

(ArcMap, 2016). In ArcGIS software, points were projected using NAD 1983, UTM 15. Other graphical representations used included pie charts, box plots, bar graphs, and cluster analyses.

UAV Survey Method

Aerial surveys of bird habitat and bird populations in Bastrop Bay and Bastrop Bayou were conducted using two models of UAV. A QUESTUAV AQUA 7ft fixed-wing Unmanned Aerial Vehicle (Figure 4) equipped with either a Sony A6000 (24.3 megapixel) camera or a Panasonic Lumix (12.8 megapixel) camera, The second UAV used was a DJI Phantom 4 Pro Quadcopter equipped with 20 megapixel camera (Figure 4). UAV surveys were conducted during the same time period as the conventional surveys. Monthly surveys were conducted, although several attempts were unsuccessful either due to UAV malfunction, wet landings, or weather. This UAV was pre-programmed to fly transects over the designated area. The fixed-wing UAV required three people to launch, control and recover the drone over the course of the survey. To launch this model of UAV, space is required to set up a tripod with a bungee mechanism (Figure 5). The UAV battery powered engine and propeller automatically turned on when launched by the bungee.

Figure 4. (Left) QUESTUAV AQUA 7ft fixed-wing Unmanned Aerial Vehicle and (Right) DJI Phantom 4 Pro Quadcopter with 20 megapixel camera.

Figure 5. QUESTUAV AQUA UAV launch at Bastrop Bay.

A fourth person acting as the land-based visual surveyor identified and counted birds and observed bird behavior before, during and after the UAV surveys from a central location in the survey area. The species composition, number of birds, distance and bearing from the surveyor's location along with pre-flight behavior were recorded prior to UAV launch. Behavioral response of the birds in the area were recorded using the following codes: "N" if there was no visible response to the presence of the UAV, "A" if the birds cease foraging and/or orient towards the UAV, and "F" if birds flush in response to UAV. When there were many birds reacting to the UAV, however, flushing behavior in response to the drone launch, flight, or landing were the only reactions that can feasibly recorded. UAV flight pattern included a launch into the wind followed by flying several transect lines. The UAV then flew circles over the survey areas beginning at 122 meters (400 feet) and slowly coming down to 30.5 meters (100 feet). This was followed by the landing sequence. Behavioral responses (using N, A, and F categories) of all visible birds were recorded as UAV moved through each of the flight sequence steps. Notes concerning the behavior of birds and the success of the survey were recorded at the end of each day.

When UAV surveys using still photography were conducted, the images taken by the drone were stitched together using Pix 4D software (Figure 6). This allows for a complete image of the entire survey site to be compiled for easier viewing and bird identification.

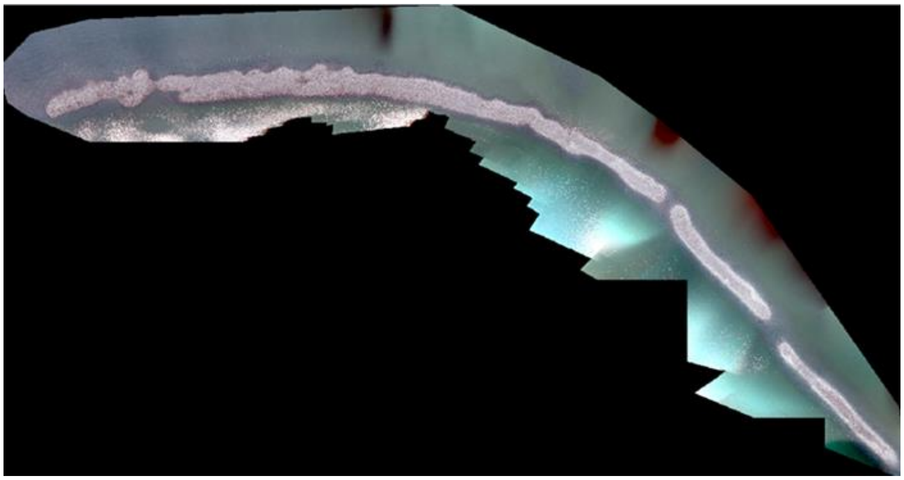

Figure 6. Stitched together image using photos collected from a completed survey by the QUESTUAV AQUA UAV.

After several fixed-wing still photography survey days were completed, the UAV was set up to record video for remaining surveys. For these surveys, the camera was set to video mode and the transect were flown in the same manner as before, starting with transects and ending with circles over the area of interest.

The DJI Phantom 4 Pro Quadcopter with equipped camera was also used to obtain video recordings. This quadcopter-style UAV can be launched almost anywhere, only needing a stable flat surface as a takeoff point. Though it is capable of taking still photos, the quadcopter was only used to obatin video recordings for this study.

The two best quality videos, one from each UAV, were selected for processing using the new software add-in package called Full Motion Video. The Full Motion Video (FMV) is an ESRI add-in that works with the ArcMap software package. The add-in provides the capability of seamlessly mapping features by digitizing and compiling feature data right on the video using the video player within the ArcMap platform. The processing system requires that the videos are Motion Industry Standards Board (MISB) compliant MISB- compliant videos consist of images captured in time and space. The display of these images in sequence, at the same rate captured, generates the motion in a video while the direct use of geo-referencing information and sensor parameters establishes the location and coverage of each image. Sensor systems that produce MISB-compliant videos are usually very sophisticated and expensive as they record all geo-referencing information (a.k.a. metadata) directly on image frames including 3D position of sensor, orientation of sensor and time of recording. However, FMV enables the use of less expensive commercial off-the-shelf consumer-oriented video capture systems (like the DJI phantom 4 Pro system) by providing the possibility of encoding video files with the required metadata using the Video Multiplexer GP tool. Thus, the produced videos include synchronized image frames and map as time passes, allowing feature capturing (i.e. birds in our application) in ArcMap. After implementing this software, birds were counted from the video frames and identified to the lowest possible taxon. Counts from the video were then compared to those taken in the field to compare the differences in survey count results collected using the two methods.

CHAPTER III:

RESULTS

Conventional Surveys

Abundance

A total of 19 bird surveys were conducted in Bastrop Bay between August 25, 2016 and July 6, 2017. These surveys included 3,267 total sightings of 17,764 birds from nine different orders and 63 different species.

Table 4. All recorded species, their four-digit code and the number of individuals counted over the course of the conventional surveys.

Code	Species
AMAV	American Avocet
AMBI	American Bittern
AMOY	American Oystercatcher
BBPL	Black-bellied Plover
BBWD	Black-bellied Whistling Duck
BCNH	Black-crowned Night Heron
BLSK	Black Skimmer
BLTE	Black Tern
BNST	Black-necked Stilt
BRPE	Brown Pelican
BUFF	Bufflehead
CAEG	Cattle Egret
CATE	Caspian Tern
COLO	Common Loon
Cormorant Spp.	Neotropical and Double-breasted Cormorant
CRCA	Crested Caracara
DUNL	Dunlin
FOTE	Forster's Tern
GBHE	Great Blue Heron
GOPL	Golden Plover
GREG	Great Egret
GRFR	Great Frigatebird
GRYE	Greater Yellowlegs
HAHA	Harris's Hawk
HEGU	Herring Gull
HOME	Hooded Merganser
KILL	Killdeer
KIRA	King Rail
LAGU	Laughing Gull
LBCU	Long-billed Curlew
LBHE	Little Blue Heron
LESA	Least Sandpiper
LETE	Least Tern
LEYE	Lesser Yellowlegs

Code	Species
MAGO	Marbled Godwit
MAWR	Marsh Wren
NOHA	Northern Harrier
NOPI	Northern Pintail
OSPR	Osprey
PBGR	Pied-billed Grebe
PIPL	Piping Plover
Plover Sp.	Unidentified Plovers
RBGU	Ring-billed Gull
RBME	Red-breasted Merganser
REEG	Reddish Egret
RNDU	Ring-necked Duck
ROSP	Roseate Spoonbill
ROYT	Royal Tern
RUTU	Ruddy Turnstone
SAND	Sanderling
SATE	Sandwich Tern
SBDO	Shortbilled Dowitcher

Code	Species
SEPL	Semipalmated Plover
SNEG	Snowy Egret
SNGO	Snow Goose
SPSA	Spotted Sandpiper
SSHA	Sharp-shinned Hawk
TCHE	Tricolored Heron
WESA	Western Sandpiper
WFIB	White-faced Ibis
WHIB	White Ibis
WHIM	Whimbrel
WHPE	White Pelican
WILL	Willet
WIPL	Wilson's Plover
YCNH	Yellow-crowned Night Heron

Brown Pelican and Western Sandpiper represented the largest numbers of birds observed during the study period. Great Egret, Least Sandpiper, Northern Pintail, Snowy Egret, and White Ibis were also seen in large numbers (Figure 7). The frequency of occurrence, or how many times each species was seen over the course of all surveys, is also reported along with abundance (Figure 7). Overall abundance and frequency of occurrence were used to select ten “indicator” species to be used for further geospatial analysis. This was done by selecting species that were both frequently seen and in relatively high abundances. For example, the Western Sandpiper was seen in infrequently in large numbers. This was due to the large flocks of this species observed only a few times throughout the year. Therefore we did not include this species in some detailed analyses. In contrast, Great Egret was included as a top indicator species because a total of 951 birds were observed over 360 separate sightings (Figure 7). The other nine top species are listed in Table 5 and include Great Blue Heron, Long-billed Curlew, Little Blue Heron, Reddish Egret, Snowy Egret, Tricolored Heron, White Ibis, Willet, and all Plover species. All Plover species were combined for analyses because on several occasions during data collection, identification to the species level was impossible.

Table 5. Top ten indicator species determined by frequency and abundance.

Species	Abundance	Frequency
Great Blue Heron	250	205
Great Egret	951	360
Little Blue Heron	94	66
Long-billed Curlew	220	126
Plover spp.	195	72
Reddish Egret	131	98
Snowy Egret	722	295
Tricolored Heron	273	137
White Ibis	833	294
Willet	566	314

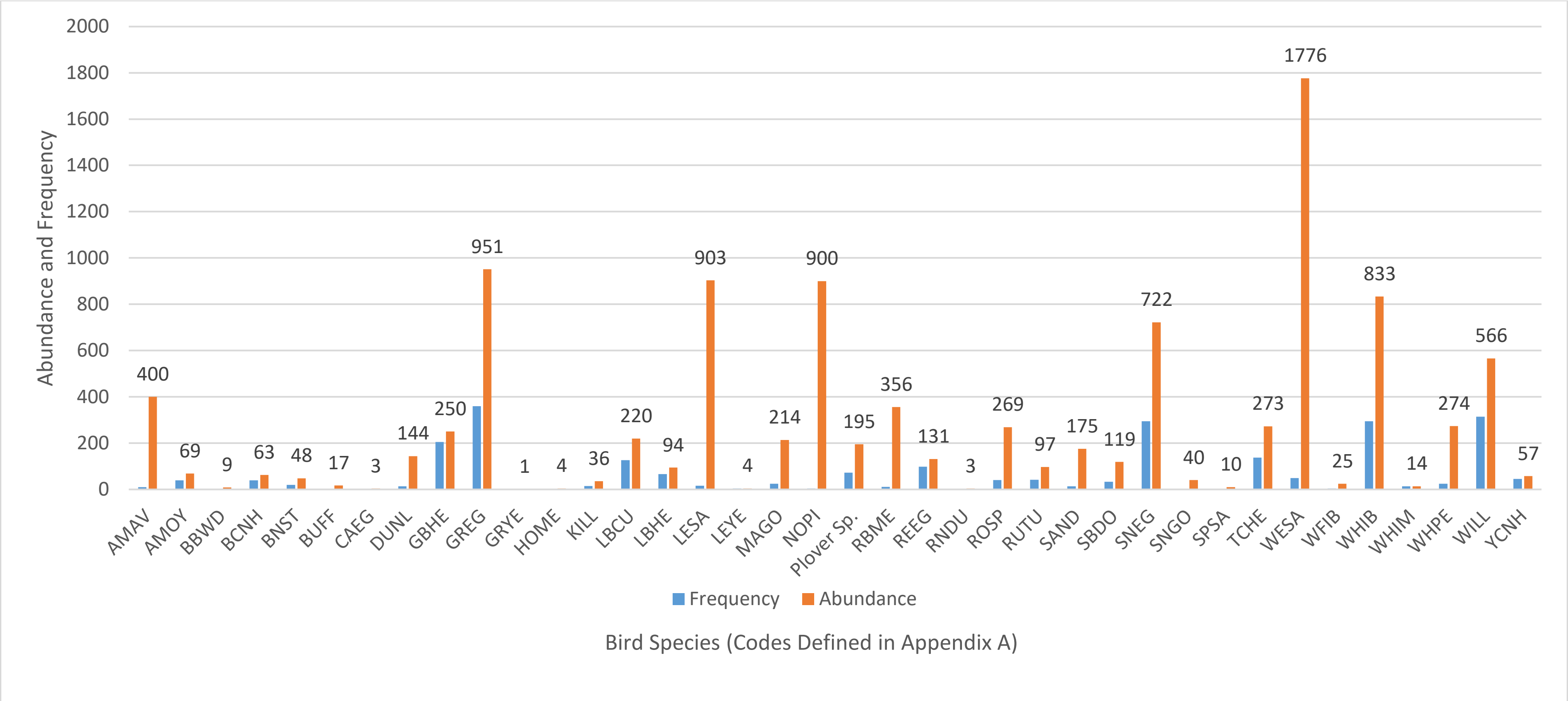

Figure 7. Frequency and abundance of all species of interest over the course of all conventional surveys. Species identified by four-digit code (Appendix A).

The abundance of birds within each taxonomic group are displayed by number of observations per minute of survey time in Figure 8. This is also displayed by season. There were significantly more shorebirds and waterfowl observed in winter than in the other three seasons. Significance was determined visually by observing standard error bars in the graphical representation. Waterbirds, however, were observed in consistent numbers throughout the year of surveys. Wading birds were observed significantly more in the summer than the other three seasons. The species that fall in each taxonomic group are listed in Appendix A.

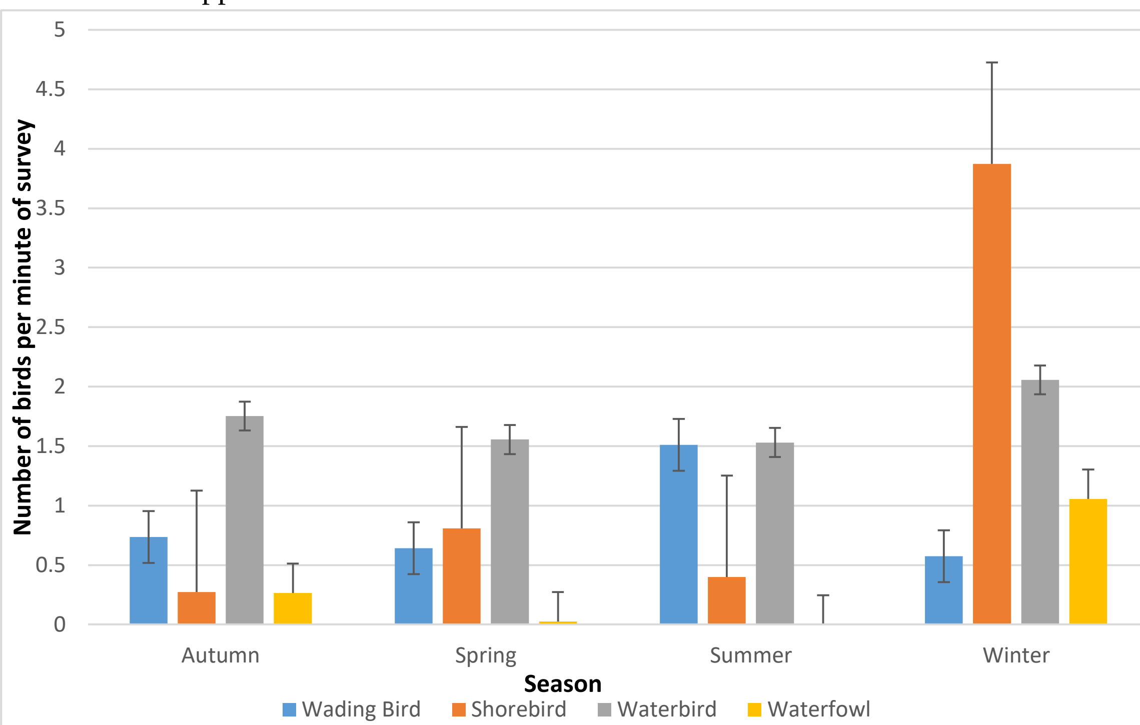

Figure 8. Abundance of birds by taxonomic group and season per, minute of survey time with (mean ± SE).

Habitat Use

The occurrence and density of birds both seasonally and over the course of the study, is displayed by order (Figure 9) and by family (Figure 10). Members of the order Charadriiformes and large groups or flocks of Pelecaniformes were frequently found at the emergent oyster reefs located in the middle of the Bastrop Bay. Large difference in abundance between Charadriiformes and Pelecaniformes from Anseriformes waterfowl can also be observed in the maps. Anseriformes, for example, were seen much less frequently than the other two orders.

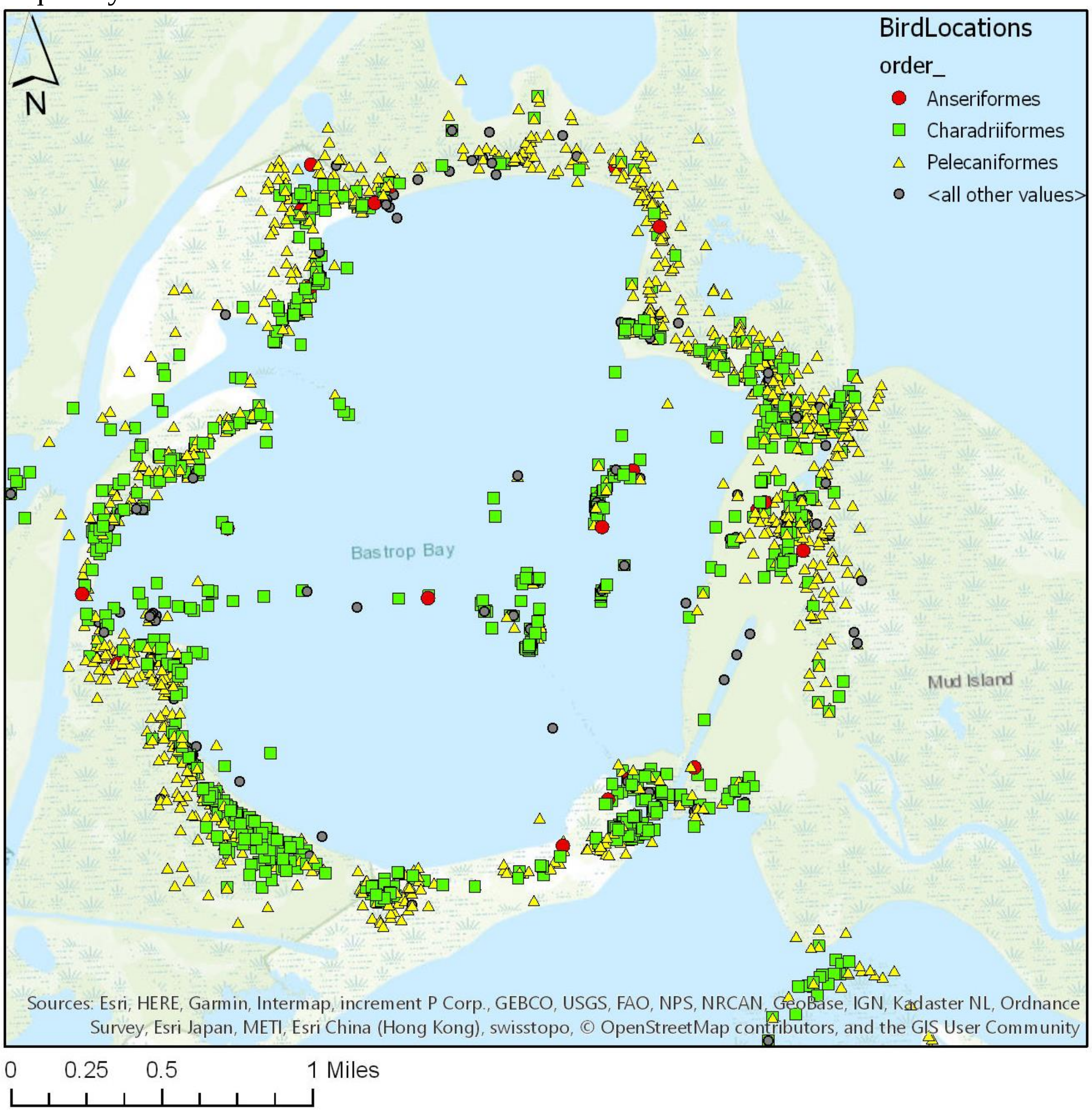

Figure 9. All bird occurrences at Bastrop Bay mapped by taxonomic order using ArcGIS Pro. One or more members of a taxa occurring at a single location and time are recorded as a single occurrence.

