FINAL REPORT

Employing the Conservation Design Approach on Sea-Level Rise Impacts on Coastal Avian Habitats along the Central Texas Coast

Submitted by

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Note: Appendices are included as separate documents

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ACKNOWLEDGEMENTS

The conservation design approach is driven by the Strategic Habitat Conservation framework that is the planning process followed in this GCPLCC project. We are thankful to many organizations and individuals who participated or facilitated many aspects of the work conducted in the development of this project. We thank the landowners who allowed access to their properties to verify and ground-truth habitat types on their properties. We are appreciative of the many stakeholders and workshop participants from several agencies and organizations that participated in the workshops and provided input. We thank Clay Green, Dale Gawlik, Mark Woodrey, Bill Vermilion, Steve Demaso, Brent Ortego, Sue Heath, Cecilia Riley, and many others who provided input and comments on different aspects of maps and species habitat use patterns. We thank the LCC science team, especially Tim Anderson, Beau Hardegree, and Cynthia Edwards for feedback and encouragement during the development of this report. Additional funding was provided by International Crane Foundation and Meadows Foundation (EHS), Gulf Coast Bird Observatory (FCR), NOAA Environmental Cooperative Science Center (LL), and Harte Research Institute for Gulf of Mexico Studies, Texas A&M University-Corpus Christi (JG). Special thanks to Diane and Al Johnson for their commitment to Whooping Crane conservation and providing an inspiring writing retreat location on their conservation easement; we dedicate this report to you and other like-minded Texans.

INTRODUCTION

The Gulf Coast Prairie LCC (GCPLCC) encompasses one of the most diverse ecoregions in the United States and into Mexico, encompassing 121 million acres with 500 species of birds in four ecoregions (Figure 1) (Bartush 2013). Declines in habitat quantity and quality as well as fragmentation of once-contiguous native habitats threaten to impact biological diversity and ecosystem health. In a recent assessment of the Gulf Coast Prairie ecoregion, 6% is managed by federal and state agencies and 8.3% by county, nongovernmental and other entities. The remainder of the landscape is owned and managed privately, a practice that has been honored for multiple generations (TNC 2002). As urban and industrial development continues to convert native habitats to development areas, the potential impacts from climate change are converting emergent and submergent habitat types to open water. The low-lying areas along the coast provide a narrow fringe of productive coastal environments that fulfill the ecological requirements for a broad diversity of coastal species. Broad-scale habitat loss and degradation has resulted in the decline of many species' populations. This issue is of particular concern when the key component of a species' life cycle is dependent on these coastal environments.

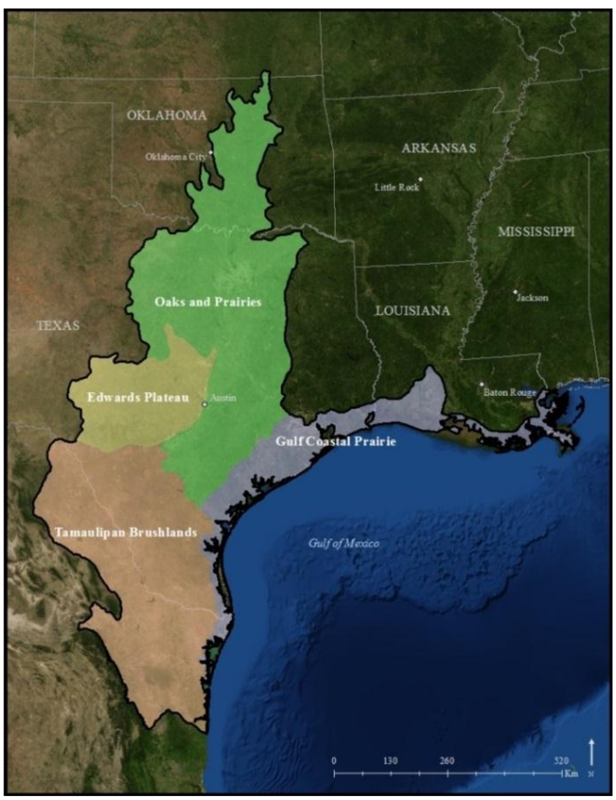


Figure 1. Gulf Coast Prairie Landscape Conservation Cooperative program area

No single agency or organization can successfully reverse the declines of species populations and prevailing trends of habitat loss. By taking an integrative approach among federal, state and nongovernmental organizations, the Landscape Conservation Cooperative (LCC) can effectively maximize our resources and collectively address these goals. It is also understood among the conservation community that, to conserve our native populations, we must focus on a landscape-level approach. The Strategic Habitat Conservation framework developed by U.S. Fish & Wildlife and U. S. Geological Survey provides technical elements that can be followed to develop regional conservation outcomes that may, indeed, have global significance to species conservation. The necessity of developing strategies that have a spatial context leads to explicit, measurable objectives as well as define limiting factors that will affect management priorities. The development of science-based conservation plans that introduce the challenges within a specific region and provide specific information to achieve objectives can then be communicated to the public and decision makers to promote that change. This report provides a comprehensive landscape approach to characterize the current and future habitat availability for a selected suite of species of concern within the Gulf Coast Prairies ecoregion along the central Texas coast.

Sea Level Rise on the Texas Coast

Sea level rise is an ongoing phenomenon and is a concern both locally and worldwide. While the process is not wholly accepted by the public, evidence that relative sea levels are changing throughout the world is widely available (IPCC 2007). Low-lying coastal areas are particularly at risk to flooding and inundation which impacts a large proportion of the human population of the world that are concentrated in these areas. While more local, state and federal governments have become concerned with the potential effects predicted sea levels will have on their communities and coastal landscapes, less concern has been focused on the potential effects that changes in sea level will have on natural communities and particularly animal species that depend on them. The rate of increase in sea level is also reason for concern for the natural communities present along the coasts. For example within this project area, average sea level at the Rockport, Texas tidal gauge has risen by 4.6 mm/year since 1948, due to a combination of absolute sea level rise and local land subsidence (Montagna et al. 2007, Snay et al. 2007). By combining the rate of local land subsidence with IPCC climate models, the projected relative sea-level rise at Rockport from 2000 to 2100 is estimated at between 0.46 to 0.87 m (Montagna et al. 2007).