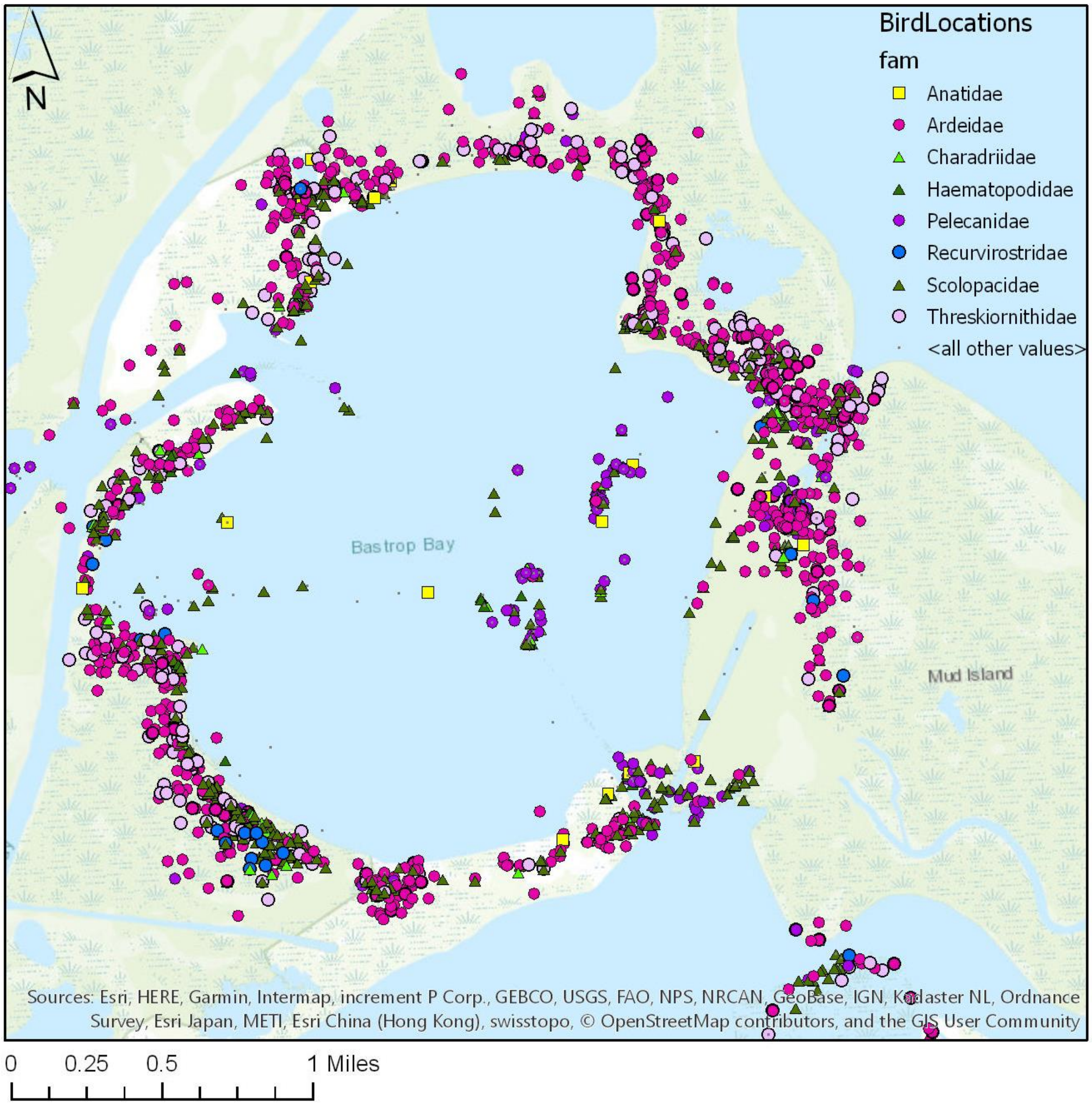

Figure 10. All bird observations at Bastrop Bay mapped by family using ArcGIS Pro. One or more members of a taxa occurring at a single location and time are recorded as a single occurrence.

Substrate Use

Understanding the use of substrate between the indicator taxa was one of the main goals of this study. The substrate use of the three orders of interest for this study are represented in Figure 11. Substrate types are described in Table 3. Based on our observations members of the Order Anseriformes primarily utilized oyster substrate, while birds within the Order Pelecaniformes were found mainly in marsh habitat.

Members of the Order Charadriiformes used both soft bottom and oyster substrate in similar amounts (41.5% and 34.0%). Figure 12 displays substrate use by the families of interest (including the *Laridae* family for comparison). These include all the families of shorebird, wading bird, and waterfowl. Five out of the nine bird families (*Anatidae*, *Charadriidae*, *Haematopodidae*, *Laridae*, and *Pelecanidae*) utilized oyster more frequently than any of the other substrates. Two of the families (*Recurvirostridae* and *Scolopacidae*) primarily utilized mud. The remaining (*Ardeidae* and *Threskionithidae*) families primarily utilized marsh substrate

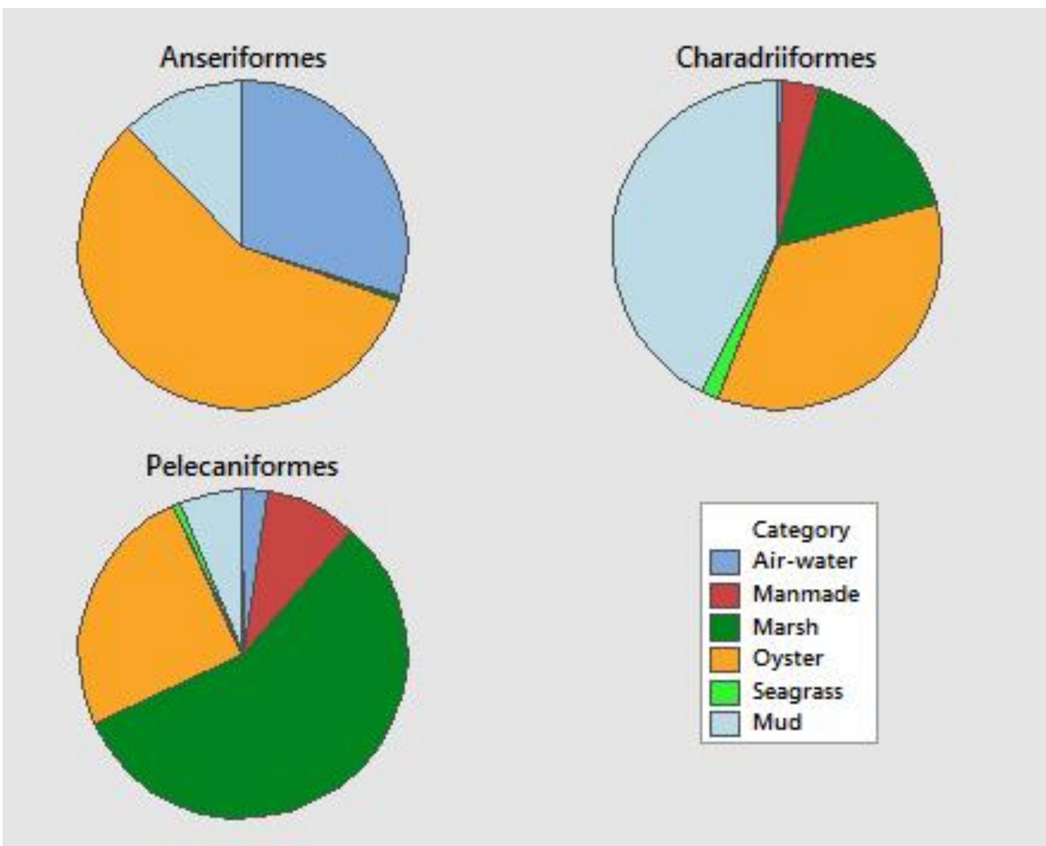

Figure 11. Substrate use for the three orders of interest over the course of all conventional bird surveys.

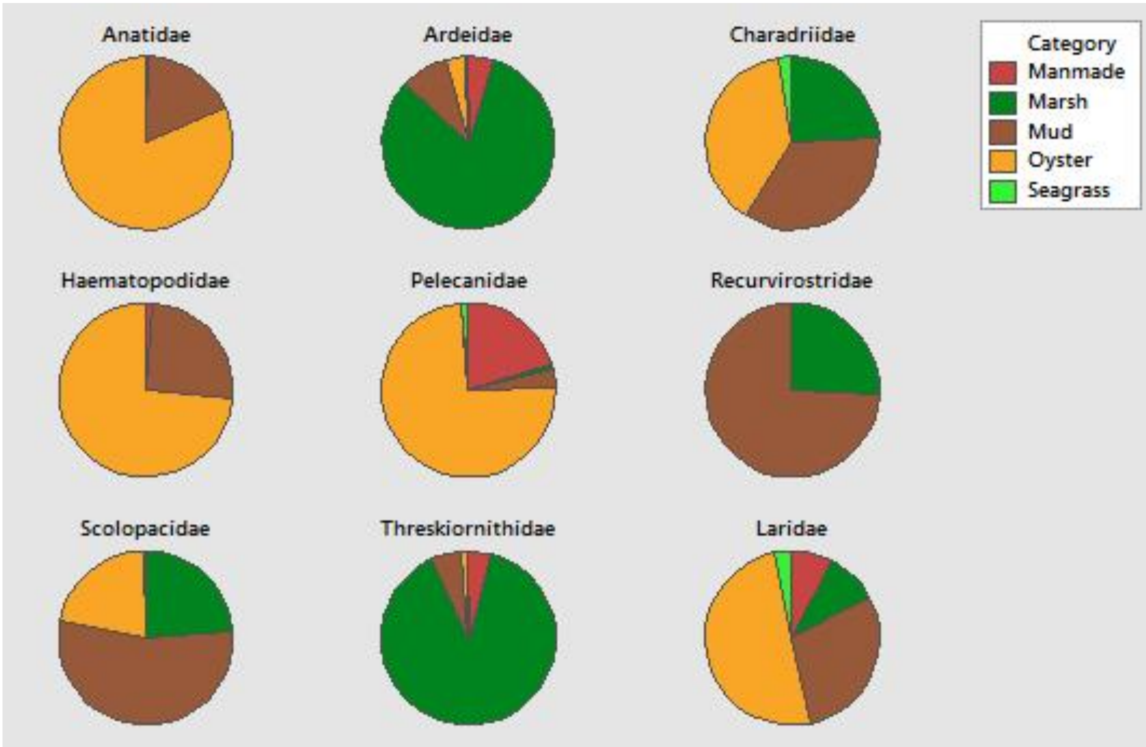

Figure 12. Substrate use for the eight families that include species of interest and the family Laridae. Families of interest include all families of shorebird, wading bird, and waterfowl.

The substrate preference of the ten indicator species were also displayed using pie charts (Figure 7 & Figure 13). All but two of these species were seen most often in marshes. Plovers were seen most frequently on oyster and mud substrates, while Long-billed Curlew were observed using oyster and marsh substrate in similar amounts.

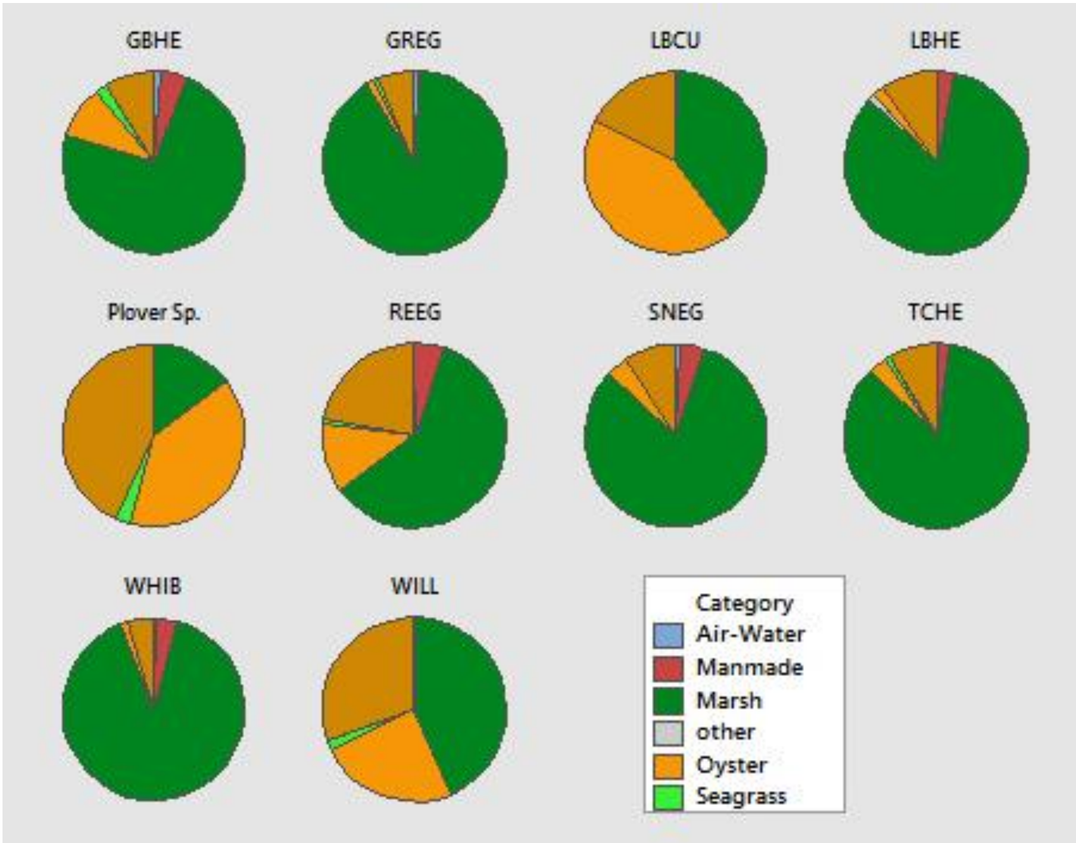

Figure 13. Substrate use for the top ten species observed during the conventional surveys.

Species composition and abundance of all species of interest compared by substrate use was input into Primer 7 statistical analysis software. The sum of the substrate use by all the species of interest was calculated across the entirety of the study data. To reduce variance, the biological data was first transformed using the square root transformation. A resemblance matrix was created using the Bray Curtis similarity index. A cluster analysis was conducted using Group Average algorithm. In addition, ordination was conducted using non-metric MDS. A SIMPROF test was used to determine significance, displayed as solid lines on the cluster analysis output. The cluster analysis (Figure 14) suggests that the bird assemblage using marsh habitat was significantly different from the other substrates, though it is most similar to mud and oyster. Open water, manmade, and seagrass were utilized by a similar species assemblage. Birds that were in flight at time of observation (air) and shell were similar as well. These findings are also displayed in the non-metric MDS (Figure 15). In this figure, it is evident that the assemblage of all birds of interest utilizing mud, marsh, and oyster habitats are similar in contrast to the assemblages utilizing seagrass and manmade habitats. Open water, shell, and air assemblages did not show strong similarities to the two previous groups (Figure 15).

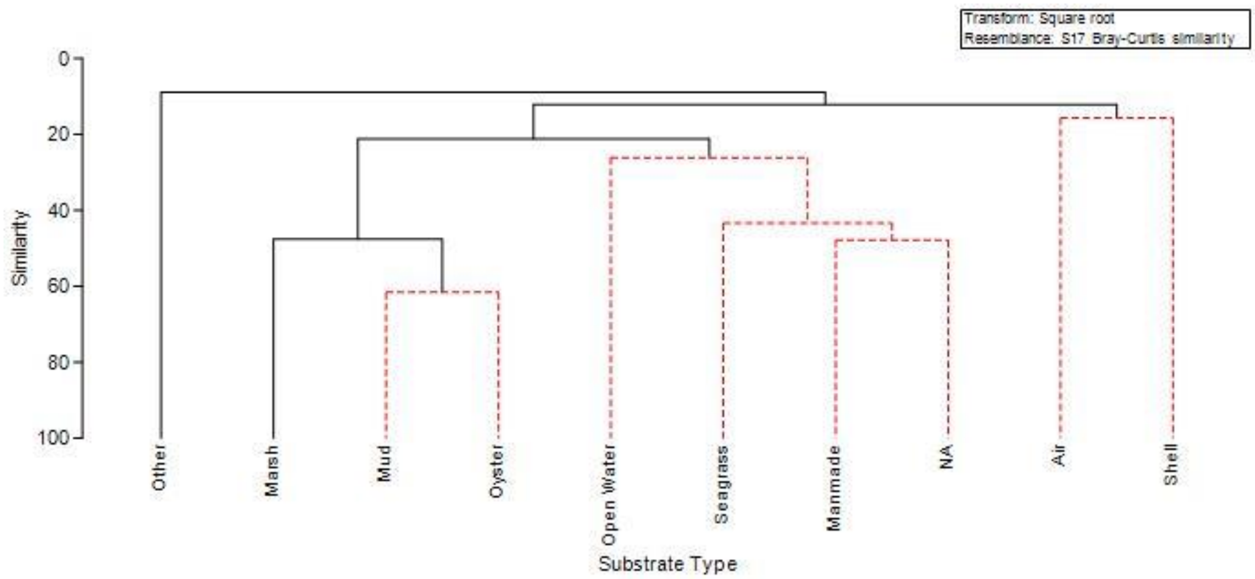

Figure 14. Classification of substrate types using cluster analysis of species total abundance across the entire study period.