Predicted increases in sea levels will have significant effects on the natural coastal environments. Coastal environments are unique physical and vegetative landscape and are important habitat for many year-round residents and migratory bird species. Increasing sea levels mean greater volume of open water and deeper bays which could affect foraging habitat for wading birds, such as the Reddish Egret which forages in shallow bay waters. The area of estuarine habitats will be reduced, affecting habitat for species such as the Whooping Crane, rails, and Seaside Sparrow which are estuarine vegetated marsh specialists. Even at the lowest expected sea level rise scenarios, the lateral shifts in bayside marshes may replace uplands 1-2 km inland on the Texas coast including the southern portion of our study area (Montagna et al. 2007). Salt marshes are not the only associations that will be affected as water level and salinities will increase along the low-lying uplands where inundation will cause habitat shifts in prairies and savannahs to a more estuarine environment.

Avian Species

The coastal areas of the Gulf of Mexico in Texas are important areas for many bird species and populations. Year round residents are joined by hundreds of species and millions of individuals of migratory and winter resident birds from fall to spring time. Aransas National Wildlife Refuge has recorded 405 species of birds. Many factors influence the number of species observed in this area, which includes the diversity of environments and plant communities found over short distances. The variety of habitat types include marine beaches and estuarine flats, estuarine vegetated marshes and open water, salty and upland grasslands, freshwater wetlands, and oak shrublands and woodlands. In addition, the central Texas coast is a major migratory corridor for birds travelling between North and South America so many North American species that breed farther north may be seen during the spring and fall migration in this area. A unique feature of the central Texas coast is that it is the winter home of the Whooping Crane, which is the only place in the world where it is found naturally during the winter months.

The last wild population of Whooping Crane winters exclusively on the Texas coast in and around Aransas and Matagorda Island National Wildlife Refuges. With a population of approximately 300 individuals it is the rarest crane in the world and listed as a critically endangered species (Birdlife International 2013). Along the central Texas coastline Whooping Cranes establish winter territories (Stehn and Johnson 1985, Stehn and Prieto 2010) encompassing the estuarine vegetated marsh complex where they defend their territory against other Whooping Cranes. The vast majority of their winter period is spent in these territories when conditions are suitable, characterized by plentiful food resources and low salinity levels. Whooping Cranes feed to a large extent on blue crab and wolfberries (Hunt and Slack 1989, Westwood and Chavez-Ramirez 2005) which can be found in abundance in the coastal marshes during most years. Intermediate salinities are favorable to the presence and abundance of blue crabs and also for Whooping Cranes to drink. Whooping Cranes are believed to be able to drink brackish water with salinities up to about 23 ppt (CWS and USFWS 2007), however direct field observations suggest the threshold is more around 15 ppt. When salinities increase Whooping Cranes must fly to uplands outside their territories to drink at freshwater sources such as wetlands and ponds (CWS and USFWS 2007).

One primary area of concern for long-term conservation of Whooping Cranes is the protection of winter habitat within its current range as well as areas of potential growth and expansion in the future (CWS-USFWS 2007). It is important to determine the location and availability of current coastal marsh habitat in the vicinity of Whooping Crane range that will determine the availability of area for Whooping Crane expansion as the population increases. In addition, it is important to evaluate the potential impacts of predicted sea level rise scenarios on the habitat used by Whooping Cranes at present and what effects it might have on the availability of current and potential habitat used in the future (CWS-USFWS 2007). In a recent evaluation of potential impacts to climate change scenarios on Whooping Cranes, sea level rise was identified as one of the primary concerns for future Whooping Crane winter range along the Texas coast (Chavez-Ramirez and Wehtje, 2011). A better understanding of potential changes in the distribution and availability of different habitat types used will improve conservation planning efforts to secure the future of Whooping Cranes. While in the past estuarine marsh complexes would shift inland and occupy areas of low-lying uplands in response to sea-level rise, such shifts are heavily constrained by human structures such as housing, agriculture, and industrial development. Hundreds of other avian species that utilize the Gulf Coast face similar challenges. Their continued sustainability is intimately tied to the physical presence and functional well-being of the coastal landscape.

As conditions along the coastlines continue to naturally change and are modified by sea level rise and human development, it is imperative that we evaluate the potential effects this may have on our natural resources in the future. Considerable effort has recently been focused on evaluating the potential effect that sea level rise will have on coastal human communities and overall development in coastal areas in different parts of the US and the world. Considerably less effort has been implemented to evaluate potential impacts on natural populations of wild birds and other animals. Many species of birds utilize coastal areas to greater or lesser extents and understanding how potential changes in habitat types over time may affect populations or species is important to evaluate.

A focus on birds as potential indicators of environmental change is also warranted. Waterbirds are highly mobile and able to quickly respond to changing environmental conditions and also provide important ecosystem services (Green and Elmberg, 2013). However, the long-term loss of habitat may have significant negative impacts on bird populations. Many coastal specialist birds depend entirely on coastal resources and a focus on a specific group or species may provide insights as to the conditions of these resources. For example, wading birds forage on fish and other crustaceans along the estuarine coastal areas and their dispersion patterns (concentrations) and permanence in an area are indicative of food resources present in different areas. Many species also have specific preference for certain water depths and their presence in different areas is indicative of those specific environmental conditions (Kushlan 1976, Custer and Osborn 1978).

Many species, particularly the waterfowl and Northern Bobwhite Quail, are economically important species as hunting of these species for sport generates billions of dollars annually to the US economy. While most ducks and geese are not entirely dependent on coastal areas for survival, some species such as the Redhead have large proportions (75-80%) of their US populations dependent on coastal environments along Texas and Mexico to overwinter.

Most species only use coastal areas partially, that is coastal areas are only a small fraction of their overall range (see species range maps below), a few however, are highly dependent on the coastal environment. For example Reddish Egret, Clapper Rail, and Seaside Sparrow have distribution range maps that closely follow the shape of coastlines. These species are particularly dependent on the coastal conditions for their survival and long-term permanence. Reddish Egrets forage along shallow estuarine environments and rely almost entirely on open water habitats, whereas the Clapper Rail and Seaside Sparrow depend on the emergent vegetation as shelter and nesting sites. They forage for the most part in exposed flats at low water levels at the base of the vegetation and adjacent flats. Other species appear to be less dependent on the estuarine intertidal zone because they forage in open water, such as terns and Black Skimmer primarily foraging in areas not far from coastal edge.

In some scenarios a species may be wholly dependent on the coastal environment for one portion of its annual cycle. The last wild population of the Whooping Crane uses coastal marsh habitat during almost half of the year, and that population migrates from one nesting area in Canada to one wintering area in the Gulf Coast Prairies ecoregion along the central Texas coast. In these cases, the conservation strategy must be closely focused on a specific area with emphasis on remaining habitat in a few estuarine bay systems.

OBJECTIVES

The overall goal of this project employs the conservation design approach to develop habitat type maps using available spatial environmental data for Whooping Crane, and other selected bird species of concern in Aransas, San Antonio, and Matagorda Bay systems. These maps incorporate species-specific habitat requirements and define current habitat types available as well as evaluate how landscape changes likely to occur under various sea-level rise scenarios will affect conservation strategies.

Specific project objectives were to:

1. Create a Composite Habitat Type Dataset that identifies spatial location and extent of coastal habitat types, developed lands, and protected areas in GCPLCC pilot project area.
2. Estimate the amount and spatial configuration of habitat type needs for Whooping Cranes in the pilot project area
3. Develop projections of the amount and spatial configuration of appropriate habitat types and evaluate potential impacts on selected bird species numbers.
4. Construct maps that depict habitat type shifts in coastal prairie and marshes under various sea-level rise scenarios and define the shifts in habitat availability and extent for the Whooping Crane and other selected species.
5. Recommend ways to apply methods used to develop these projections to extend results to additional areas within the Gulf Coast Prairies and Marshes Ecoregion.

The project was initiated in March 2012, project objectives generally proceeded concurrently, and final report was completed in summer 2014. The accelerated timeline adhered to by this project team was necessary to provide a preliminary deliverable that would be useful to ongoing and anticipated conservation opportunities along the Central Texas Coast. The conservation design approach employed in this project will provide the framework to follow a similar track in other coastal areas.

METHODS OF APPROACH

Research Design

The conservation design approach is the second element within the Strategic Habitat Conservation framework that was followed in this GCPLCC project. Our work incorporated information developed within the Biologic Planning element into developing decision support tools within Conservation Design element (Figure 2). Since the GCPLCC Science Team was in the process of selecting focal species, we selected a suite of avian species of conservation concern to develop the tools and evaluate the process. We assembled a multi-disciplinary team that could provide the expertise and guidance that a project of this complexity requires. International Crane Foundation provided project oversight and integration of GIS and avian habitat components. Gulf Coast Bird Observatory focused on guiding data development to refine GIS that represented avian habitat needs for conservation mapping. Available GIS data were reviewed and combined by Coastal and Marine Geospatial Lab at Harte Research Institute for Gulf of Mexico Studies, using ground-truthing survey data provided by Conrad Blucher Institute at Texas A&M University-Corpus Christi.

Mission-Aransas National Estuarine Research Reserve at University of Texas Marine Science Institute facilitated several preparatory meetings and stakeholder workshops. Stakeholders from diverse backgrounds were solicited for their input at two workshops to assist in defining an initial list of species, then evaluating the information that was generated and spatially modeled using GIS. Initial results were further reviewed by GCPLCC Science team members and the final deliverables were provided for use in promoting conservation efforts in the central Texas coast area of the Gulf Coast Prairies ecoregion. Identification of knowledge gaps and recommendations are also provided that can guide research efforts to improve the integrative approach. Ultimately, the goal of the process is to continue to develop spatially-explicit conservation plans for selected species in the Gulf Coast Prairies Ecoregion, as well as address the knowledge gaps that will continue to refine the process.

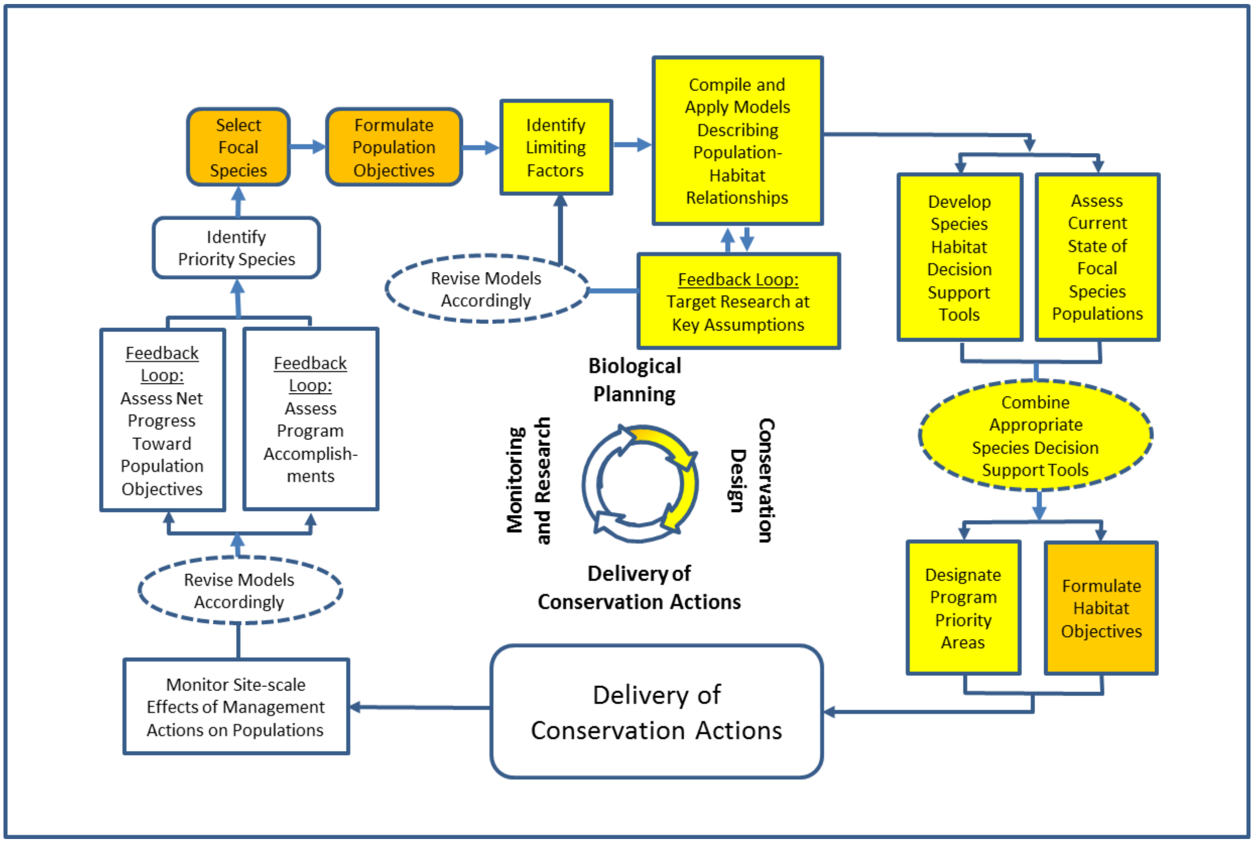


Figure 2. Schematic showing technical elements in the Strategic Habitat Conservation framework highlighting steps addressed in this project (NTAT 2008). (Note: Formulating habitat objectives must fit into Biological Planning prior to the Conservation Design process.)