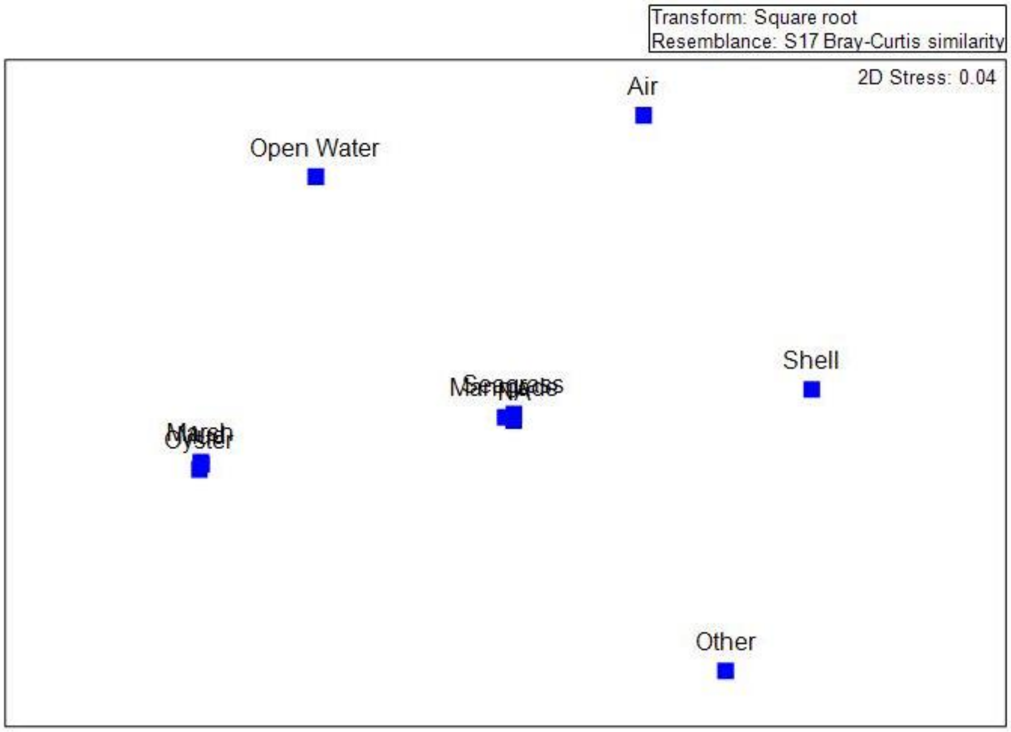

Figure 15. Non-Metric MDS ordination of substrate use by abundance of all species of interest.

A boxplot of the total abundance of all species of interest by each substrate type was constructed (Figure 16). Marsh and oyster substrate supported the highest density of bird species of interest. Air/water, manmade, other, and seagrass habitat were used less often.

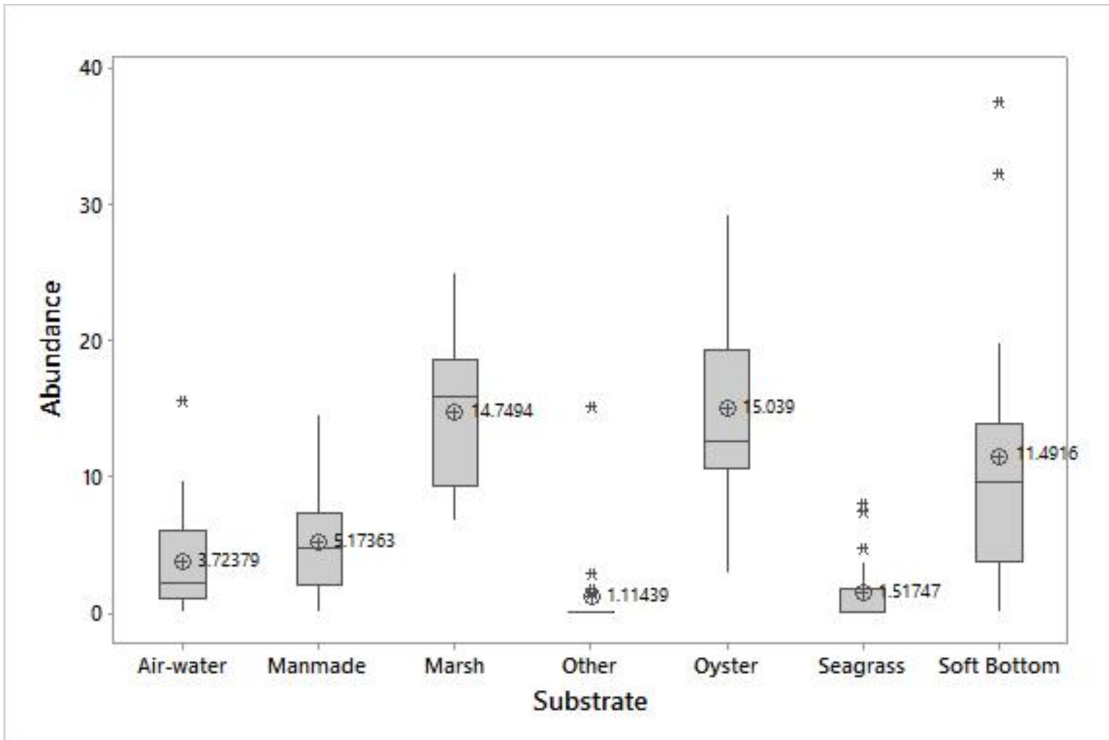

Figure 16. Boxplot of the sum of the abundance of all species of interest by substrate.

Water Level

It was hypothesized that water level would have an impact on bird sightings, abundance, and substrate use. Average water level for sightings of each species was calculated and is displayed (Figure 16). Waterfowl species were observed more often at lower average water levels than other species (e.g., Bufflehead 0.385 ft.; Hooded Merganser 0.42 ft.). The average water level by order exhibited a much lower average water level at sightings for birds within the Order Anseriformes (0.481 ft) than the other two orders. Charadriiformes had an average water level of 0.977 feet, while Pelecaniformes were observed on average at 1.158 feet.

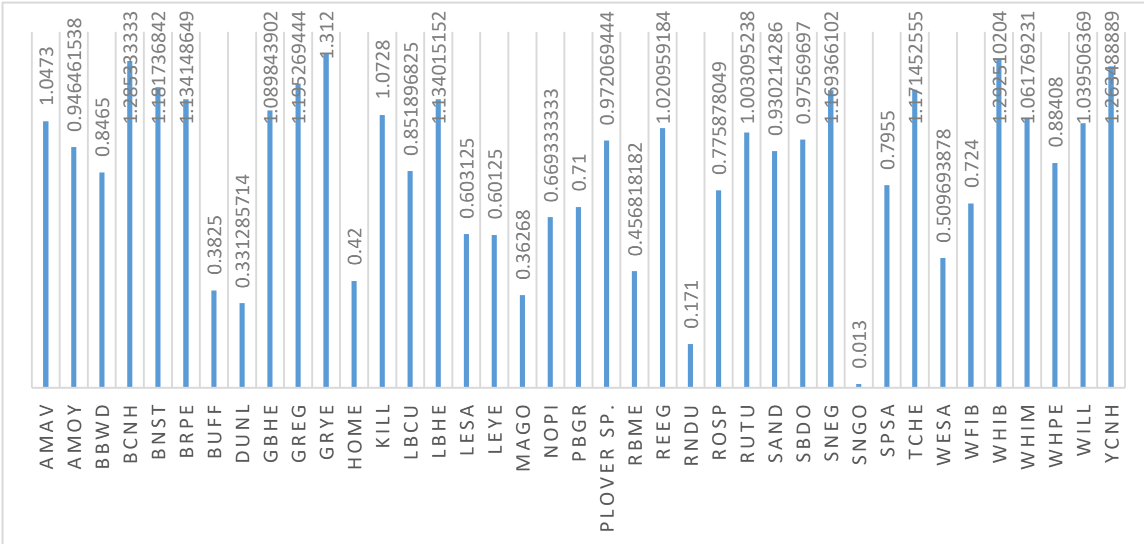

Figure 17. The average water level for each species sighting was averaged across all surveys and is displayed by species of interest.

Figure 18 is an interval plot of average water level at observation for each taxonomic group of birds. Waterfowl as a group were observed at lower average water levels than all other groups, but at significantly lower water levels than shorebirds, wading birds, and waterbirds. Wading birds were seen at significantly higher water levels than shorebirds and waterbirds on average (Figure 17). Bars denote the 95th confidence interval of the mean, and were used for visually determining significance. Groups without overlapping confidence intervals were considered statistically different.

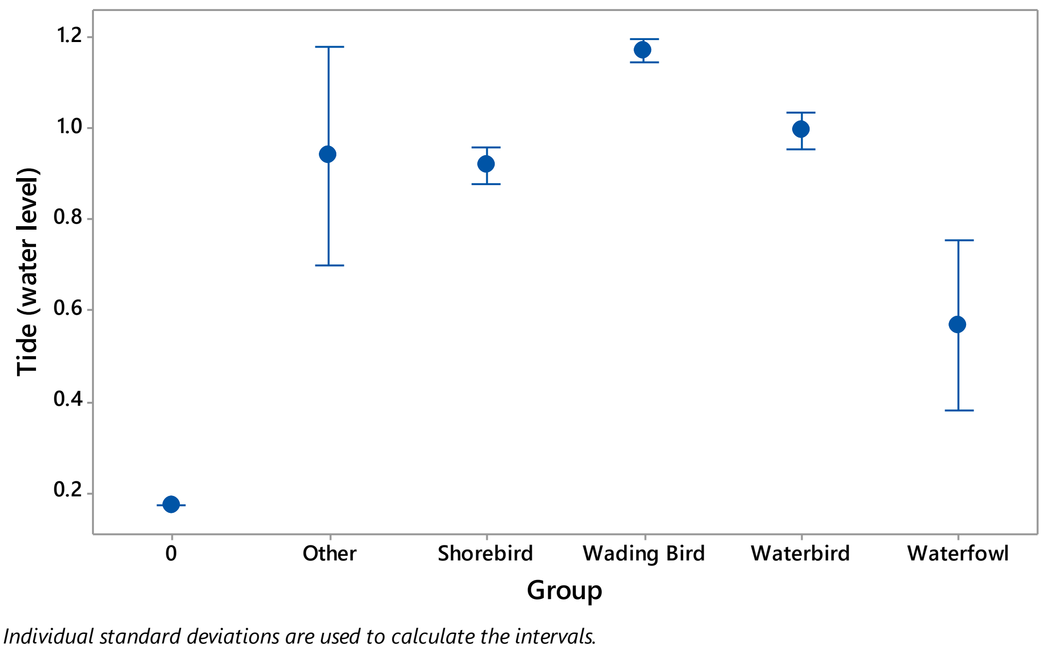

Figure 18. Interval plot of water level by taxonomic group of bird. Bars denote the 95th confidence interval of the mean. Groups without overlapping confidence intervals were considered statistically different.

Groupings of bird abundance based on combinations of season and substrate were constructed to examine the combined influence of these factors on patterns in bird community assemblages. Prior to analysis bird abundance data was transformed using the square root transformation. A Bray Curtis resemblance matrix was calculated then calculated for pairwise combinations of groups. A cluster analysis was conducted using the group average algorithm, followed by nMDS. Birds were absent during winter survey events within seagrass beds and were therefore significantly different than all other seasonal habitat groupings. The bird assemblage found in seagrass during the spring was also significantly different from the other groups (Figure 19). The dendrogram illustrates that most bird assemblage season/substrate clusters appeared to form combinations based more on similar substrate characteristic rather than season. For example, one group cluster was composed of bird communities surveyed at manmade structures during winter, summer, and autumn. Similarly bird communities at the oyster reef formed a cluster composed of all seasonal bird survey results along with three season's bird community data collected at mudflat sites (Figure 19)

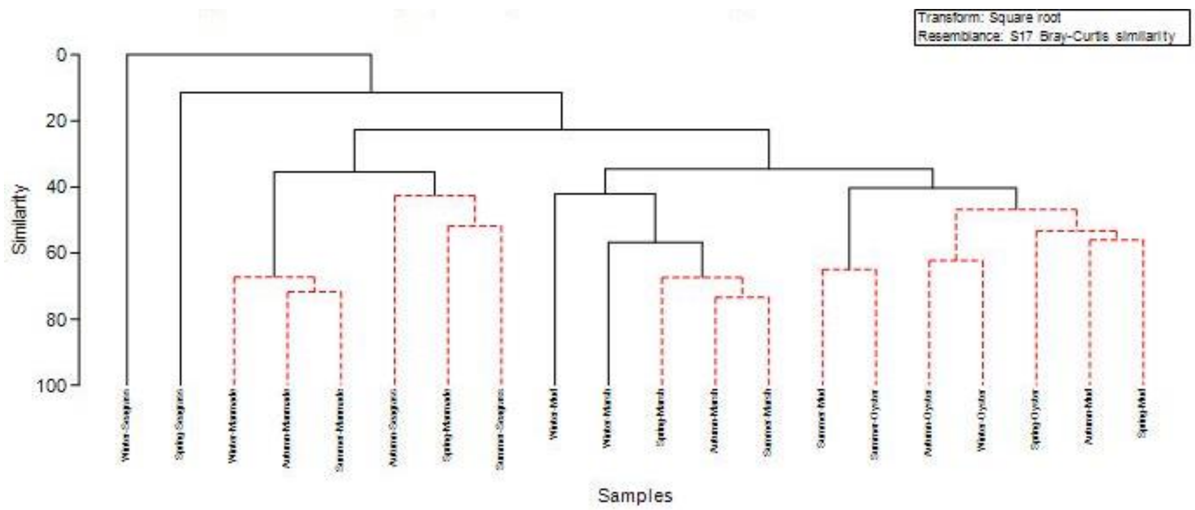

Figure 19. Cluster analysis of species abundance by both substrate and season.

The nMDS was run comparing bird communities using bird densities, season, and substrate for species of interest (Figure 20). Based on examination of the dendrogram Survey clusters were, again, formed more often formed by substrate categories than by season. SIMPROF was run with a 5% significance level to determine the number of clusters and their locations. For example, all bird community composition based on surveys during four seasons at oyster reefs were grouped data from mudflats collected during the spring, winter, and autumn. Three seasons of seagrass were also grouped for similarity.

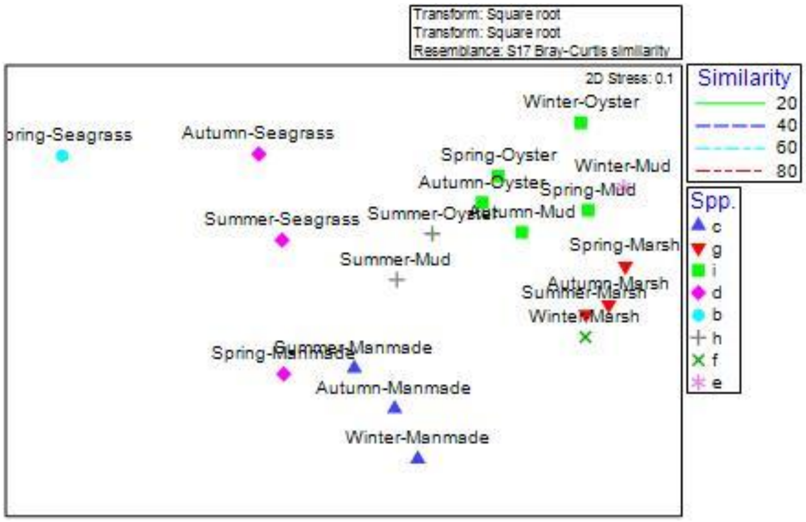

Figure 20. Non-Metric MDS for species abundance by both season and substrate.

Hot Spot Analysis

Finally, data in ArcGIS Pro was analyzed using "optimized hotspot" and "emerging hotspot" analyses to better understand which parts of the bay were utilized most by wading birds and shorebirds. Optimized hot spot analysis was run and found five hot spot areas of high bird use, three of which were large. All five lined up with observation patterns in the field (Figure 21).

Figure 21. Optimized Hot Spot Analysis of all birds surveyed during conventional surveys.

An emerging hotspot analysis was also run (Figure 22). The dataset collected was only a year, which is limited for most emerging hot spot analyses. It did, however, provide three large hotspots, similar to the three observed using the emerging hot spot analysis. All of these hot spots included areas of "sporadic hot spot", indicating that the hot spots were not consistent over the year of surveys. One area included portions of "new hot" spot as well, indicating an increase in usage over the course of the surveys. Taking this data into account, another emerging hot spot analysis was run using the space time tool in ArcGIS Pro. This provides a visual of how the hot spots are changing over time. Looking through the 3D visual, patterns revealed there were more areas of hot spot during the winter and spring months than the summer and fall. Specifically, areas of oyster reefs appeared to have higher instances of hot spot during the winter than in other seasons.

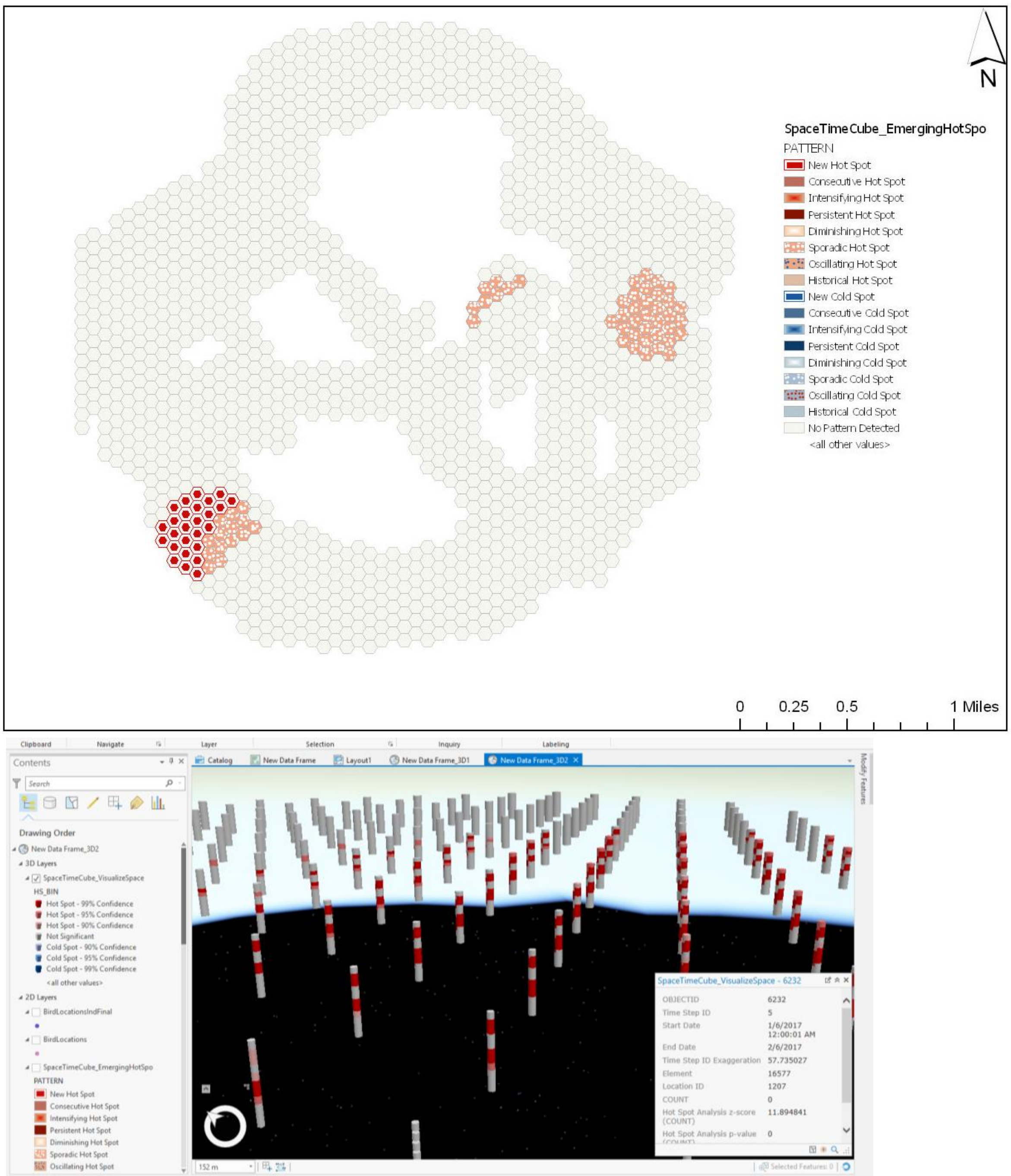

Figure 22. Emerging Hot Spot Analysis of all birds surveyed during conventional methods (top) with screen shot of the 3D visual provided by ArcGIS (bottom).

Texas Species of Concern

All migratory and resident bird species in Texas are facing potential challenges their continued population viability. The Texas Parks and Wildlife Department has identified bird species of greatest conservation need that may be facing declines in abundance (TPWD, 2011). These species include Reddish Egret, Piping Plover and Black Skimmer. American Oystercatchers are no longer listed as a species of concern, but they are still a species of interest along the Gulf Coast because of their reliance on intertidal oyster reef and habitats that are in decline. Reddish Egret, American Oystercatcher and Plovers were, thus, mapped using ArcGIS Pro to depict their distribution across the bay throughout the study period. Their use of substrate by season was graphed in Excel to show the changes in sightings across the year. Reddish Egrets had sightings around the bay and were seen using all the substrate possibilities over the year of surveys (Figures 23). The highest number of Reddish Egrets were seen in autumn utilizing marsh for foraging. Autumn had the highest abundance of Reddish Egrets (38), while spring had the lowest (14). Winter was the only season where Reddish Egrets were seen utilizing mud in higher numbers than marsh (Figure 24).

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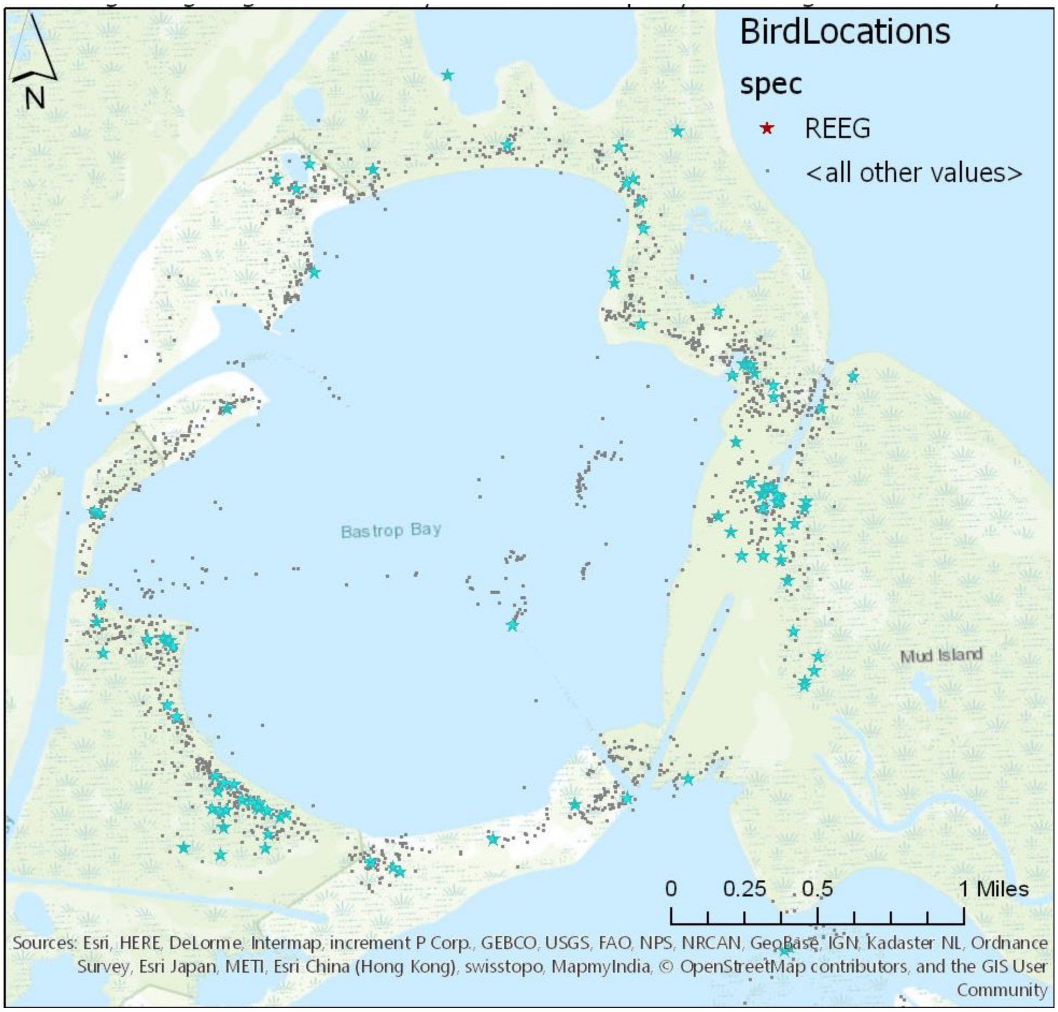

Figure 23. Map of all Reddish Egret sightings at Bastrop Bay during conventional surveys

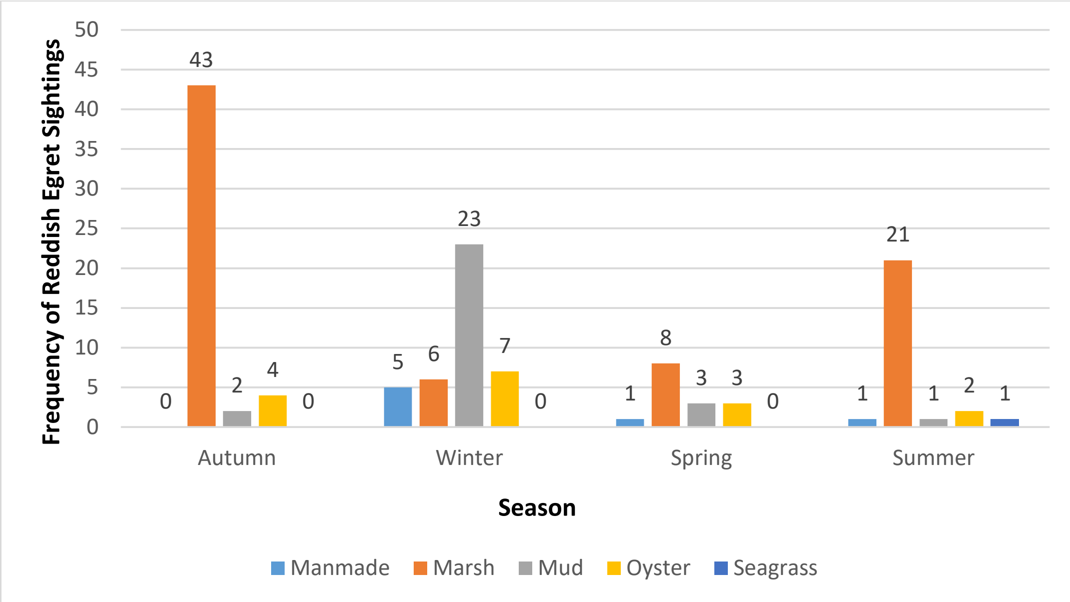

Figure 24. Frequency of Reddish Egret substrate use across all surveys by season.

Plover species that were grouped together to be mapped included Black-bellied Plover, Piping Plover, Semipalmated Plover, Wilson's Plover and Golden Plover. The highest numbers of plover were seen in the southwestern portion of the bay, with the fewest number seen in the northern portion of the bay (Figure 26). Plovers were seen using mostly mudflats during the spring, while during autumn they were observed using marsh and oyster substrate at comparable frequencies. The fewest sightings of plovers occurred during the summer and winter when these species were observed using mostly oyster substrate, with a few sightings in mud (Figure 27).

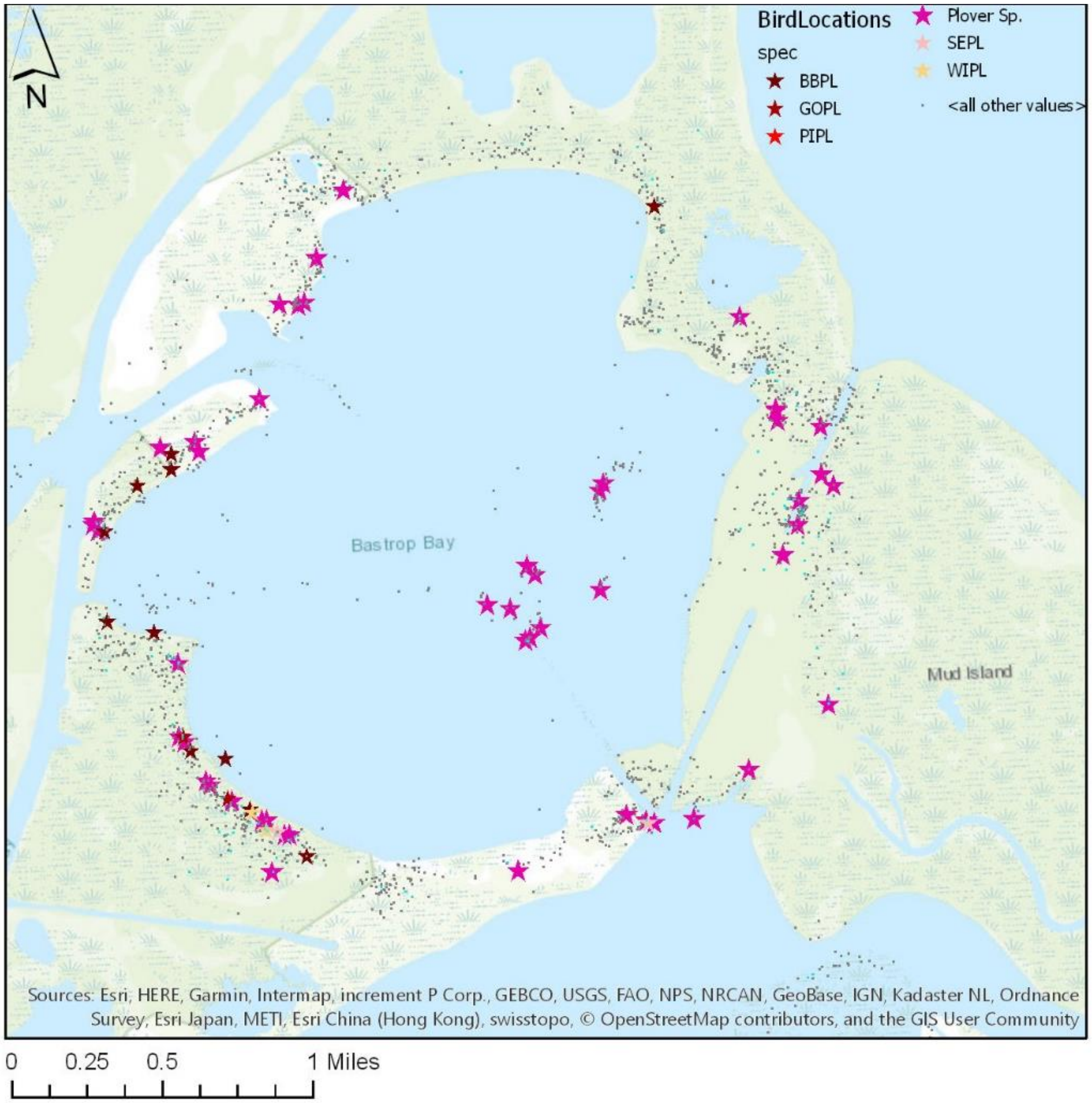

Figure 25. Map of all Plover sightings (all identified species and those unidentified to the species level) at Bastrop Bay during conventional surveys BBPL = Black-bellied Plover, GOPL = Golden Plover, PIPL = Piping Plover, SEPL = Semipalmated Plover, WIPL = Wilson's Plover.

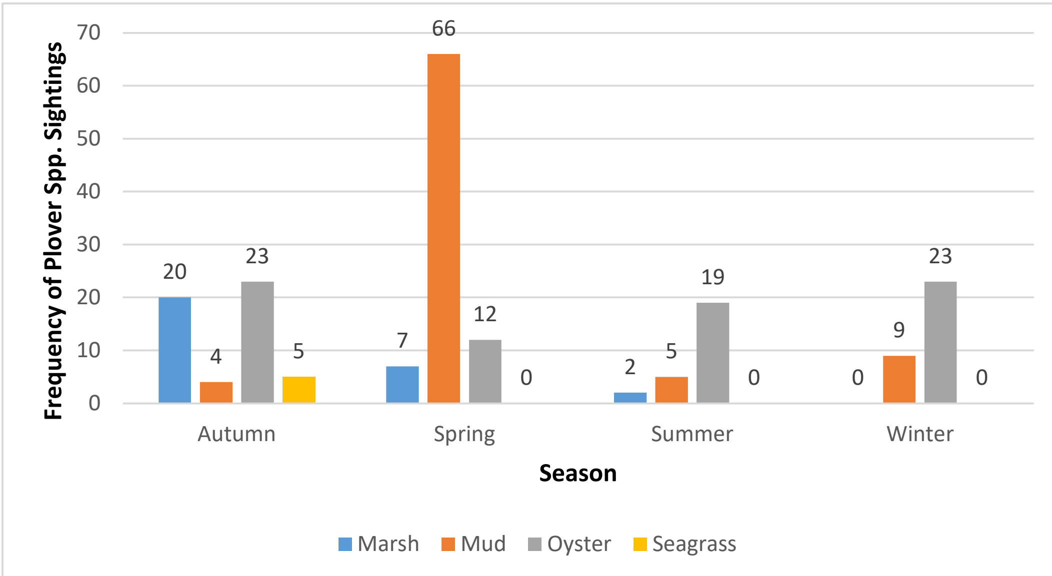

Figure 26. Plover (all identified species and those unidentified to the species level) substrate use across all surveys by season

American Oystercatchers were predominately observed on the using emergent oyster reefs in the middle of the bay, although they were also seen less frequently along the oyster shell beaches and reefs around the bay (Figure 28). During the summer, American Oystercatchers were seen only utilizing oyster substrate. During the other three seasons, however, they were seen using mudflats on occasion. This species was seen in the fewest numbers during the summer.

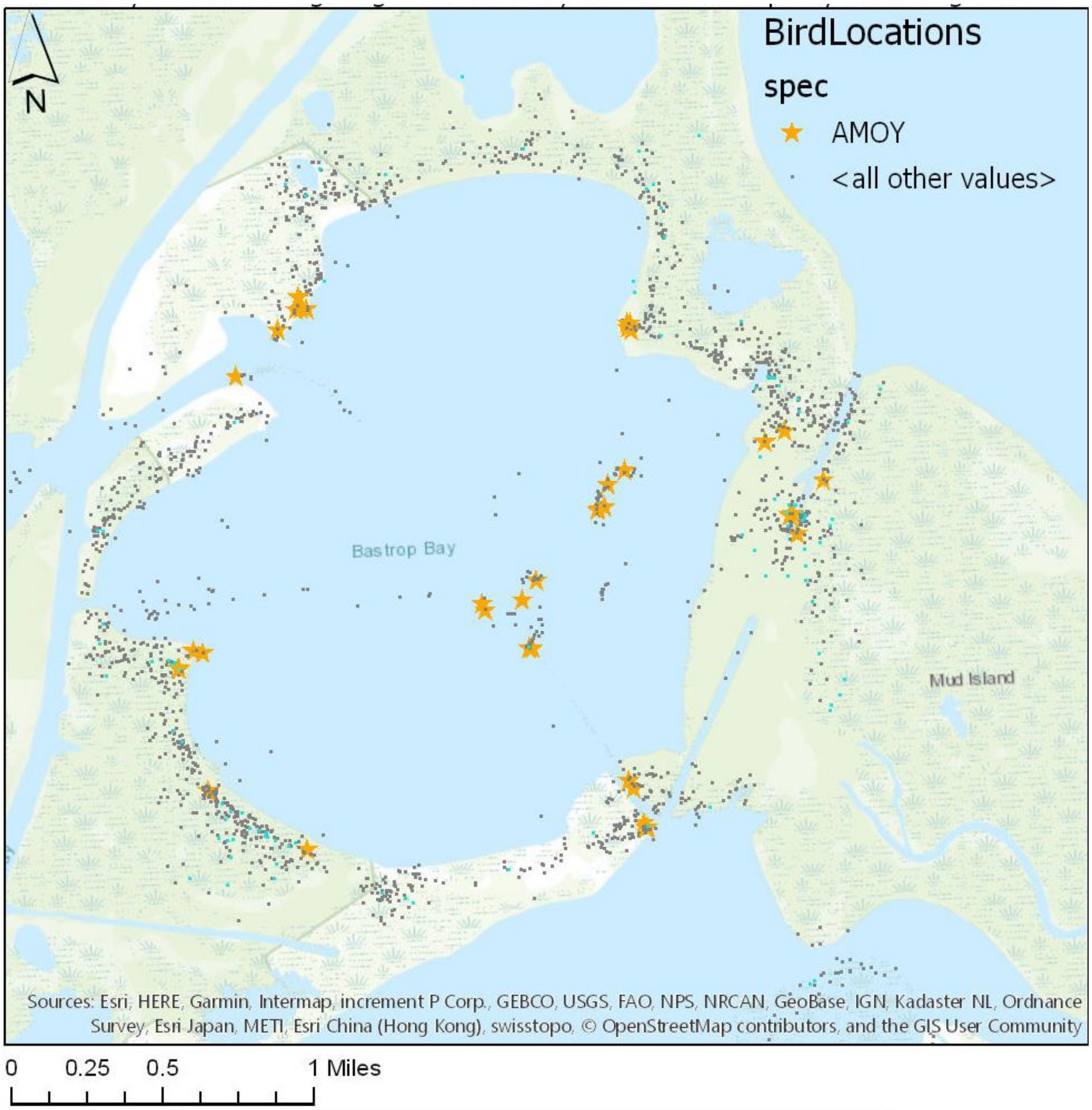

Figure 27. Map of all American Oystercatcher sightings at Bastrop Bay during conventional surveys.

UAV Surveys

Fixed-wing surveys were conducted more frequently than quadcopter surveys primarily because the fixed UAV was available during the entire survey versus the quadcopter, which was purchased during the last few months of the study.

Data was collected on the behavior of the birds during the UAV surveys, specifically if and when they flushed during the flight duration. This included the number of birds and the species that flushed during launch, flight, and landing.

Using Primer, a Principle Components Analysis was conducted to analyze the relationship of height of the UAV flight and the various species flushing behavior. The data was square root transformed and was run using Euclidean distance. The circle on the graph represents the base variables. Based on this analysis, there were three principal components that accounted for almost 95% of the variation (PC1 = 82%, PC2 = 7.7%, PC3 = 5.0%). Principle component 1 was defined as PC1 = 0.931 (300 feet) + 0.326 (75-100 feet) + 0.149 (50 feet). Principle component 2 was defined as PC2 = 0.776 (75-100 feet) + 0.417 (200 feet) -0.343 (300 feet). This means that 300 feet had a great deal of influence on PC1 and 75-100 feet had a great deal of influence on PC2. This is evident in the PCA biplot as the 300 feet vector is very long and pointed mostly to the right. The vector for 75-100 feet, on the other hand is long and pointed mostly up. The other UAV heights have shorter vectors, indicating less species flushing at those heights. Most of the species did flush at around 300 feet, driving the PC1 vector. Western Sandpiper, Snowy Egret, Roseate Spoonbill, and Tricolored Heron were found to be the species driving this association. Black-necked Stilts, on the other hand, were more likely to flush in the 75-100 foot range, driving PC2 (Figure 28).

A cluster analysis of the species of birds by what height they flushed is displayed in Figure 29. In this analysis, it is evident that Western Sandpiper (WESA) and White Ibis (WHIB) flushed at significantly different heights than the other species. This is indicated by the solid, black lines. This is likely due to the fact the Western Sandpiper and White Ibis flushed often at 300 feet.