GCPLCC Pilot Project Area

The geographic area was generally defined in the proposal submitted to the Gulf Coast Prairie Landscape Conservation Cooperative (GCPLCC) Advisory Committee: the northern and southern extents of the study area were chosen to encompass the central Texas coast as well as the current extent of Whooping Crane winter range, and the initial inland boundary was chosen to generally follow major highways through the coastal area. The inland boundary was further refined using the Maximum of the Maximum (MOM) Envelope of High Water from the Seas, Lakes, and Overland Surges from Hurricanes (SLOSH) model developed by the National Weather Service that models local, hydrologic impacts from a category 5 hurricane striking Matagorda Bay, Texas, at high tide (Jelesnianski et al. 1992). THE SLOSH model predicts inundation by storm surge under many possible scenarios of wind speed and direction and angle of landfall approach of a hurricane under a variety of initial tide levels. The National Hurricane Center recommends using the MOM product for Tier 3 hurricane response planning and mitigation activities. This approach would represent a snapshot “worst case scenario” for storm-surge inundation that would affect vegetation assemblages, and was determined to be a good "rule of thumb" proxy for the inland extent of future sea level rise scenarios. The MOM is not storm specific, but represents a compilation of all model outputs for a particular storm category under "perfect" storm conditions within a single basin. In some cases, it may be necessary to merge results from multiple storm surge basins to achieve continuous data coverage for a coastal area of interest. For the central Texas coast project area, the SLOSH model run for Matagorda Bay was the most appropriate (Figure 3). It covered the entire study area and included a major

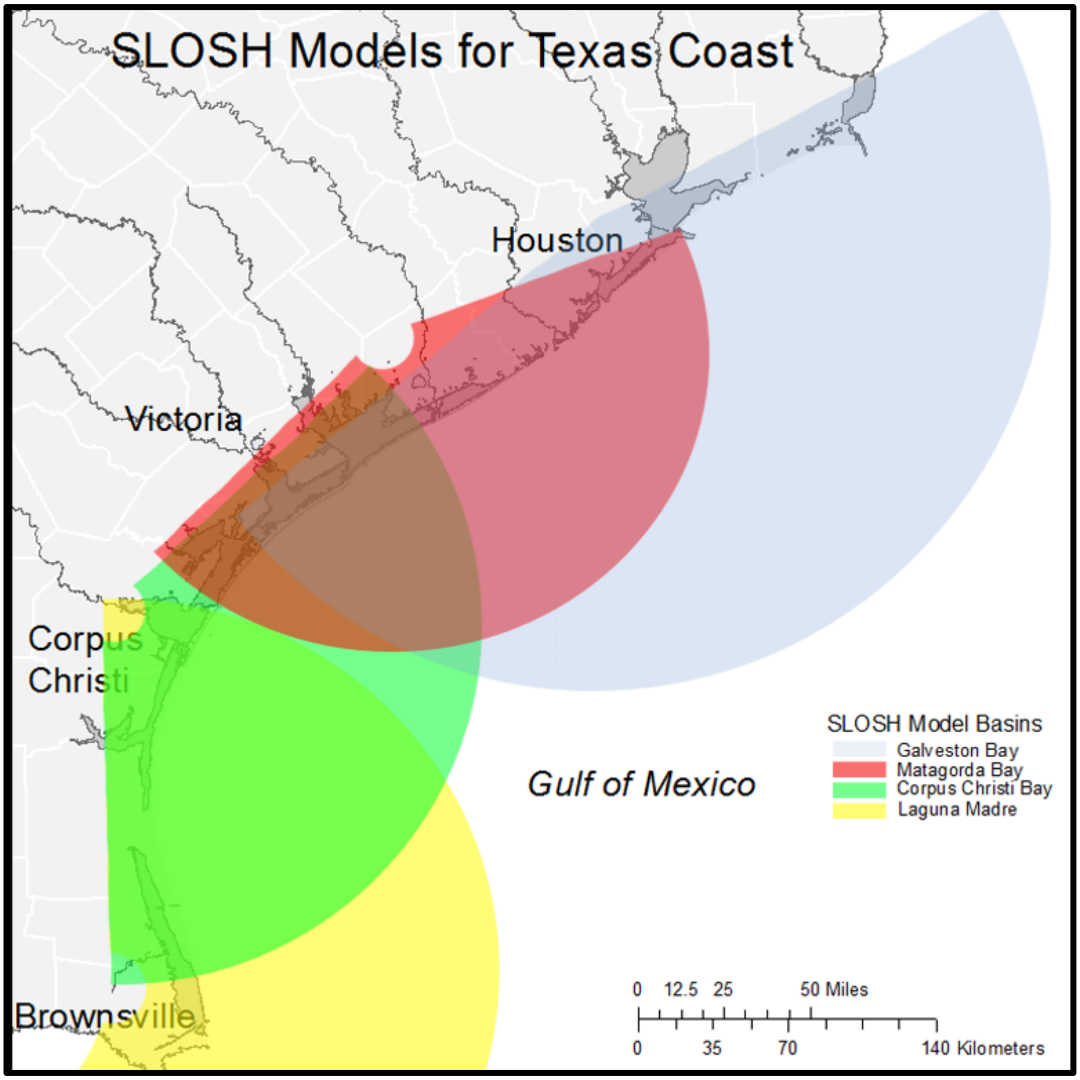


Figure 3. SLOSH model basins targeting at risk communities along the Texas coast and coverage of Matagorda basin (32) used in this project (modified from Meisner 2006).

bay within the study area. The two adjacent model runs (Galveston and Corpus Christi Bays) had only partial coverage in the study area and the majors bays included in those runs did not lie within the project area of interest.