A cluster analysis and an nMDS of the number of each indicator species and at what point in the survey they flushed (launch, flight, landing) were created. In the cluster analysis (Figure 30), there are several significant groupings of birds. Western Sandpipers and White Ibis, for example flushed at different points in the UAV flight pattern than the other species. This is likely a result of them flushing regularly at 300 feet. Killdeer and Yellow-crowned Night Heron were also, again, significantly different than the other species. The nMDS (Figure 31) shows similar groupings of birds based on pattern of similar flushing behavior in response to flight stage. The YCNH and KILL exhibited similar behavior as depicted in the ordination plot. Other smaller groups included one of only Western Sandpiper and White Ibis, one with Snowy Egret and Great Egret, and a grouping with Roseate Spoonbill, Willet and Tricolored Heron. The last group included all other species of interest. The differences in

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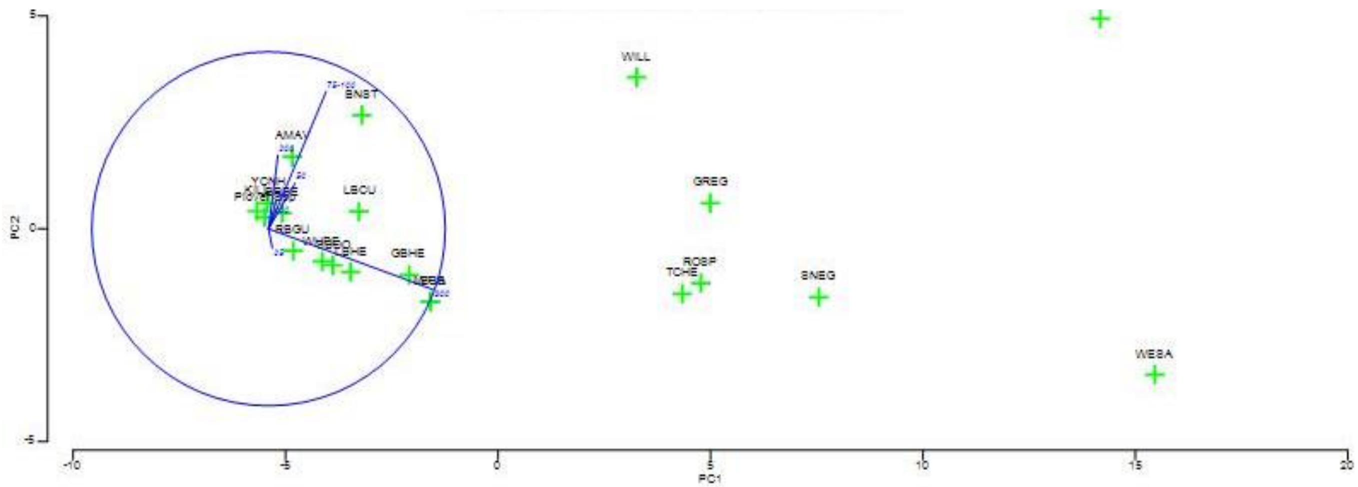

Figure 28. Principal components biplot of the altitude of the UAV at which various species flushed.

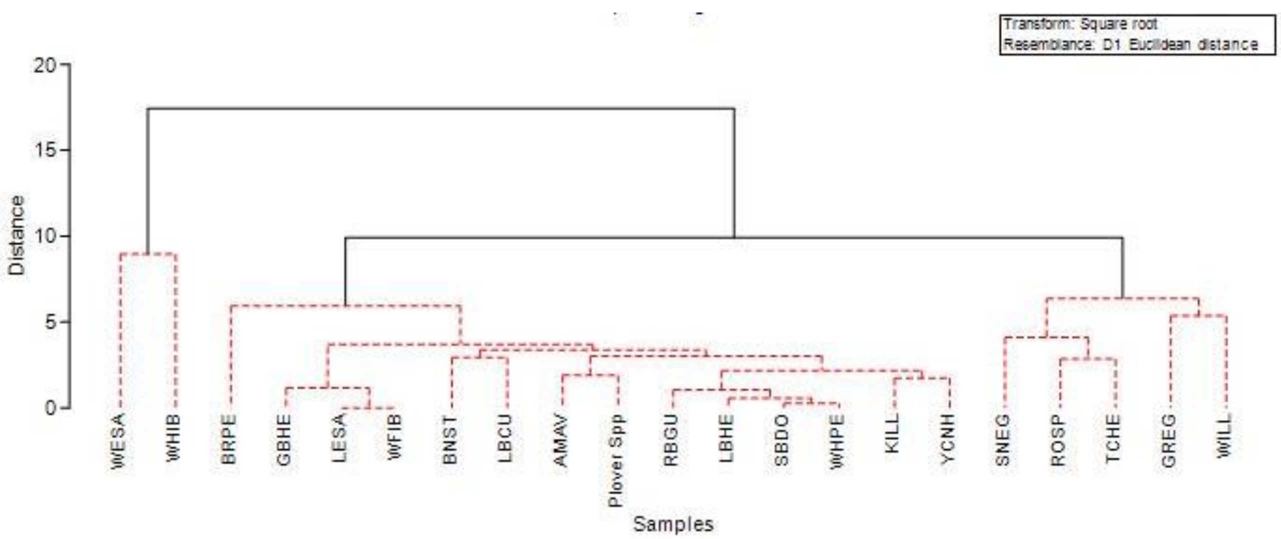

Figure 29. Cluster analysis of the height of UAV for flushing behavior by species of interest

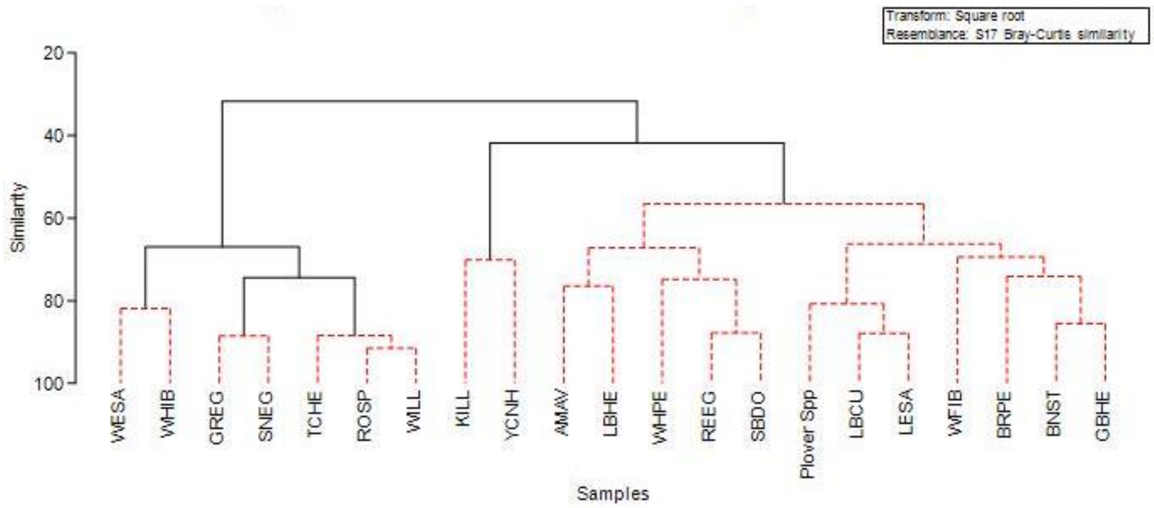

Figure 30. Cluster analysis of the flushing response of bird species of interest based on the 60% similarity.

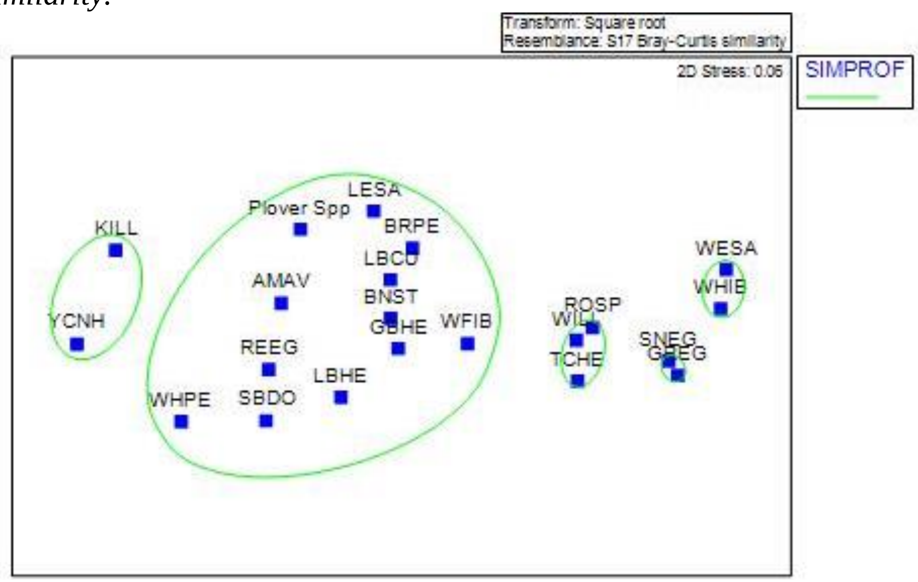

Figure 31. Non-Metric MDS of which stage during UAV surveys birds flushed by species.

Figure 33 displays an nMDS that was run using the same data as Figure 32, except it didn't include the categories "never flushed" or "all flushed" as characteristics used in the classification. Yellow-crowned Night Heron and Killdeer, for example, were grouped at the 60% similarity level in Figure 32 because they had the same number of individuals flushing overall. In figure 33, they are also grouped at the 60% similarity level, but on opposite sides of the figure. This is because Killdeer flushed during launch more often and Yellow-crowned Night Heron flushed during landing more often. Both figures show similar groupings of birds. Finally, an nMDS was run for the number of individuals in each species that flushed at all during the flights (Figure 33). Using the SIMPROF (60% and 80%) overlays, similar groupings appear as found in Figures 31 and 32.

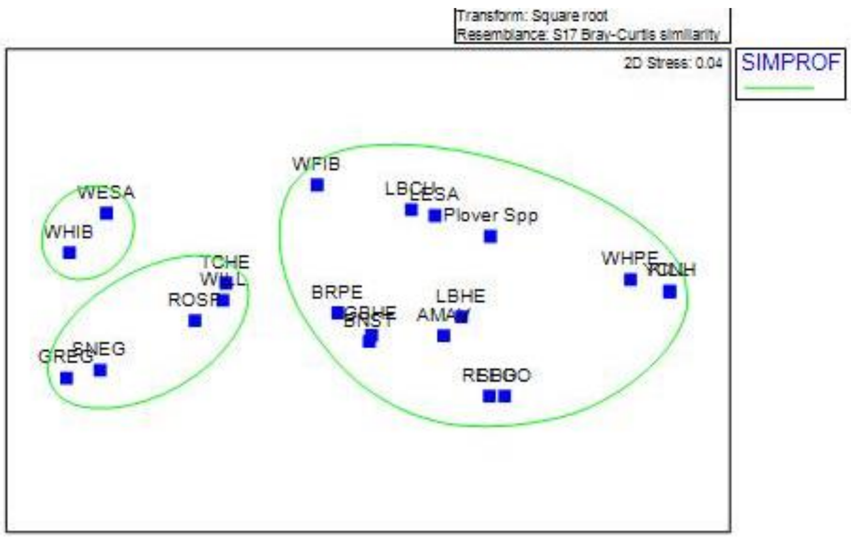

Figure 32. Non-Metric MDS of the species of interest by when they flushed during the UAV survey, not including those that did not flush.

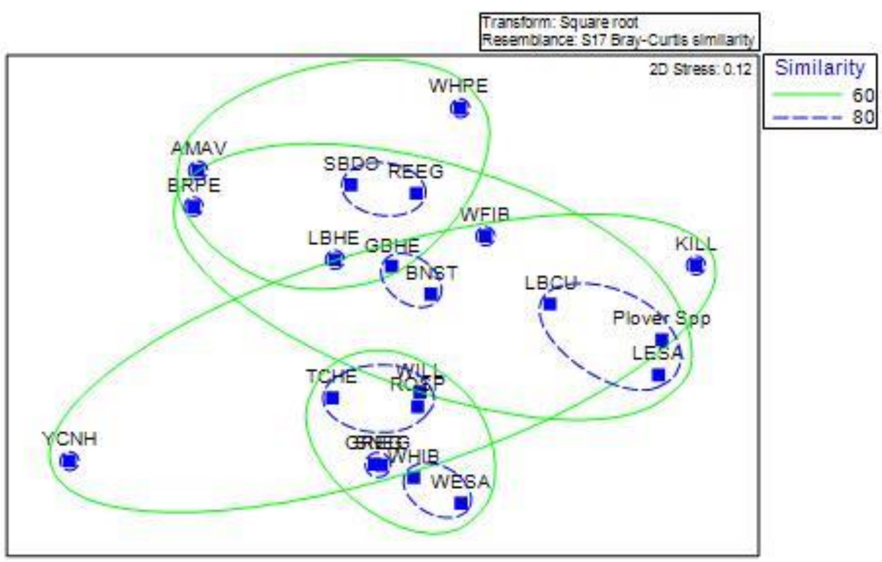

Figure 33.Non-Metric MDS of the number of individuals of each species that flushed during UAV surveys.

The number of birds surveyed using the two types of UAV were graphed (Figure 34). The categories included those that never flushed throughout the entirety of the survey, those that flushed at some point after launch, and those that flushed at any point during the survey. The last category is the number of birds and species that were counted from the video footage after the survey was completed. It is evident that a much higher percentage of species were identifiable from the quadcopter footage than the fixed-wing footage (73% and 30% of ground survey numbers). In fact, 70 more birds were counted using the quadcopter footage than the associated conventional field count. The fixed-wing footage only provided high enough detail to identify three species of bird, White Pelicans, Great Egret and Snowy Egret. These were only identifiable by general size and color. In contrast, all but the smallest species of bird were identifiable from the quadcopter footage.

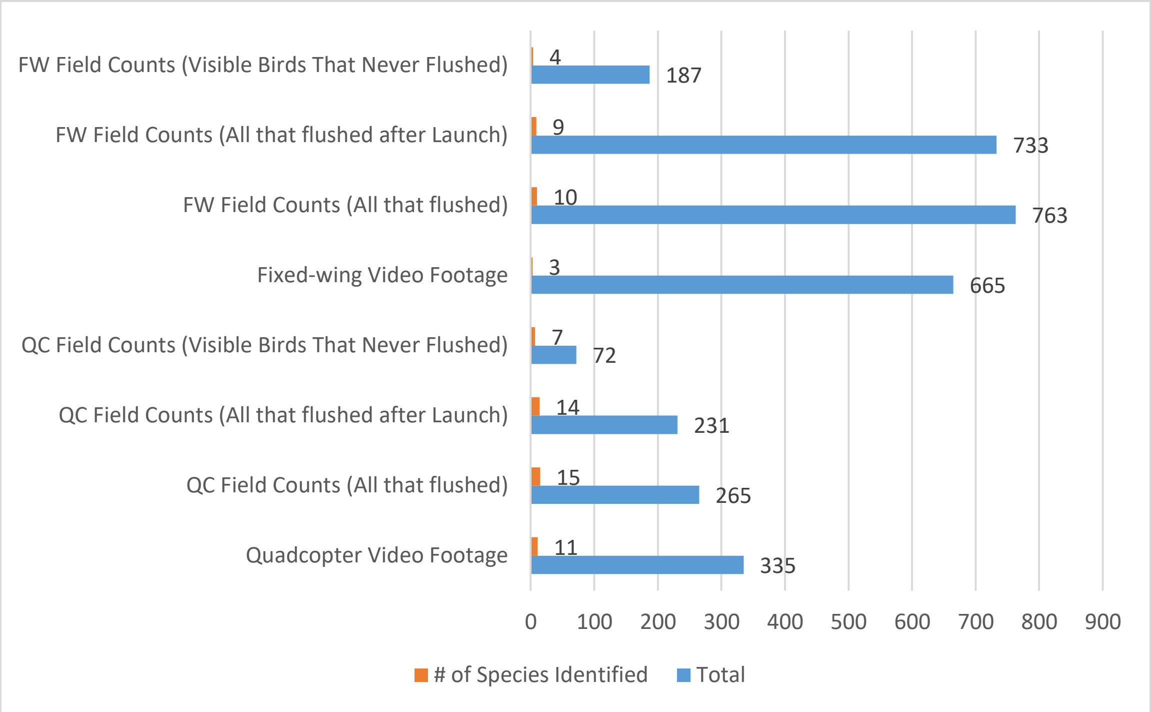

Figure 34. Counts of all birds surveyed using footage from both the fixed-wing UAV and the Quadcopter UAV, as well as from conventional survey methods conducted during those UAV flights.

In comparison to the fixed winged UAV, the quadcopter also failed to illicit a flushing response from a larger numbers of species, and a slightly higher percentage of the individual birds that never flushed (27% compared to 24% for the fixed-wing UAV). Despite the presence of fewer individuals in the quadcopter surveys as compared to the fixed-wing survey, there were more species that were identifiable. There were also more "missed" birds found while observing quadcopter footage than the fixed-wing footage, indicating a greater success of the survey.

CHAPTER IV:

DISCUSSION

Conventional Surveys

The primary objectives of this study included identifying important habitat for water-dependent birds in intertidal zones such as Bastrop Bay, Texas. Substrate preferences and changes in these preferences dependent on season and tidal influence were also of interest.

During this study a complete census of the majority of bird species inhabiting the designated survey area within Bastrop Bay was conducted. Estimates of the abundance and diversity of index species was also successfully conducted. During the study shorebirds and waterfowl, as a group, were observed in much higher numbers during the winter than in the other three seasons. This pattern is consistent with past literature and observations that have documented the use of the Texas Gulf Coast as an important stopover by bird migrating along the central flyway (Ortego and Ealy, 2009). According to the 2009 Winter Texas Gulf Coast Aerial Shorebird Survey, Texas has served and can continue to serve as a significant site for wintering shorebirds, but documentation efforts along the coast have been lacking (Texas Ornithological Society, 2010). During their one-week, winter survey, a total of 45,948 shorebirds were counted across Galveston Bay (Ortego and Ealy, 2009). By comparison, over the course of five days in the field surveying half of Bastrop Bay each day during winter, we observed 3,276 shorebirds. These data supports the theory that Bastrop Bay is providing exceptional habitat for wintering birds, specifically shorebirds.

Determining use of Bastrop Bay as a habitat is important for guiding coastal management decisions in the future. Bastrop Bay has numerous substrates and foraging areas present within its boundaries, which provides a complex mosaic of habitat for birds.

The ArcGIS maps created for this study displayed a high usage of emergent oyster reefs by Charadriiformes and Pelecaniformes. Additional graphical and statistical analyses indicated that members of Charadriiformes were observed using marsh, oyster, and soft-bottom at substrate at relatively equivalent frequencies. Members of order Pelecaniformes, however, were more likely to be seen using marsh than the other substrate types. Individuals within the Anseriformes were most often seen associated with oyster reef, although they are also seen in open water most likely while they were foraging (Rylander, 2002).

Distinct patterns in substrate preference were observed by family. Members of the families Ardeidae and Threskiornithidae, or the herons, egrets, ibises and spoonbills, were most frequently observed in marsh habitat. Members of the family Recurvirostridae, stilts and avocets, were seen utilizing only two substrates, mud and marsh (about 75% and 25% of the time, respectively). These patterns observed during the surveys at Bastrop Bay align closely with what is known about foraging behavior for many of these species (Rylander, 2002). Analysis of the most common and abundant species of birds supports previously documented general patterns in habitat usage by these species. The herons and egrets observed during the study all used marsh as the predominant substrate. Great Egrets favor shallow coastal lagoons and large marshes (Rylander, 2002). The three shorebird species examined were in contrast observed using multiple types of substrates in Bastrop Bay during the study period.