The northeastern boundary of the study area was chosen to exclude the Colorado River and its related delta, and the southwestern boundary of the study area was chosen to encompass Live Oak Peninsula and its coastal environments, yet exclude Corpus Christi bay. The MOM was clipped to the north and south according to these delineations, and buffered by 2 km to include potential inland area that may be affected by storm surge at higher sea levels. The resulting polygon was smoothed and simplified and was used to clip all other databases within the pilot project area for all further steps.

Habitat Use Background and Analysis Summary

Habitat is defined as the collection of resources and conditions necessary for its occupancy by a species (Leopold 1933, Morrison et al 1992). Habitat definitions are by "definition" species specific. For example, a grassland cannot be a generically good habitat, as is commonly discussed, however it may be good or bad habitat for Eastern Meadowlarks for example. A particular wetland is not a generically good or bad habitat in general, but rather good nesting habitat for Canada geese, or bad habitat for a ground squirrel. The wetland is the same but, depending on the species specific connotation, may be considered both good and bad depending on what animals we are referring to and what they require for occupancy.

Habitat use is simply the way a species uses spatial and other resources of its environment. From a quantitative standpoint if a species is present in a particular habitat type it is considered to be using it (Johnson 1980). Habitat use does not differentiate the importance of one habitat type to another even though different habitat types may be used for different purposes such as foraging, resting, nesting, drinking water etc. In wildlife studies, we better understand the relationship of a species to its environments and for conservation and management purposes if we try to evaluate or measure habitat selection and habitat preference. When we are able to quantify differential use of different habitat types we are able to define habitat selection. Habitat selection is when an individual or species demonstrates disproportional use for one resource or habitat type over others (Johnson 1980, Block and Brenan 1993). Habitat preference is the likelihood of a resource being chosen if offered on an equal basis with other resources. As previously suggested by Garshelis (2000) use results from selection, selection results from preference, and preference presumably results from resource-specific differential fitness.

Generally, macrohabitat refers to landscape-scale features such as seral stages (succession phases) or zones of specific vegetation associations (Block and Brennan 1993), in essence broad habitat type categories such as upland and salt marsh. Within each macrohabitat type there are smaller discrete and definable patches we refer to as mesohabitat types. For example, within a salt marsh macrohabitat there are areas of open water, flooded vegetated areas, mud flats etc. Microhabitats are smaller units or patches within a mesohabitat, usually refers to finer scaled habitat features. For example, within an open water area in a salt marsh, microhabitats could include openwater-vegetated edge, different distances from the edge, and/or elements such as water depth. Johnson (1980) recognized this hierarchical nature of habitat use where a selection process will be of higher order than another if it is conditional upon the latter. Johnson describes four natural ordering of habitat selection processes for wildlife (Johnson 1980):

> First-order selection. This is essentially the selection of the physical or geographical range of a species. (For our purposes it is whether the species range overlaps the project area)
>
> Second-order selection. The second-order selection is the home range of an individual or social group within their geographical range.
>
> Third-order selection. This relates to how the habitat components within the home range are used (i.e., areas used for foraging).
>
> Fourth-order selection. This order of habitat selection relates to how components of a habitat are used. If third-order selection determines a foraging site, the fourth-order would be the actual procurement of food items from those available at that site.

The above ordering process also represents a natural hierarchical type organization scheme which is similar to Hutto's (1985) migratory bird habitat selection process. This hierarchical habitat selection scheme is suitable for application with spatial data as that which we are using for this project; most land cover classifications follow an explicit or implicit hierarchical organization schemes.

The amount of information available for each of our selected species differed significantly. The largest actual dataset and most detailed information were available for Whooping Cranes and will be described in detail below. For other species there is lack of specific spatially explicit information regarding habitat types used specifically within our project area. In some cases, information such as territory size and home range is available but described for different portions of their life cycle and/or range. For example, breeding information may be available for birds that only winter in our project area. Therefore, for each species we attempted to categorize the quality of the spatial dispersion data available by defining what order level could be analyzed based on Johnson's habitat selection process categories described above.

Objective 1 Composite Habitat Type Dataset

The conservation design approach involves the use of Geographical Information Systems (GIS) to address spatial elements along with biological information and models to achieve the goal of Strategic Habitat Conservation. Spatial analysis provides the technological and conceptual means for handling large quantities of spatially explicit data. These tools are essential for evaluating the entire study area in terms of species use and habitat type availability, as well as dealing with future sea level rise and potential environmental changes due to sea level rise and their impacts on species use. The first step involved the development of a single database that most accurately describes the land cover of the study area relevant for determining habitat conservation priorities for coastal avian habitat along the central Texas coast. Subtidal, intertidal wetland, fresh marsh, and upland habitat types are all important for a variety of bird species in the pilot project area. The most appropriate databases for representing each broad set of habitat types were determined. ArcGIS was used to compile, organize, analyze, and modify all geospatial data. (ESRI 2011). ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.)

The GOMA portal was used to search for appropriate data for use in this project, before any other data sources were consulted. GOMAportal.org is a metadata catalog and data repository for Gulf of Mexico related geospatial databases. Funded by NOAA through the Gulf of Mexico Alliance (GOMA), GOMAportal.org houses the results of a multi-year project by the GOMA Ecosystems Integration and Assessment (EIA) Priority Issue Team (PIT) to improve the Gulf state's metadata and discoverability of geospatial databases. Lead by EIA PIT members at the Harte Research Institute for Gulf of Mexico Studies (HRI), EIA PIT state partners collected geospatial database and metadata records, and upgraded them for compliance with the Federal Geospatial Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) standard, while preserving as much of the original character of the metadata as possible. For this project, the original databases were also obtained where available and renamed to have meaningful file names. Finally, available data were packaged with the upgraded metadata, and made available for download via FTP.

A matrix was developed to assess potentially useful spatial data for this project. Databases were grouped into broad types, such as elevation data, vegetation/land cover data,land use data, and model results. Attributes examined for each data set included originator, map projection, horizontal and spatial reference, mapping theme, classification system and method, data type (point, raster), data format, age of the data set, spatial resolution, minimum mapping unit, mapping scale, data source, spatial coverage, and intended application. Databases were evaluated for issues such as inappropriate resolution, inadequate spatial coverage, or outdated data, and other notes were made, including possible future changes or improvements to the database or recent applications of the database in known projects. Databases deemed suitable for this project would include those recently developed, displaying a high level of spatial and thematic resolution, using classifications based on a commonly used or well-documented standard, and having spatial coverage extending to the entire GCPLCC pilot project area.