The bird species composition that primarily utilized marsh habitat was significantly different from the community utilizing mud and oyster reef. The other substrates were used less frequently by birds and were, thus, significantly different from these top three substrates. The marsh bird community was likely significantly different from mud and oyster reef due to the high numbers of foraging herons and egrets occupying the lakes and edges of the marsh. These large waders are seen less often utilizing mud flats and oyster reef. Instead, other shorebirds are seen in higher numbers on these substrates. This could be partly as a result of a preference for these substrates, and partly as a result of observer bias when surveying marsh areas. Seeing small shorebirds on mud flats, for example, is much easier than observing them from a boat in a marsh that possesses dense stands of *Spartina alterniflora* or *Spartina patens*. Taller colorful or predominantly white herons and egrets stand out of the marsh, and are, thus, observed more easily.

It was hypothesized that water level would have an impact on what substrate was available and therefore utilized, thus influencing which species were observed. This hypothesis was supported as waterfowl were seen at significantly lower water levels than shorebirds, wading birds, and waterbirds. Wading birds were also seen at significantly higher average water levels than shorebirds, waterbirds, and waterfowl.

Data was examined to determine if seasonality would have an impact on what substrates birds are utilizing. The Texas coast is visited by has high numbers of wintering birds during the time when water levels are often very low due to strong northern cold fronts. These meteorological events expose large areas of the intertidal zone which provides more substrate, including oyster reef and seagrass beds as foraging habitat for birds. However, data collected during this study did not support water levels as having a major influence on substrate use. Furthermore species composition and abundance appeared to be more influenced by the substrate type than the season. Similar assemblage of birds based on taxonomy and order or family appeared to use a given substrate across all seasons, despite the influx of seasonal migrants.

Three large areas and two small areas of Bastrop Bay were determined to be hot spots. A hot spot was defined as an area with high values of z-scores and p-scores, and is surrounded by other areas of high scores.   The largest hot spot area identified was a shallow mud flat, which contained the highest abundance of visible seagrass in the bay. This area also enclosed oyster reef habitat that was exposed during low water levels, fishing camp houses and docks, and surrounding marsh grasses. In summary this area contained the highest variety of substrates that all species of interest use, and was frequently utilized by large, diverse flocks of birds (Figure 35).

Figure 35. Photo of a portion of the largest hot spot identified during this study which included manmade substrate, marsh, oyster reef, seagrass and mudflats.

The second hot spot is an area of oyster reef and an associated shell hash island that was usually exposed in the center of the bay (Figure 36). This reef regularly harbored large flocks of Brown and White Pelican as well as a variety of waterbird and shorebird species. Great Blue Heron were occasionally observed using this substrate habitat as well.

Figure 36. Photo of the second largest hotspot in Bastrop Bay, an emergent oyster reef and shell hash island in the middle of the bay that was often utilized by pelicans and shorebirds.

The third hot spot was a marsh area with many shallow ponds/lakes and mud flats that are utilized by shorebirds and wading birds for foraging (Figure 37). The two small hot spots were emergent oyster reefs. All hot sports provided substrate for high concentrations of species of concern as well. For example, Reddish Egret were seen regularly using the first hot spot in the eastern portion of the bay as well as the western-most hot spot. Plovers were seen using all three large hot spots in high numbers. American Oystercatchers were seen using the oyster reef portions of all the hot spots.

Figure 37. Photo of the third largest hot spot in Bastrop Bay, depicting mud flats and intertidal marsh utilized by a large diversity of bird species.

The results of this analysis can be used in making management decisions of proposed and future activities within this bay system. The western-most hot spot, for example, is part of Brazoria National Wildlife Refuge and is therefore protected by existing federal conservation programs and regulations. In contrast, the eastern-most hot spot is surrounded by the aforementioned fishing camps and is regularly traversed by fishermen and recreational boaters. During surveys, regular disturbance of birds in this area was observed. During one survey, no birds were seen using this hotspot, but fresh prints from a person and their dog were visible in the mud. Based on this evidence it was postulated that all birds using the area had recently been flushed as a result of visitation by humans and dogs. This area is evidently an important foraging habitat for many species of bird, including migratory birds and species of concern, but is at risk of high disturbance.

Most of the data collected during the study period at Bastrop Bay supports the past literature on the ecology and life history of the observed species. However, little was known about the bird community utilizing Bastrop Bay. This study provides unique baseline data on the species composition, diversity and abundance of coastal birds using this estuarine system. This data can be used for future management efforts or continued monitoring of avian species in the area.

If this study were to be conducted again, it is recommended that points around Bastrop Bay be randomly generated for certain substrates and visited each survey. At these points, total counts of all birds within 400 yards in each direction should be recorded. This would facilitate probability based statistical analyses. This method would also save time in the field and would enable for testing assumptions regarding bird species composition, diversity, and seasonal variations for the entire bay. The generation of habitat maps illustrating the distribution of the different substrates would also be of use for future continuations of this study. These could be used to determine the number of birds per amount of substrate area and would help determine importance of these foraging substrates. For example, understanding how many birds were utilizing the relatively small amount of seagrass present may indicate that seagrass is a preferred or highly important substrate for implementation of bird management practices.

Developing a system to better monitor the water levels would be useful for continuation of this study, as well. Deploying site-specific water level monitors would permit better modeling or exposed habitat during different water levels.

UAV Surveys

One of the original objectives of this study included utilizing UAV technology, specifically the fixed-wing UAV model, to conduct bi-monthly surveys of bird populations. The methodology design was based on the success of a similar study conducted McEvoy et al. (2016) using fixed-wing drones for surveying waterfowl. When field tests were conducted, however, the fixed-wing UAV was found to cause a high level of disturbance across many species of interest. At this point, study objectives were adjusted. The new objective goal was to determine and develop a UAV flight protocol that has the smallest amount of disturbance on the coastal birds surveyed, while still obtaining high-quality imagery for species identification and covering the largest amount of area possible. By doing so, UAV technology can be implemented effectively in surveys of intertidal areas such as Bastrop Bay, increasing the ease and accuracy of data collection and, thus, enhance better management of this habitat.

To develop a protocol, an understanding of effects of UAVs on birds must first be determined. During this study the first UAV survey attempts, all fixed-wing, performed poorly. Some surveys ended prematurely due to logistical issues associated with operation of the fixed-wing UAV. In some cases weather made it impossible to launch or land the UAV. In other cases, user error ended with the UAV landing prematurely or landing in the water, ending all surveys for that day. As users became more familiar with the operation of the fixed wing UAV the number of successful surveys increased. Although the surveys were technically successful many bird species were observed flushing, specifically during the launch sequence. Over the course of seven of the fixed-wing UAV flights (12/6/2016, 12/16/2016, 1/24/2017, 3/13/2017, 4/7/2017, 6/8/2017, 5/31/3017), 17.2% of all birds present flushed at launch. Therefore, 17.2% of birds, represented by 24 different species, were not captured in the survey footage. This performance metric represents an unacceptable percentage by most survey standards.

Individuals that did not flush at launch during fixed-wing surveys in most cases flushed at other points in the survey sequence. For example, of the 763 birds counted during one fixed-wing survey (06/08/2017), only 187 birds were observed not flushing at all during the survey. Different species were observed flushing more often at certain flight heights and certain stages during the surveys. For example, Snowy Egret and Great

Egret flushed at similar heights and stages during surveys. In most cases these species were some of the last species to flush when the UAV passed over. In contrast, Killdeer were quick to flush, most often at launch of the UAV. Yellow-crowned Night Heron, however, was more likely to flush at landing. McEvoy et al. (2016) suggested that flushing behavior during launch was often as a result of launching in the direction of the birds. In the case of the fixed-wing UAV used in this survey, however, the direction of launch is based on wind direction and often cannot be changed to accommodate the location of the birds. During their study, McEvoy et al. (2016) also suggested that the shape of the UAV causes different levels of disturbance behavior, those shaped like birds of prey causing the most disturbance. It is difficult to change the shape of a fixed wing UAV to anything not resembling a large bird (e.g., raptor) expanded wings and still maintain aerodynamic features.

The quadcopter caused visibly less disturbance during surveys than the fixed-wing. Fewer birds flushed at launch using the quadcopter, likely because it can be launched from the boat, moving straight up to the appropriate survey height before flying over birds of interest. The Quadcopter is easier to set up, potentially causing less disturbance as a result of observers and UAV operators preparing to launch the fixed-wing UAV. As a result, over the course of four short quadcopter surveys, only 8.3% birds flushed during launch stage. This percentage is also likely inflated because the data was collected during our first trip out with the quadcopter, and the pilot was not yet used to handing the UAV. Using the quadcopter, we were also able to fly at much lower heights, both as a result of control over the UAV, and because it causes less disturbance at lower heights than the fixed-wing. We were able to lower the quadcopter over a group of birds down to within 30 feet without flushing individuals. When the quadcopter was moved from side-to-side at this height, however, we saw disturbance. It was found that very few birds flushed during quadcopter surveys that were done at 20 meters height and around 10-12 kilometers per hours speed. At this height, we were able to still observed a large area and identify many of the bird species.

Identification of birds using video is an important aspect of utilizing this technology for surveying and development of resource management options in the future. Video obtained using the fixed-wing UAV with equipped Sony A6000 camera did not yield sufficiently high enough quality images to identify many of the individuals observed in the footage to species level. In fact, only two large species could be identified, White Pelican and Great Egret. These two species are both large, white birds and show up well in the footage. All other species present during the survey, approximately ten of them, were not identifiable. In fact, more individuals were counted during concurrent field surveys than examining video footage (763 individuals counted in the field, 665 individuals marked in the footage). The quadcopter footage, however, provided footage of birds that were missed during field counts. During one concurrent survey, 265 birds were counted during the conventional field count while 335 birds were counted when video footage was examined. Eleven of the 15 species observed could be identified using the footage. Only the smallest birds (plover spp. Killdeer, etc.) were not identifiable using the quadcopter footage.

Although McEvoy et al. (2016) suggest using a fixed-wing UAV, they had access to extremely high-quality and expensive cameras. Studies conducted with a smaller budget cannot afford such equipment. We suggest using a medium-sized quadcopter UAV with at a minimum of a 20 megapixel camera to survey shorebirds and wading birds in intertidal habitats. Flying this type of UAV at around 20 meters height allows for most species to be identified and for more precise counts than traditional ground surveys. By following this protocol, it is likely that surveys can be conducted in a more accurate manner than even traditional aerial counts. As cameras continue to improve and become less expensive, the success of this methodology will only improve. As the prices of high quality cameras declines this may also increase the utility of using fixed UAV under special circumstances such as colonial waterbird counts and surveys of larger and medium flocks of single species.

Due to time and funding constraints, limited quadcopter surveys were conducted. To continue this research and get a better quantify disturbance potential by species, more surveys will need to be conducted. One challenge that was discovered during this study is that many of these species of birds will move frequently in the absence of any obvious man-made disturbance. Flocks of birds appear to naturally exhibit constant movement while foraging. Determining what movement is caused by the UAV and what is natural will continue to be a challenge for understanding disturbance potential. We suggest utilizing a second quadcopter UAV to survey the entire area of interest while the first conducts transect lines at a lower altitude. Using this approach background and daily or diel natural movement patterns can be determined.

When conducting conventional field counts, the first step in conducting a field survey of an area is to scan the area of interest to determine where birds are located within the area. After this, observers will begin to count birds within the location to obtain a total count of the area. The use of the proposed second UAV can serve as the initial scanning platform and take the place of this step in conventional field surveys. This method would allow observers to use both sets of footage in order to obtain the most precise number of birds. The second UAV would provide information on movement in and out of the survey area, as well as any potential for double-counts of individuals that move within the study area. By combining the information from both UAVs, the complete picture of an area of interest is obtained.

It is recommended that this research continue. Specifically future research should continue to adopt smaller, more affordable and higher resolution cameras as the technology evolves. The adoption of such technology will enhance accurate data collection, reduce the size of UAV needed to carry the camera hardware and reduce flushing behavior. The adoption of future UAV units that include the technology described will enable biologists to accurately survey many bird species including those found in hard to access locations. At that point it is highly likely that UAVs will be the technology of choice for surveys and management of intertidal, coastal, and wetland ecosystems. This will provide an affordable alternative alone and when coupled with traditional surveys and satellite imagery to document changes in habitat and resources. This will be useful for coastal and natural resource managers dealing with the impacts of climate change, severe storms, channel dredging, coastal barriers, and land-use changes on critical natural habitat and associated resources.

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APPENDIX A: SPECIES INFORMATION

Species	Code	Group	Order	Family	Size
American Avocet	AMAV	Shorebird	*Charadriiformes*	Recurvirostridae	L
American Bittern	AMBI	Wading Bird	Pelecaniformes	Ardeidae	NA
American Oystercatcher	AMOY	Shorebird	Charadriiformes	Haematopodidae	M
Black-bellied Plover	BBPL	Shorebird	Charadriiformes	Charadriidae	S
Black-bellied Whistling Duck	BBWD	Waterfowl	Anseriformes	Anatidae	D
Black-crowned Night Heron	BCNH	Wading Bird	Pelecaniformes	Ardeidae	M
Belted Kingfisher	BEKI	Other	Coraciiformes	Alcedinidae	NA
Black Skimmer	BLSK	Waterbird	Charadriiformes	Laridae	M
Black Tern	BLTE	Waterbird	Charadriiformes	Laridae	NA
Black-necked Stilt	BNST	Shorebird	Charadriiformes	Recurvirostridae	M
Brown Pelican	BRPE	Waterbird	Pelecaniformes	Pelecanidae	XL
Bufflehead	BUFF	Waterfowl	Anseriformes	Anatidae	D
Cattle Egret	CAEG	Wading Bird	Pelecaniformes	Ardeidae	M
Caspian Tern	CATE	Waterbird	Charadriiformes	Laridae	NA
Clapper Rail	CLRA	Other	Gruiformes	Rallidae	NA
Common Loon	COLO	Waterfowl	Gaviiformes	Gaviidae	NA
Cormorant Spp.	Cormorant Sp.	Waterbird	Suliformes	Phalacrocoridae	NA
Dunlin	DUNL	Shorebird	Charadriiformes	Scolopacidae	M
Forster's Tern	FOTE	Waterbird	Charadriiformes	Laridae	NA
Great Blue Heron	GBHE	Wading Bird	Pelecaniformes	Ardeidae	XL
Great Egret	GREG	Wading Bird	Pelecaniformes	Ardeidae	XL
Great Frigatebird	GRFR	Other	Suliformes	Fregatidae	NA
Green Heron	GRHE	Wading Bird	Pelecaniformes	Ardeidae	M
Greater Yellowlegs	GRYE	Shorebird	Charadriiformes	Scolopacidae	M
Harris's Hawk	HAHA	Other	Accipitriformes	Accipitridae	NA
Herring Gull	HEGU	Waterbird	Charadriiformes	Laridae	NA
Hooded Merganser	HOME	Waterfowl	Anseriformes	Anatidae	D
Killdeer	KILL	Shorebird	Charadriiformes	Charadriidae	S
King Rail	KIRA	Other	Gruiformes	Rallidae	NA
Laughing Gull	LAGU	Waterbird	Charadriiformes	Laridae	NA
Long-billed Curlew	LBCU	Shorebird	Charadriiformes	Scolopacidae	L
Little Blue Heron	LBHE	Wading Bird	Pelecaniformes	Ardeidae	L
Least Sandpiper	LESA	Shorebird	Charadriiformes	Scolopacidae	S

Least Tern	LETE	Waterbird	Charadriiformes	Laridae	NA
Lesser Yellowlegs	LEYE	Shorebird	Charadriiformes	Scolopacidae	M
Marbled Godwit	MAGO	Shorebird	Charadriiformes	Scolopacidae	L
Marsh Wren	MAWR	Other	NA	NA	NA
Northern Harrier	NOHA	Other	Accipitriformes	Accipitridae	NA
Northern Pintail	NOPI	Waterfowl	Anseriformes	Anatidae	D
Osprey	OSPR	Other	Accipitriformes	Pandionidae	NA
Pied-billed Grebe	PBGR	Waterfowl	Podicipediformes	Podicipedidae	NA
Plover Species	Plover Sp.	Shorebird	Charadriiformes	Charadriidae	S
Ring-billed Gull	RBGU	Waterbird	Charadriiformes	Laridae	NA
Red-breasted Merganser	RBME	Waterfowl	Anseriformes	Anatidae	D
Reddish Egret	REEG	Wading Bird	Pelecaniformes	Ardeidae	L
Ring-necked Duck	RNDU	Waterfowl	Anseriformes	Anatidae	D
Roseate Spoonbill	ROSP	Wading Bird	Pelecaniformes	Threskiornithidae	L
Royal Tern	ROYT	Waterbird	Charadriiformes	Laridae	NA
Ruddy Turnstone	RUTU	Shorebird	Charadriiformes	Scolopacidae	S
Sanderling	SAND	Shorebird	Charadriiformes	Scolopacidae	S
Sandwich Tern	SATE	Waterbird	Charadriiformes	Laridae	NA
Short-billed Dowitcher	SBDO	Shorebird	Charadriiformes	Scolopacidae	M
Semi-palmated Plover	SEPL	Shorebird	Charadriiformes	Charadriidae	S
Snowy Egret	SNEG	Wading Bird	Pelecaniformes	Ardeidae	L
Snow Goose	SNGO	Waterfowl	Anseriformes	Anatidae	D
Spotted Sandpiper	SPSA	Shorebird	Charadriiformes	Scolopacidae	S
Sharp-shinned Hawk	SSHA	Other	Accipitriformes	Accipitridae	NA
Tricolored Heron	TCHE	Wading Bird	Pelecaniformes	Ardeidae	L
Western Sandpiper	WESA	Shorebird	Charadriiformes	Scolopacidae	S
White-faced Ibis	WFIB	Wading Bird	Pelecaniformes	Threskiornithidae	L
White Ibis	WHIB	Wading Bird	Pelecaniformes	Threskiornithidae	L
White Pelican	WHPE	Waterbird	Pelecaniformes	Pelecanidae	XL
Willet	WILL	Shorebird	Charadriiformes	Scolopacidae	M
Wilson's Plover	WIPL	Shorebird	Charadriiformes	Charadriidae	S
Tyellow-Crowned Night Heron	YCNH	Wading Bird	Pelecaniformes	Ardeidae	M

APPENDIX B: PRINCIPAL COMPONENT ANALYSES

PCA [FIGURE 21]

Principal Component Analysis

Data worksheet
Name: Data7
Data type: Abundance
Sample selection: All
Variable selection: All

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	1.83E+03	71.5	71.5
2	730	28.4	99.9
3	2.19	0.1	100.0
4	0	0.0	100.0

Eigenvectors
(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4
Wading	-0.614	0.556	0.253	0.500
Shore	0.776	0.293	0.251	0.500
Water Level	-0.015	-0.075	-0.863	0.500
Wind Avg	-0.146	-0.774	0.359	0.500

Principal Component Scores

Sample	SCORE1	SCORE2	SCORE3	SCORE4
Autumn-Manmade	-58.4	13.2	-0.604	0
Autumn-Marsh	-39.9	25.4	0.71	0
Autumn-Mud	20.4	7.65	0.108	0
Autumn-Oyster	37.8	3.26	-0.00298	0
Autumn-Seagrass	12.1	-20.8	-2.43	0
Spring-Manmade	-33.1	-15.4	-0.754	0
Spring-Marsh	-16	20.6	0.705	0
Spring-Mud	40.9	9.06	0.614	0
Spring-Oyster	48	4.32	0.478	0
Spring-Seagrass	-20.3	-61.6	-2.41	0
Summer-Manmade	-60.6	18.6	-0.786	0
Summer-Marsh	-50.7	27.6	0.71	0
Summer-Mud	34.8	1.78	-0.724	0
Summer-Oyster	40.5	6.28	0.0498	0
Summer-Seagrass	-3.25	-6.13	-2.79	0
Winter-Manmade	-63.2	18	1.17	0
Winter-Marsh	10.9	15.4	0.741	0
Winter-Mud	63.9	6.04	0.659	0
Winter-Oyster	-27.6	-78.6	3.88	0
Winter-Seagrass	63.8	5.45	0.678	0