Data from the NOAA Benthic Habitat Atlas (BHA), the USFWS National Wetlands Inventory (NWI), and the TPWD Texas Ecological Systems Database (TESD), were further evaluated for their appropriateness based on our criteria described above.

A general rule was constructed in the order and merging of the data:

- In entire project area:
  TESD **EXCEPT** where NWI data exists
    - In intertidal estuarine and upland freshwater wetland areas:
      NWI **EXCEPT** where BHA data exists
        - In mangrove, oyster reef, and seagrass areas

All databases were clipped to the GCPLCC pilot project area. Then the portions of the TESD that were covered by the NWI were removed and the datasets were merged. We then removed portions of the resulting dataset that were covered by the BHA and all these datasets were merged.

Each database selected for use in the Composite Habitat Type Dataset (CHTD) was first assessed to determine the most appropriate level of detail to represent habitat types in the GCPLCC pilot project area (Figure 4). Land cover categories from the different data sets are redefined as habitat types as in our CHTD as they are now used in reference to their sutability as habitat for birds of interest. The TESD (see Appendix A for source and summary) follows the classification developed for Texas using an international classification that is being used to map terrestrial systems of the United States (Grossman et al. 1998). For the TESD, the broadest level used in the database is the Physiognomic Type and related to the vegetation structure. The TESD classification further divides geographic areas into Ecological Systems that are described as related to regional characteristics. Upland areas were best described by the finest level of description in the hierarchy listed as Ecological Mapping System Common Name (which incorporates a subset of the ecological system and vegetation type) within the attribute table (Figure 5). Depending on the level of regional knowledge and mapping accuracy at the vegetation type (60%) (Ludeke et al. 2009), data were used at either microhabitat type (lowest level) or mesohabitat type (Physiognomic level) and grouped within the macrohabitat level following NWI system classification.

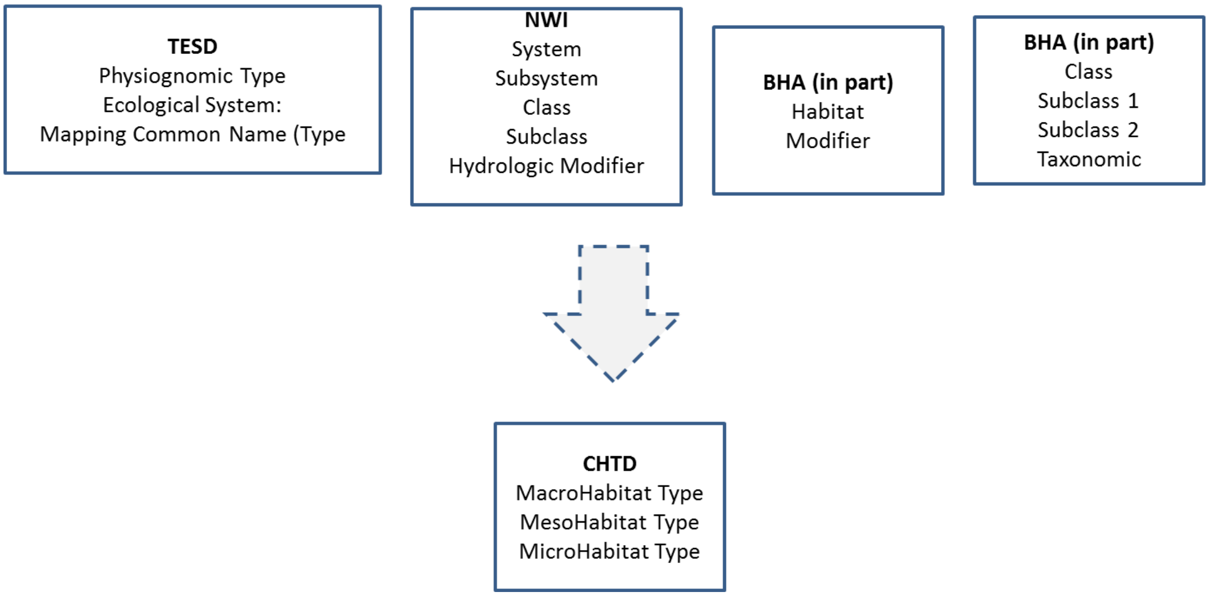


Figure 4. Various labels of hierarchy in the Texas Ecological Systems Database, National Wetlands Inventory, and Benthic Habitat Atlas that comprised the CHTD hierarchical level following development of crosswalks.

The NWI database downloaded from the NWI website (Appendix A) incorporates various levels of the Cowardin classification (Cowardin et al. 1978), as well as some fields that generally correspond to structural hydrologic names under Wetland_TY, and represented both freshwater inland and estuarine and marine systems (Figure 6). Over 100 unique wetland attribute (modifiers) were described within the pilot project area and were grouped into a more manageable number by joining attributes with similar hydrologic modifiers. Attributes with grouped modifiers were used within the microhabitat type level, Wetland_TY as was Class, Subclass descriptors within the mesohabitat level, and system within the macroabitat level. To fully cover the pilot project area, microhabitat type level mapping units from the TESD were also incorporated into the Estuarine Emergent Marsh and Estuarine unvegetated Flat macrohabitat types.