PCA [Figure 29]
Principal Component Analysis

Data worksheet
Name: Data4
Data type: Other
Sample selection: All
Variable selection: All

Eigenvalues

PC	Eigenvalues	%Variation	Cum.%Variation
1	40.6	82.0	82.0
2	3.81	7.7	89.7
3	2.47	5.0	94.7
4	1.64	3.3	98.0
5	0.723	1.5	99.5

Eigenvectors
(Coefficients in the linear combinations of variables making up PC's)

Variable	PC1	PC2	PC3	PC4	PC5
25	0.021	-0.109	0.467	-0.504	0.707
40	0.041	0.154	-0.137	-0.016	0.149
50	0.149	0.258	0.727	-0.192	-0.546
75-100	0.326	0.776	0.047	0.379	0.339
200	0.053	0.417	-0.418	-0.704	-0.220
300	0.931	-0.343	-0.108	-0.042	-0.044
400	0.026	0.069	-0.214	-0.261	0.120

Principal Component Scores

Sample	SCORE1	SCORE2	SCORE3	SCORE4	SCORE5
AMAV	-4.84	1.69	1.89	0.811	-0.888
BNST	-3.21	2.67	0.0398	0.0545	-0.28
BRPE	-5.08	0.372	4.39	-1.97	1.07
GBHE	-2.09	-1.09	-1.19	-0.0164	-0.12
GREG	5	0.602	-3	-0.452	1.15
KILL	-5.67	0.413	-0.947	-0.143	-0.0396
LBCU	-3.28	0.406	-0.389	-1.25	-1.09
LBHE	-3.47	-1.02	-0.621	0.748	0.163
LESA	-1.59	-1.71	-0.839	0.662	0.0728
Plover Spp	-5.49	0.269	0.903	0.519	-0.675
RBGU	-4.82	-0.52	-0.464	0.809	0.227
ROSP	4.78	-1.28	2.2	-0.236	-1.19
SBDO	-3.89	-0.863	-0.572	0.767	0.182
SNEG	7.55	-1.61	0.245	-1.72	1.65
TCHE	4.34	-1.53	0.847	-1.23	0.844
WESA	15.5	-3.43	0.383	0.64	-1.5
WFIB	-1.59	-1.71	-0.839	0.662	0.0728
WHIB	14.2	4.94	1.02	2.52	0.709
WHPE	-4.14	-0.771	-0.543	0.778	0.194
WILL	3.26	3.56	-2.2	-3.19	-1.15
YCNH	-5.42	0.599	-0.308	1.23	0.61

APPENDIX C: FIXED-WING UAV FIELD NOTES

Bird and UAV Study – Data Collection Day 7/29/16

Location: N 29.09885; W -95.20590

Bird Surveyors: Anna Vallery & Tyler Swanson

UAV Team: Mustafa Mokrech, James Yokley, Cory Scanes

This was the first official day out to try and take bird surveys from the ground and with the UAV simultaneously. We had some issues with 17' Tiller this morning, but hooked up the 14'Tiller and managed to get on the road, arriving at Bastrop Boat ramp around 9:30 am. We arrived at the site about a half hour after that. The UAV crew went to the launch site and our bird survey crew headed to the spit island located slightly south of the launch site (GPS coordinates).

A preliminary bird survey was conducted about 10-15 minutes prior to the launch. When the UAV was launched, it was immediately evident that the noise from the launch, which is louder than its actual traveling noise, effected the birds. All visible terns in the area that were perched left and didn't return. Willet and Curlew that had previously been noted were no longer visible. Gulls and Cormorants didn't leave the area, but were observed taking note of the UAV and exhibiting awareness of its presence. Pelican, egret, and heron species, however, seemed unaffected by the UAV noise throughout the launch, flight and landing. Other species of bird did return to perch once the drone was moving at around 300 feet, though it is unclear if they all returned or if some left the area completely. While the drone conducted its survey, another ground survey of birds around the spit island was conducted.

The landing of the drone ended up in the water. Ground survey team recovered the drone using the 14' Tiller. When they returned back to their site, they conducted a third and final survey of the area. Because of the water landing, no more drone surveys could be done today. In the future we hope to conduct at least two, if not three, surveys in an outing.

Bird and UAV Study – Data Collection Day 8/9/16

Location: N 29.09885; W -95.20590

Bird Surveyors: Anna Vallery & Tyler Swanson

UAV Team: Mustafa Mokrech, James Yokley, Allison Norris

We were able to get out on the water around 8:30 this morning and to the site around 9:15. Pre-flight surveys revealed the typical cormorants, pelicans, and terns along with a Black Skimmer and varying species of egret and heron. There weren't as many birds nearby as the last time we were at the site, though. When the drone was launched, a flock of about 20 or so gulls and terns (as well as the black skimmer) immediately flushed. The drone was launched in their general direction, though, as a result of wind direction. This brought my count of birds for the flight survey to much smaller than would have been there without the disturbance of the drone and our presence.

Today, after the drone completed transects, it went into our discussed "behavioral" test. I would have liked to have started with the circular behavioral test and then gone into the normal transects, but we were not sure if the battery life would sustain both. The circles began at 400 feet and yielded only awareness from the remaining birds. At 300 feet, they remained aware, but did not flush. At 200 feet, the one Willet in the area flushed and it appeared the cormorants and terns that were watching the drone began to get more agitated. At this point, the battery power was low and the drone had to land.

Unfortunately, the drone landed in the water, making it impossible to conduct another aerial survey for the day.

Bird and UAV Study – Data Collection Day 12/06/16

Location: N 29.03133; W -95.47688

Bird Surveyors: Anna Vallery & Nicole Morris

UAV Team: Mustafa Mokrech, James Yokley, Cory Scanes

Flight 1: Several birds left prior to flight, including about 150 Western Sandpipers. At launch, all Long-billed Curlew in the area left as soon as the drone made any noise. They tried to return, but left whenever the drone came within 200-300 yards of their position. A Snowy Egret and a Roseate Spoonbill flushed from the grass when the drone went by. Their exact origin and pre=-launch behavior were unknown. Western Sandpiper in the area were aware of drone during survey, but settled back down until the circling part of the survey began. At this point, a few more Western Sandpiper flew in, then the whole flock left when the drone was circling at around 100 feet. Willet were also aware during survey, but did not flush until 100 feet. The two roosting Western Sandpiper near our position did not react to the UAV, but they were not in the actual survey area.

Flight 2: Started with behavioral circles. During launch, Long-billed Curlew, White Ibis and several of the Western Sandpiper flushed. Some Western Sandpiper and Willet stayed, including the two Western Sandpiper that were roosting during the first survey. By the time the survey transects began, all visible birds in the area had flushed.

Bird and UAV Study – Data Collection Day 2/1/17

Location: N 29.1082; W -95.1887

Bird Surveyors: Anna Vallery & Kaylei Chau

UAV Team: Mustafa Mokrech, James Yokley, Cory Scanes

UAV/Bird survey began at 9:40 am. UAV was launched south at the launch location that was south of many of the birds. The birds were primarily GREG, WHIB, WFIB, ROSP, REEG, GBHE, and Cormorant. Most appeared to be roosting or perched prior to launch. There were two major groups of birds with a few individuals spaced out between them.

Upon launch, about half of the closest flock (located at 98 yards and 323 degrees from our location) flushed. Of those, about half settled back down while the other half either flew to the secondary flock or flew out of the survey area. Birds remained until the drone made its first transect near the primary flock. They then had another large group flush, again, with some settling back down and the others moving on.

Overall, the birds from both flocks moved quite a bit more during the drone flight than before. Drone landed in the water after completing 4/6 transect lines. We were unable to complete another survey. Instead, the eastern two quadrats of Bastrop Bay were surveyed using conventional methods.

Bird and UAV Study – Data Collection Day 03/13/17

Location: N 29.08061; W -95.19228

Bird Surveyors: Anna Vallery & Kris Warner

UAV Team: Mustafa Mokrech, James Yokley, Cory Scanes

WESA and WILL in the center of the transect area flushed when drone passed near on route. This occurred multiple times. When the drone landed in their vicinity, however, group of WESA did not flush. Groups of wading birds north of the survey location flushed when drone passed by, but landed back and settled down. Overall, we found that all visible birds and many that were not visible before drone survey flushed at least once over the course of the survey. Only the WESA and WILL group seemed to return and become, possibly, desensitized to the drone presence.

Bird and UAV Study – Data Collection Day 04/17/17

Location: N 29.09708; W -95.20947

Bird Surveyors: Anna Vallery & Tyler Swanson

UAV Team: Mustafa Mokrech, James Yokley, Cory Scanes

The third flight attempt was the first with a successful launch. Upon launch (launched eastward towards water), most of the previously observed birds flushed along with several unobserved birds (Willet and LBCU). When the drone hit its northernmost portion of the transect, it flushed a large group of gulls that perch on the reef just on the other side of the ICW. It did not appear to fly directly over them, just nearby. BNST (x4) started north of our viewing site, flushed when the drone approached, landed directly in front of the viewing point, and flushed permanently when the drone flew by again. It seemed like many birds in this area are not utilizing the exposed reef (very low water levels today). This is potentially due to high boat traffic through the channel, though.

Bird and UAV Study – Data Collection Day 06/08/2017

Location: N 29.08358; W -95.19637

Bird Surveyors: Anna Vallery & Kaylei Chau

UAV Team: Mustafa Mokrech, James Yokley, Cory Scanes

Large flocks of birds (GREG, SNEG, WHIB, ROSP, LBHE, WHPE, REEG, TCHE) further inland. Large numbers of birds flushed when drone was launched, some settled back down into the survey area. When drone flew overhead, large numbers of birds flushed, most for good. The remaining birds would slowly filter out, some flushing for good, and some settling down. We ended the survey with several Great Egrets and a large group of Snowy Egrets, still in place, but aware of UAV. I am unsure if that group had previously flushed. There should be birds on camera, both flushing and standing.

APPENDIX D: USFWS SPECIAL USE PERMIT

United States Department of the Interior
U.S. Fish and Wildlife Service

National Wildlife Refuge System Research and Monitoring Special Use Application and Permit

OMB Control Number 1018-0102
Expiration Date: 06/30/2014

Name of Refuge: Brazoria National Wildlife Refuge

Address: 24907 FM 2004 Angleton, Texas 77515

Attn: (Refuge Official) Cody Dingee

Phone #: 979-922-1037 E-mail: cody_dingee@fws.gov

Application

(To be filled out by applicant. Note: Not all information is required for each use. See instructions at the end of the notice for specific information required.)

1) ◉ New ○ Renewal ○ Modification ○ Other

Applicant Information

2) Principal investigator: Dr. George Guillen

3) Is curriculum vitae or resume attached? ◉ Yes ○ No ○ N/A

4) Address: 2700 Bay Area Blvd. MC 540 North Office Anex

5) City/State/Zip: Houston, TX 77058

6) Phone #: 281-283-3950

7) Fax #:

8) E-mail: guillen@uhcl.edu

9a) Affiliation/organization: Environmental Institute of Houston/University of Houston - Clear Lake

9b) Relationship to affiliation/organization: (professor, staff, student, etc.) Executive Director

10) Assistants/subcontractors/subpermittees: (List full names, addresses and phone #'s and specifically describe services provided if subcontractors are used.)

Anna Vallery - Research Assistant
813-466-9522; vallery@uhcl.edu
Mustafa Mokrech - Senior Research Scientist/UAV pilot
281-935-2261; mokrech@uhcl.edu

Project Information

(Depending on the project for which you are requesting a permit, we may ask you for the following project information. Please contact the specific refuge where the project is being conducted to determine what project information is required.)

11) Title: Evaluation of coastal wading bird populations in intertidal habitat using UAV assisted surveys

12a) Is full research proposal required? ◉ Yes ○ No

12b) Is full research proposal attached? ◉ Yes ○ No

13) Describe activity: (Specifically identify timing, frequency, and how the project is expected to proceed.)

Data will be collected over the course of one year spanning from July of 2016 to July of 2017. A tide gauge will be set up to accurately track the tides for the survey area. A nearby weather station will be used to note weather and rainfall prior to conducting population and habitat survey within UAV assisted overflights. Preliminary ground-truthing of substrate types will be conducted at up to 20% of the study areas. During ground truth surveys a 10 X 10 meter quadrat will be deployed at

14) Location: (Identify specific location; GPS location preferred.)

29° 6'20.95"N, 95°11'24.89"W
29° 5'53.00"N, 95°12'33.18"W
29° 5'27.89"N, 95°13'14.33"W
(See attached map)

15a) Is map of location(s) required? ◉ Yes ○ No ○ N/A

15b) Is map of location(s) attached? ◉ Yes ○ No

16) Project/site occupancy timeline: (Specifically identify beginning and ending dates, site occupation timeline, hours, clean-up and other major events.)

Project will take place from July 2016 to July 2017. Surveys will be conducted approximately three times per month, at a high tide event, a low tide event, and an intermediate tide. Surveys will begin as early as possible in the morning and continue until three successful flights have been conducted. The crew will be ~~finished before sunset of survey days.~~

FWS Form 3-1383-R
03/11

17) Species or habitats being studied:

Any birds observed during the regular surveys taken will be counted, including any vagrants. Anticipated species include the American Oystercatcher, Long-billed Curlew, Marbled Gowdwit, Red Knot, Reddish Egret, and Black Skimmer, all of which are species of conservation concern in Texas and the United States. Other expected species include the Western Sandpiper, Laughing and Herring Gull, Brown and White Pelican as well as several heron and egret species, plovers, and killdeer. Note: no live birds will be handled, only remote aerial imagery and binocular surveys will be conducted.

18) Purpose/hypothesis:

The purpose of this study is to determine how effective UAV technology is for conducting surveys of shorebirds and if it is possible to utilize this technology for monitoring of similar populations of birds in the future. Gaining an understanding of foraging habitat preferences in shore birds is another purpose of this study, specifically changes in preferences based on changes in water levels as a result of high and low tides.

19) Expected benefits of research/monitoring:

New UAV technology has the potential to make conservation efforts in regards to shorebird monitoring significantly easier and less expensive. Current methods for surveying populations of shore birds require low-flying aerial surveys from small planes, an expensive and somewhat dangerous practice. If UAV technology is found capable of producing accurate surveys, monitoring efforts may be made easier, safer and faster than before.

20) Briefly describe project history and context of research/monitoring project:

The project will primarily occur during the summer 2016 through spring 2017 and will extend efforts started earlier this year involving mapping of intertidal oyster reef habitat in Bastrop Bay and Christmas Bay.

21) Briefly describe project's relationship to other research/monitoring projects either known of or conducted by the applicant:

The proposed project entitled "Mapping Shallow Reefs Using Low-cost Side Scanning Sonar and Drone Photography Systems"was partially funded by the Gulf Coast Prairie LCC Grant program in 2015 through 2017. Remaining funding for the project was provided by the Environmental Institute of Houston Clear Lake (EIH), University of Houston Clear Lake (UHCL). The PI's for the project are Drs. George Guillen and Mustafa Mokrech. Anna Vallery, a graduate student of Dr. Guillen, will expand this work to include surveys of wading birds using intertidal reef habitat.

22) Identify the types of samples to be taken or data to be collected during the proposed project:

Photos will be collected through the use of QUESTUAV AQUA Drone, a fixed-wing drone equppied with a Sony 6000A camera. Ground-surveys will be conducted of shorebirds at several points within the drone survey area. No physical samples will be collected.

23) List other cooperators and institutions involved in the project:

Gulf Coast Prairie LCC grant program.

24) Generally identify the anticipated timeline for analysis, write-up and publication:

Data will be collected from July 2016 to July 2017. Write-up will occur during that time and finished in the following months, August-October of 2017. A completed Thesis will be submitted in October and defended soon thereafter. Manuscripts for publications will be submitted during this time as well.

25) For research involving animals, has an Assurance of Animal Care Form, Institutional Animal Care and Use Committee approval (or equivalent) been completed? ○ Yes ○ No ◉ N/A

Is form attached? ○ Yes ◉ No

Certifications/Permits

26a) Is rat free certification required?
○ Yes ○ No ◉ N/A

Copy of certification provided:
○ Yes ○ No

26b) Is hull inspection certification required?
○ Yes ○ No ◉ N/A

Copy of certification provided:
○ Yes ○ No

26c) Is EMT/first aid certification required?
○ Yes ○ No ◉ N/A

Copy of certification provided:
○ Yes ○ No

26d) Are other certifications required?
○ Yes ○ No ◉ N/A

Copy of certification provided:
○ Yes ○ No

27a) Are State permits required?
◉ Yes ○ No ○ N/A

Copy of permits provided:
◉ Yes ○ No

27b) Are Federal permits required?
○ Yes ○ No ◉ N/A

Copy of permits provided:
○ Yes ○ No

27c) Are tribal permits required?
○ Yes ○ No ◉ N/A

Copy of permits provided:
○ Yes ○ No

27d) Are other permits required?
◉ Yes ○ No ○ N/A

Copy of permits provided:
◉ Yes ○ No

Logistics and Transportation

28a) Does activity require personnel to stay overnight onsite?
○ Yes ◉ No

28b) Personnel involved:

29) Specifically describe all equipment/gear and materials used:

QUESTUAV AQUA Drone equipped with Sony A6000 camera; Binoculars; Laser Rangefinder; RazorXD Spotting Scope; Tide gauge; digital camera

30a) Dates of installation of instrumentation:

Tide gage will be installed during July-August 2016 in Bastrop Bay.

30b) Dates of instrumentation removal:

Tide gage will be removed during July -August 2017

30c) If instrumentation is permanent, describe need:

NA. Instrument will be temporarily installed. However, accurate tide levels are needed to estimate extent of water level coverage in Bastrop and Christmas Bay

30d) Instrumentation maintenance schedule:

Instrument will be checked, cleaned and downloaded once a month.

30e) Data collection schedule:

Monthly to weekly surveys of birds and intertidal habitat in Bastrop and Christmas Bay will be conducted during July to August 2016 through August 2017.

31) Logistical arrangements for offsite transportation of samples:

N/A

32a) Transportation description(s) and license number(s) to access refuge(s): (Provide description of and specific auto license/boat/plane registration number(s).)

Diamondback Airboat (1998) – Trailer License Plate #904-3145 – Hull ID TX 4679 JC – Chevy 454 motor 17' Weldcraft – Trailer License Plate #907-7555 – Hull ID TX 7237 KC - 40hp Evinrude E-tec motor
17' Weldcraft Center Console – Trailer License Plate # 905-9910 – Hull ID TX 9285 AZ - 40hp Evinrude E-tec motor
Canoe (Sundolphin)

32b) Specifically describe ship-to-shore transportation:

Vehicle will be parked at boat ramp off 2004. Boat will be launched and taken to the study site. No vehicle will be used once at the study site, we will be walking/wading

32c) Specifically describe intersite transportation:

Intersite transportation will be walking/wading or use of the boat.

32d) Specifically describe onsite transportation:

Walking/wading will be done onsite, no transportation needed.

33a) Is fuel cache needed?

○ Yes ◉ No

33b) Specific location(s) of fuel caches: (GPS Coordinates preferred)

34a) Is Safety Plan required?

○ Yes ◉ No

34b) Safety Plan attached:

○ Yes ◉ No

Work and Living Accommodations

35) Specifically describe onsite work and/or living accommodations, including spike camps:

No overnight accommodations will be set up. During the day, a canopy may be set up for shade. All materials will be carried to the study site at the beginning of the day and removed at the end of the day.