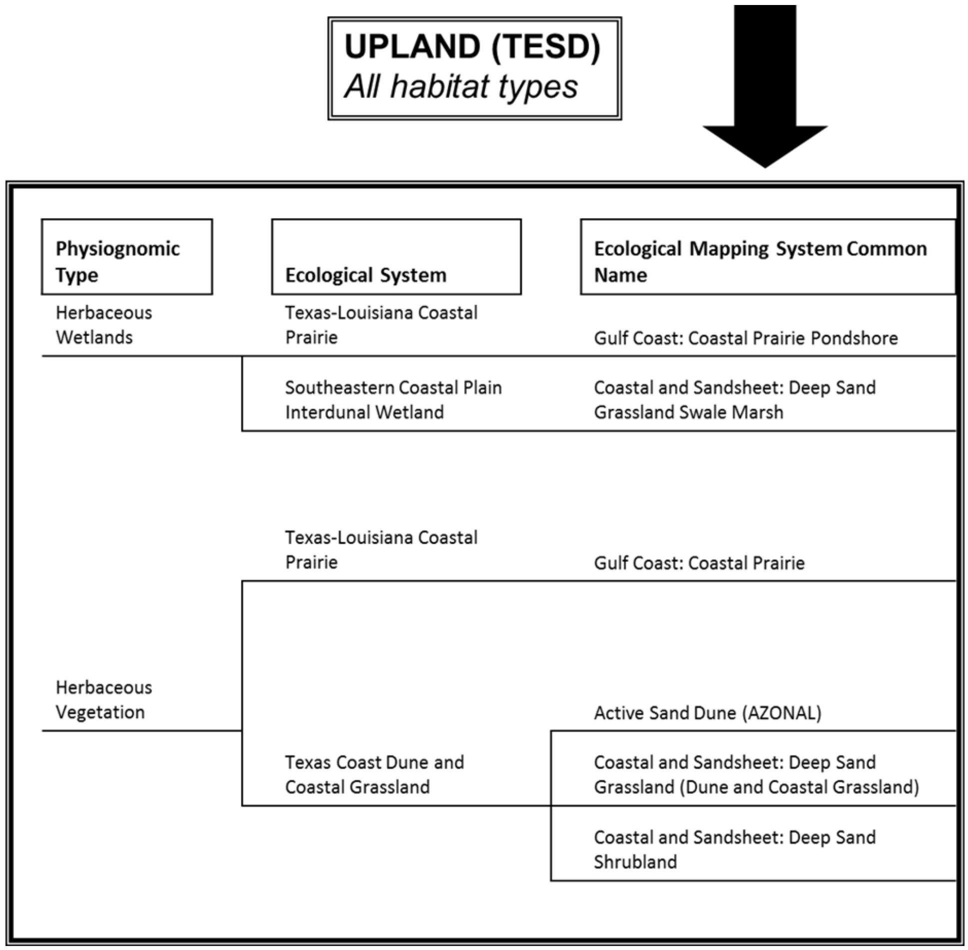


Figure 5. Hierarchical organization within Texas Ecological System Database used primarily for upland area.

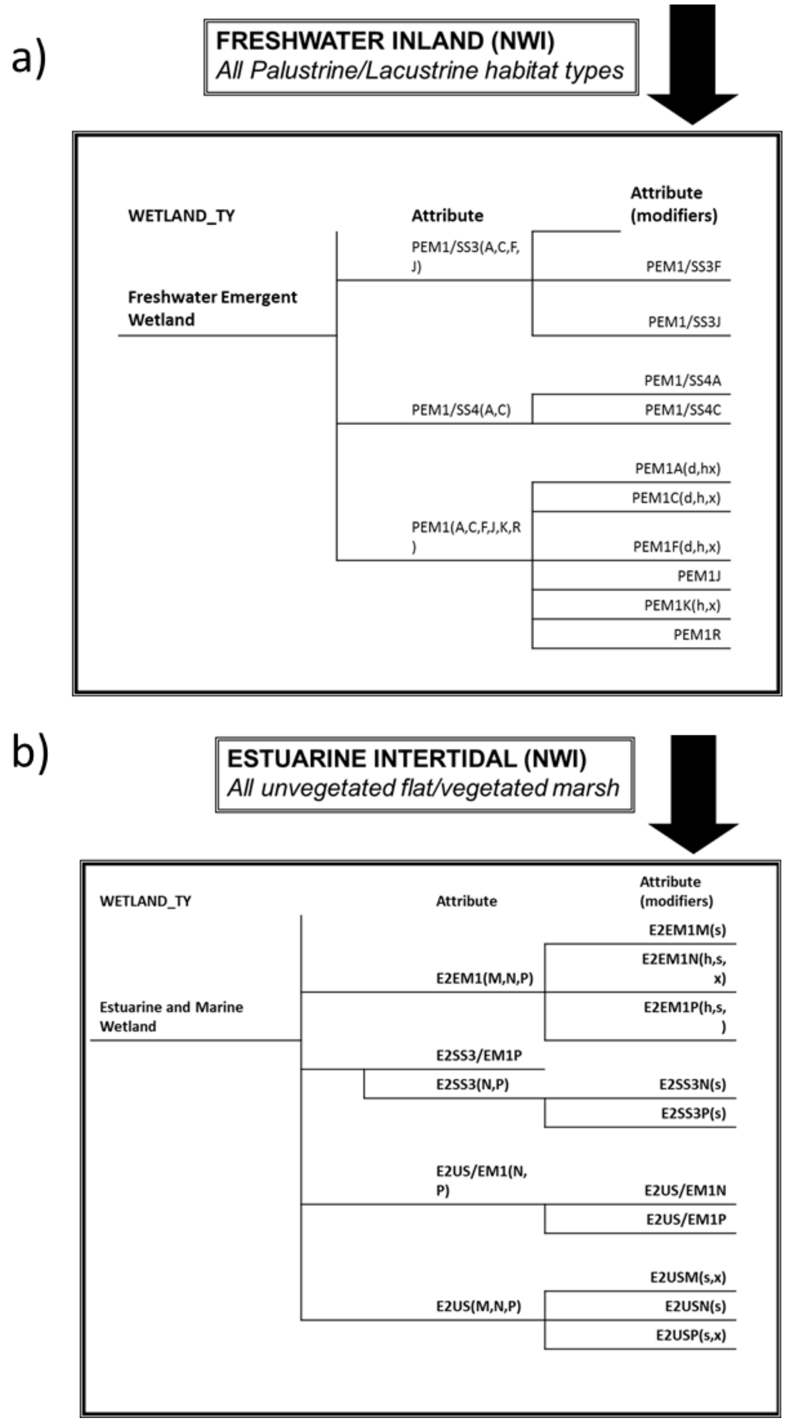


Figure 6. Selected examples of the hierarchical organization among National Wetland Inventory databases for a) freshwater and b) estuarine systems.

Seagrasses were mapped within the BHA databases (Appendix A) as submerged rooted vascular (SRV) at a continuous and patchy (or discontinuous) Habitat level within each of the bay system databases available (Figure 7). Although modifiers were used in most of the bay databases, use of modifers was not consistent and therefore not used in this project. In the CHTD, the Habitat and Subclass 2 descriptors were used in the microhabitat level, Class descriptor in the mesohabitat level, and System level from NWI for macrohabitat level. In some areas, wetland attribute modifiers (Estuarine Subtidal Aquatic Bed) were included in the seagrass microhabitat type level to encompass all areas of the pilot project area.