36) Specifically describe on or offsite hazardous material storage or other on or offsite material storage space (including on and offsite fuel caches):

NA

37) Signature of Applicant George J. Guillen Digitally signed by George J. Guillen Date: 2016.07.15 12:56:31 -05'00' Date of Application: 7-15-2016

Sign, date, and print this form and return it to the refuge for processing.
Do not fill out information below this page.

PRINT FORM

OMB Control Number 1018-0102
Expiration Date: 06/30/2014

For Official Use Only **(This section to be filled out by refuge personnel only.)**

Special Use Permit

Permit #: 21543-1-16-8

1) Date: 8/3/2016 2) ◉ Permit Approved ○ Permit Denied 3) Station #: 21543 - Brazoria

4) Additional special conditions required: (Special conditions may include activity reports, before and after photographs, and other conditions.)

◉ Yes ○ No ○ N/A

Additional sheets attached:

◉ Yes ○ No

5) Other licenses/permits required:

○ Yes ○ No ◉ N/A

Verification of other licenses/permits, type:

6) Minimum requirements analysis has been conducted:

○ Yes ○ No ◉ N/A

Assessment attached:

○ Yes ◉ No

7) Assurance of Animal Care Form or Institutional Animal Approval form attached:

◉ Yes ○ No ○ N/A

Approval form attached:

◉ Yes ○ No

8) Record of Payments: ◉ Exempt ○ Partial ○ Full

Amount of payment: ______ Record of partial payment: ______

9) Bond Paid: ○ Yes ○ No ◉ N/A

This permit is issued by the U.S. Fish and Wildlife Service and ~~accepted by the applicant signed below,~~ subject to the terms, covenants, obligations, and reservations, expressed or implied herein, and to the notice, conditions, and requirements included or attached. A copy of this permit should be kept on hand so that it may be shown at any time to any refuge staff.

Permit approved and issued by (Signature and title):

JAMES DINGEE Digitally signed by JAMES DINGEE
Date: 2016.08.03 08:25:11 -05'00' Date: ______

Permit accepted by (Signature of applicant):

______ Date: ______

FWS Form 3-1383-R
03/11

Notice

In accordance with the Privacy Act (5 U.S. C. 552a) and the Paperwork Reduction Act (44 U.S. C. 3501), please note the following information:

1. The issuance of a permit and collection of fees on lands of the National Wildlife Refuge System are authorized by the National Wildlife Refuge System Administration Act (16 U.S. C. 668dd-ee) as amended, and the Refuge Recreation Act (16 U.S. C. 460k-460k-4).

2. The information that you provide is voluntary; however submission of requested information is required to evaluate the qualifications, determine eligibility, and document permit applicants under the above Acts. It is our policy not to use your name for any other purpose. The information is maintained in accordance with the Privacy Act. All information you provide will be considered in reviewing this application. False, fictitious, or fraudulent statements or representations made in the application may be grounds for revocation of the Special Use Permit and may be punishable by fine or imprisonment (18 U.S.C. 1001). Failure to provide all required information is sufficient cause for the U.S. Fish and Wildlife Service to deny a permit.

3. No Members of Congress or Resident Commissioner shall participate in any part of this contract or to any benefit that may arise from it, but this provision shall not pertain to this contract if made with a corporation for its general benefit.

4. The Permittee agrees to be bound by the equal opportunity "nondiscrimination in employment" clause of Executive Order 11246.

5. Routine use disclosures may also be made: (a) to the U.S. Department of Justice when related to litigation or anticipated litigation; (b) of information indicating a violation or potential violation of a statute, rule, order, or license to appropriate Federal, State, local or foreign agencies responsible for investigating or prosecuting the violation or for enforcing or implementing the statute, rule, regulations, order, or license; (c) from the record of the individual in response to an inquiry from a Congressional office made at the request of the individual (42 FR 19083; April 11,1977); and (d) to provide addresses obtained from the Internal Revenue Service to debt collection agencies for purposes of locating a debtor to collect or compromise a Federal Claim against the debtor, or to consumer reporting agencies to prepare a commercial credit report for use by the Department (48 FR 54716; December 6, 1983).

6. An agency may not conduct or sponsor and a person is not required to respond to a collection of information unless it displays a currently valid OMB control number. This information collection has been approved by OMB and assigned control number 1018-0102. The public reporting burden for this information collection varies based on the specific refuge use being requested. The relevant public reporting burden for the Research and Monitoring Special Use Permit Application form is estimated to average 4 hours per response, including time for reviewing instructions, gathering and maintaining data, and completing and reviewing the form. Comments on this form should be mailed to the Information Collection Clearance Officer, U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042-PDM, Arlington, Virginia, 22203.

General Conditions and Requirements

1. Responsibility of Permittee: The permittee, by operating on the premises, shall be considered to have accepted these premises with all facilities, fixtures, or improvements in their existing condition as of the date of this permit. At the end of the period specified or upon earlier termination, the permittee shall give up the premises in as good order and condition as when received except for reasonable wear, tear, or damage occurring without fault or negligence. The permittee will fully repay the Service for any and all damage directly or indirectly resulting from negligence or failure on his/her part, and/or the part of anyone of his/her associates, to use reasonable care.

2. Operating Rules and Laws: The permittee shall keep the premises in a neat and orderly condition at all times, and shall comply with all municipal, county, and State laws applicable to the operations under the permit as well as all Federal laws, rules, and regulations governing national wildlife refuges and the area described in this permit. The permittee shall comply with all instructions applicable to this permit issued by the refuge official in charge. The permittee shall take all reasonable precautions to prevent the escape of fires and to suppress fires and shall render all reasonable assistance in the suppression of refuge fires.

3. Use Limitations: The permittee's use of the described premises is limited to the purposes herein specified and does not, unless provided for in this permit, allow him/her to restrict other authorized entry onto his/her area; and permits the Service to carry on whatever activities are necessary for: (1) protection and maintenance of the premises and adjacent lands administered by the Service; and (2) the management of wildlife and fish using the premises and other Service lands.

4. Transfer of Privileges: This permit is not transferable, and no privileges herein mentioned may be sublet or made available to any person or interest not mentioned in this permit. No interest hereunder may accrue through lien or be transferred to a third party without the approval of the Regional Director of the Service and the permit shall not be used for speculative purposes.

5. Compliance: The Service's failure to require strict compliance with any of this permit's terms, conditions, and requirements shall not constitute a waiver or be considered as a giving up of the Service's right to thereafter enforce any of the permit's terms or conditions.

6. Conditions of Permit not Fulfilled: If the permittee fails to fulfill any of the conditions and requirements set forth herein, all money paid under this permit shall be retained by the Government to be used to satisfy as much of the permittee's obligation as possible.

7. Payments: All payment shall be made on or before the due date to the local representative of the Service by a postal money order or check made payable to the U.S. Fish and Wildlife Service.

8. Termination Policy: At the termination of this permit the permittee shall immediately give up possession to the Service representative, reserving, however, the rights specified in paragraph 11. If he/she fails to do so, he/she will pay the government, as liquidated damages, an amount double the rate specified in this permit for the entire time possession is withheld. Upon yielding possession, the permittee will still be allowed to reenter as needed to remove his/her property as stated in paragraph 11. The acceptance of any fee for the liquidated damages or any other act of administration relating to the continued tenancy is not to be considered as an affirmation of the permittee's action nor shall it operate as a waiver of the Government's right to terminate or cancel the permit for the breach of any specified condition or requirement.

9. Revocation Policy: This permit may be revoked by the Regional Director of the Service without notice for noncompliance with the terms hereof or for violation of general and/or specific laws or regulations governing national wildlife refuges or for nonuse. It is at all times subject to discretionary revocation by the Director of the Service. Upon such revocation the Service, by and through any authorized representative, may take possession of the said premises for its own and sole use, and/or may enter and possess the premises as the agent of the permittee and for his/her account.

10. Damages: The United States shall not be responsible for any loss or damage to property including, but not limited to, growing crops, animals, and machinery or injury to the permittee or his/her relatives, or to the officers, agents, employees, or any other who are on the premises from instructions or by the sufferance of wildlife or employees or representatives of the Government carrying out their official responsibilities. The permittee agrees to save the United States or any of its agencies harmless from any and all claims for damages or losses that may arise to be incident to the flooding of the premises resulting from any associated Government river and harbor, flood control, reclamation, or Tennessee Valley Authority activity.

11. Removal of Permittee's Property: Upon the expiration or termination of this permit, if all rental charges and/or damage claims due to the Government have been paid, the permittee may, within a reasonable period as stated in the permit or as determined by the refuge official in charge, but not to exceed 60 days, remove all structures, machinery, and/or equipment, etc. from the premises for which he/she is responsible. Within this period the permittee must also remove any other of his/her property including his/her acknowledged share of products or crops grown, cut, harvested, stored, or stacked on the premises. Upon failure to remove any of the above items within the aforesaid period, they shall become the property of the United States.

12. Collected Specimens: You may use specimens collected under this permit, any components of any specimens (including natural organisms, enzymes, genetic materials or seeds), and research results derived from collected specimens for scientific or educational purposes only, and not for commercial purposes unless you have entered into a Cooperative Research and Development Agreement (CRADA) with us. We prohibit the sale of collected research specimens or other transfers to third parties. Breach of any of the terms of this permit will be grounds for revocation of this permit and denial of future permits. Furthermore, if you sell or otherwise transfer collected specimens of any components without a CRADA, you will pay us a royalty rate of 20 percent of the gross revenue from such sales. In addition to such royalty, we may seek other damages and injunctive relief against you.

Instructions for Completing Application

You may complete the application portion verbally, in person or electronically and submit to the refuge for review. Note: Please read instructions carefully as not all information is required for each activity. Contact the specific refuge where the activity will take place if you have questions regarding the applicability of a particular item. Special conditions or permit stipulations may be added to permit prior to approval.

1. Identify if application is for a new permit or renewal or modification of an existing permit. Permit renewals may not need all information requested. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

2-3. Provide principal investigator's or applicant's full name. Attach principal investigator's Curriculum Vitae or Resume, if required. Permit renewals generally do not require a Curriculum Vitae or Resume if the project is a continuation of a previously issued permit being conducted by the same investigator. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

4-9. Provide investigator's address, phone, fax, e-mail, affiliation and or organization, and relationship to affiliation or organization (title, professor, student, etc.).

10. Provide the names and addresses of assistants, subcontractors or subpermittees. Names and address are only required if the assistants, subcontractors or subpermittees will be operating on the refuge without the permittee being present. Volunteers, assistants, subcontractors or subpermittees that are accompanied by the permittee need not be identified.

11. Provide title of research or monitoring project.

12a-12b. Attach a full research or monitoring proposal, if required. Permit renewals generally do not require a project proposal if the project is a continuation of a previously issued permit being conducted by the same investigator. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

13. Describe Activity: provide detailed information on the activity, including timing, frequency, how the project is expected to proceed, etc. Permit renewals may not need activity description, if the activity is unchanged from previous permit. Most repetitive research projects do not require an activity description for each visit to the refuge. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

14. Location: identify specific location (GPS coordinates preferred), if not a named facility. Permit renewals may not require a location if the project is essentially unchanged from the previous permit. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

15a-15b. Attach a map of location, if required and project is not conducted at a named facility. Permit renewals may not require a map if the project is essentially unchanged from the previous permit. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

16. Activity/site occupancy timeline: identify beginning and ending dates, site occupation timeline, hours, clean-up and other major events. Permit renewals may not need an activity/site occupancy timeline, if the activity is unchanged from previous permit. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

17. Identify species or habitats being studied.

18-19. Specifically identify purpose or hypothesis of the research or monitoring project and describe expected benefits. Permit renewals may not need to identify purpose or hypothesis, if the project is a continuation of a previously issued permit being conducted by the same investigator. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

20. Briefly describe project history and context. Permit renewals should describe previous research activities as part of a previously issued permit being conducted by the same investigator. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

21. Briefly describe project's relationship to other research/monitoring projects either known of or conducted by the applicant, if applicable. Include a brief statement of how the research or monitoring permit being applied for will add to or supplement other ongoing research or monitoring on the same, or related, species or habitats. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

22. Identify samples to be taken or types of data to be collected. Permit renewals may not need to identify samples taken if the project is a continuation of a previously issued permit being conducted by the same Investigator. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

23. List other cooperators and institutions involved in the project, if applicable. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

24. Generally, identify the anticipated time line for analysis, write-up and publication of project results. Include whether the project is a single, or multiple year project. Identification of an actual publication where the results are printed is not necessary. However, applicants should include the anticipated dissemination of project results. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

25. Check box acknowledging a completed Assurance of Animal Care Form or an Institutional Animal Care and Use Committee (or equivalent) has granted approval been completed, and has been submitted to refuge station, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

26a-26c. Specifically identify types and numbers of other certifications, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement, and to coordinate the simultaneous application of several types of certifications. This Special Use Permit may be processed while other certifications are being obtained.

27a-27d. Specifically identify types and numbers of other State, Federal or tribal permits, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement, and to coordinate the simultaneous application of several types of State, Federal or tribal permits. This Special Use Permit may be processed while other State, Federal or tribal permits are being obtained.

28a-28b. Provide name(s) of any personnel required to stay overnight, if applicable.

29. Identify all equipment and materials, which will be used, if required. Permit renewals may not require a list of equipment if the project is essentially unchanged from a previously issued permit. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

30a-30e. Identify types and dates of installation of any instrumentation, and data collection and maintenance schedule of instrumentation, if required. Permit renewals may not require a list of equipment if the project is essentially unchanged from a previously issued permit. However, dates of installation of any instrumentation, and data collection and maintenance schedule of instrumentation may still be required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

31. Identify logistic arrangements for offsite transportation of samples taken, if applicable.

32a-32d. Describe and provide vehicle descriptions and license plate or identification numbers of all vehicles, including boats and airplanes, if required. Motor vehicle descriptions are only required for permittee vehicle, and/or if the vehicle will be operated on the refuge without the permittee being present. Motor vehicles that are accompanied by the permittee as part of a group (convoy) activity need not be identified if cleared in advance by refuge supervisor. Specifically describe ship-to-shore, intersite (between islands, camps, or other sites) and onsite transportation mechanisms, and license plate or identification numbers, if required.

33a-33b. Identify specific location(s) of fuel cache(s) (GPS coordinates preferred), if required.

34a-34b. Attach safety plan, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine if a safety plan is required.

35. Specifically describe onsite work and/or living accommodations, if required. Include descriptions and locations (GPS coordinates preferred) of spike camps or other remote work and/or living accommodations that are not part of the base of operations. Contact the specific refuge headquarters office where the project is going to be conducted to determine if descriptions of onsite work and/or living accommodations are required.

36. Specifically describe onsite and offsite hazardous material storage, or other onsite material storage space (including on and offsite fuel caches), if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine if descriptions of hazardous material storage or other onsite material storage are required.

37 Sign, date and print the application. Click on the Print button to print the application (if using the fillable version). The refuge official will review and, if approved, fill out the remaining information, sign, and return a copy to you for signature and acceptance.

The form is not valid as a permit unless it includes refuge approval, a station number, a refuge-assigned permit number, and is signed by a refuge official.

21. Briefly describe project's relationship to other research/monitoring projects either known of or conducted by the applicant, if applicable. Include a brief statement of how the research or monitoring permit being applied for will add to or supplement other ongoing research or monitoring on the same, or related, species or habitats. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

22. Identify samples to be taken or types of data to be collected. Permit renewals may not need to identify samples taken if the project is a continuation of a previously issued permit being conducted by the same investigator. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

23. List other cooperators and institutions involved in the project, if applicable. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

24. Generally, identify the anticipated time line for analysis, write-up and publication of project results. Include whether the project is a single, or multiple year project. Identification of an actual publication where the results are printed is not necessary. However, applicants should include the anticipated dissemination of project results. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

25. Check box acknowledging a completed Assurance of Animal Care Form or an Institutional Animal Care and Use Committee (or equivalent) has granted approval been completed, and has been submitted to refuge station, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

26a-26c. Specifically identify types and numbers of other certifications, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement, and to coordinate the simultaneous application of several types of certifications. This Special Use Permit may be processed while other certifications are being obtained.

27a-27d. Specifically identify types and numbers of other State, Federal or tribal permits, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement, and to coordinate the simultaneous application of several types of State, Federal or tribal permits. This Special Use Permit may be processed while other State, Federal or tribal permits are being obtained.

28a-28b. Provide name(s) of any personnel required to stay overnight, if applicable.

29. Identify all equipment and materials, which will be used, if required. Permit renewals may not require a list of equipment if the project is essentially unchanged from a previously issued permit. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

30a-30e. Identify types and dates of installation of any instrumentation, and data collection and maintenance schedule of instrumentation, if required. Permit renewals may not require a list of equipment if the project is essentially unchanged from a previously issued permit. However, dates of installation of any instrumentation, and data collection and maintenance schedule of instrumentation may still be required. Contact the specific refuge headquarters office where the project is going to be conducted to determine applicability of this requirement.

31. Identify logistic arrangements for offsite transportation of samples taken, if applicable.

32a-32d. Describe and provide vehicle descriptions and license plate or identification numbers of all vehicles, including boats and airplanes, if required. Motor vehicle descriptions are only required for permittee vehicle, and/or if the vehicle will be operated on the refuge without the permittee being present. Motor vehicles that are accompanied by the permittee as part of a group (convoy) activity need not be identified if cleared in advance by refuge supervisor. Specifically describe ship-to-shore, intersite (between islands, camps, or other sites) and onsite transportation mechanisms, and license plate or identification numbers, if required.

33a-33b. Identify specific location(s) of fuel cache(s) (GPS coordinates preferred), if required.

34a-34b. Attach safety plan, if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine if a safety plan is required.

35. Specifically describe onsite work and/or living accommodations, if required. Include descriptions and locations (GPS coordinates preferred) of spike camps or other remote work and/or living accommodations that are not part of the base of operations. Contact the specific refuge headquarters office where the project is going to be conducted to determine if descriptions of onsite work and/or living accommodations are required.

36. Specifically describe onsite and offsite hazardous material storage, or other onsite material storage space (including on and offsite fuel caches), if required. Contact the specific refuge headquarters office where the project is going to be conducted to determine if descriptions of hazardous material storage or other onsite material storage are required.

37 Sign, date and print the application. Click on the Print button to print the application (if using the fillable version). The refuge official will review and, if approved, fill out the remaining information, sign, and return a copy to you for signature and acceptance.

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APPENDIX E: DATASHEETS

Environmental Institue of Houston- University of Houston Clear Lake
Shorebird Survey

Date:	**Location:**		
Survey Start Time:	**Survey End Time:**	**High Tide:**	**Low Tide:**
Weather: *Wind Direction:*	*Wind Speed (mph):*	*% Cloud Cover:*	**Surveyors:**

Behaviors: Perched (P), Foraging (F), Nesting (N), Open Water (OW), Flying (FL), Preening (PR), Roosting, Other (O)

Time	GPS	Distance	Bearing	Species	No. of Birds	Behavior	Substrate	Flag

Page _____ of _____

Environmental Institue of Houston- University of Houston Clear Lake

Bird/UAV Behavioral Response Datasheet

Date:	Location: Lat/Long:	Start Time:	End Time:	Observers:
Weather:	Wind MPH:	Wind Direction:	Percent Cloud Cover:	

N = No response | A = Birds cease foraging and/or orient towards UAV | F = Birds took flight in reposnse to UAV

Species	Number of Birds	Distance (yds)	Bearing (degrees)	Behavior Pre-Flight	Behavioral Response to UAV N = No response | A = Birds cease foraging and/or orient towards UAV | F = Birds took flight in reposnse to UAV							
					Launch	Flying overhead	Flying Nearby	Circling (400)	Circling (300)	Circling (200)	Circling (100)	Landing

UAV Information: Flight Height_________ Number of Transects _________ Successful Landing _________

Notes:

Page ______ of ______