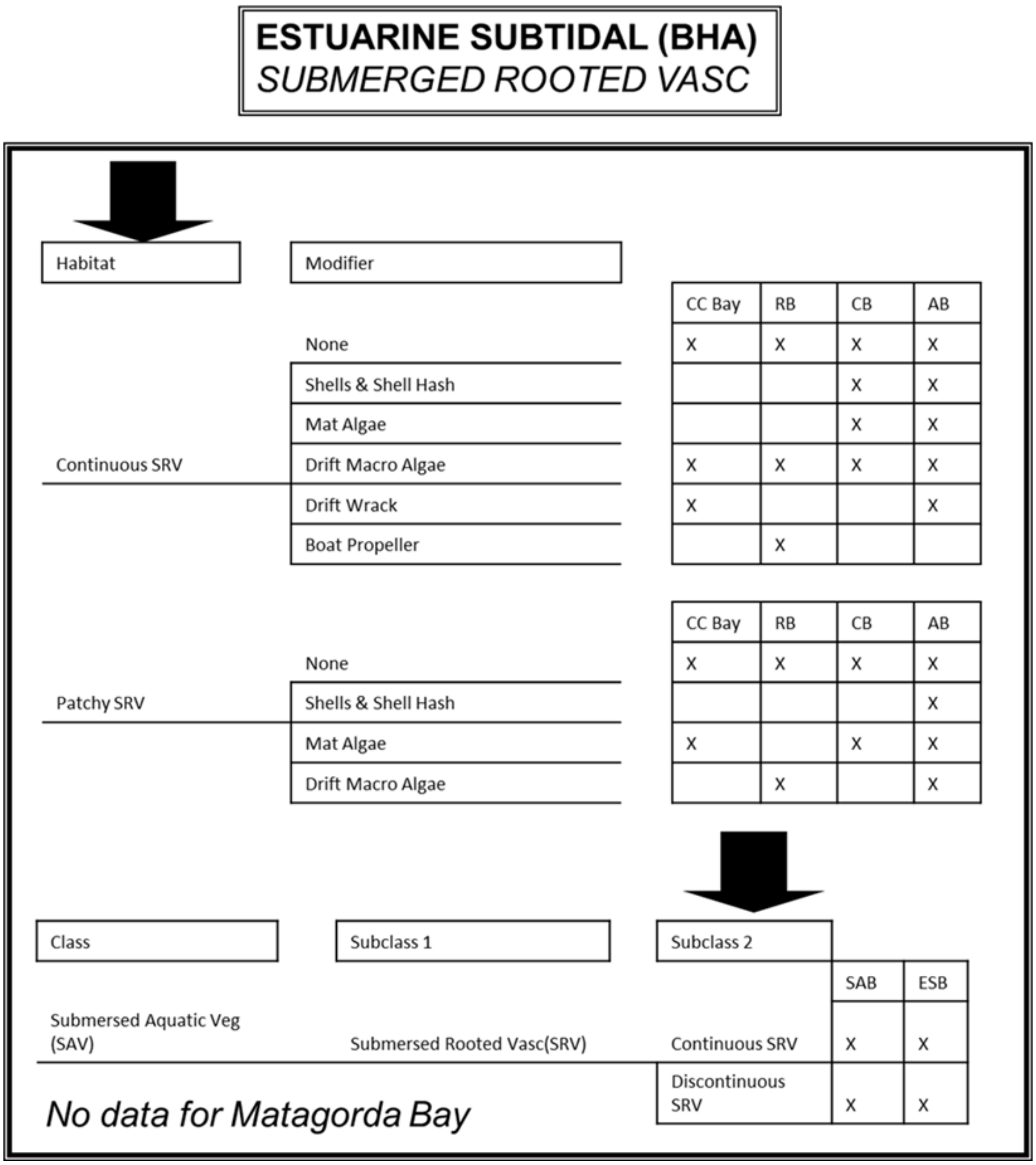


Figure 7. Hierarchical organization among NOAA Benthic Habitat Atlas datbases for submerged rooted vegetation (seagrass).

Mangroves are best represented in the BHA databases within the Habitat (Mangrove) and Taxonomic (*Avicennia germinans*) classifications, depending on bay system dataset (Figure 8). In the CHTD, both Habitat and Taxonomic were used at the microhabitat; mesohabitat and macrohabitat levels were designated from Class and System of NWI classification. To fully encompass all the spatial extent of the pilot project area, ecological system mapping units from TESD and estuarine shrub-scrub attributes in the NWI database that likely represent mangroves were also included in the microhabitat and mesohabitat type Mangroves. Oyster reefs were mapped in most of the BHA databases as Bivalve Reef under Habitat and Subclass 2 classifications (Figure 9), which were used in the CHTD as microhabitat level. Mesohabitat and macrohabitat levels were named after NWI classification (bivalve reef).

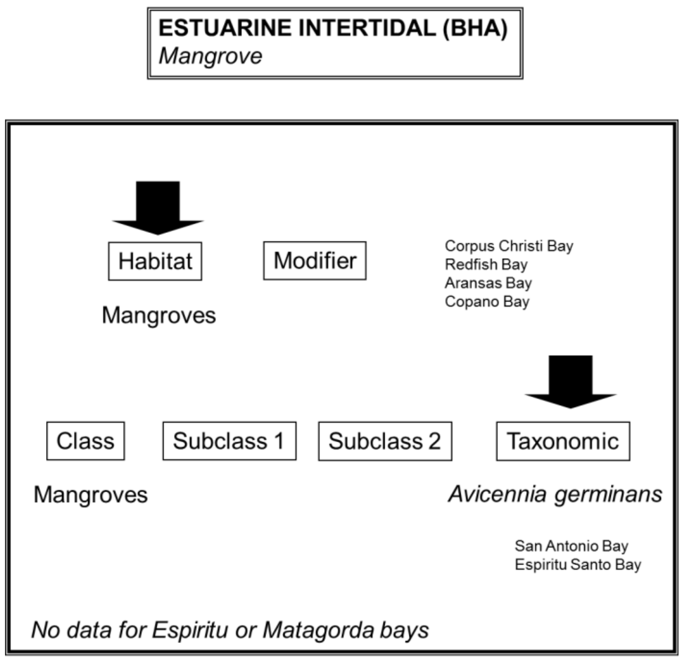


Figure 8. Hierarchical organization among NOAA Benthic Habitat Atlas database for mangrove.

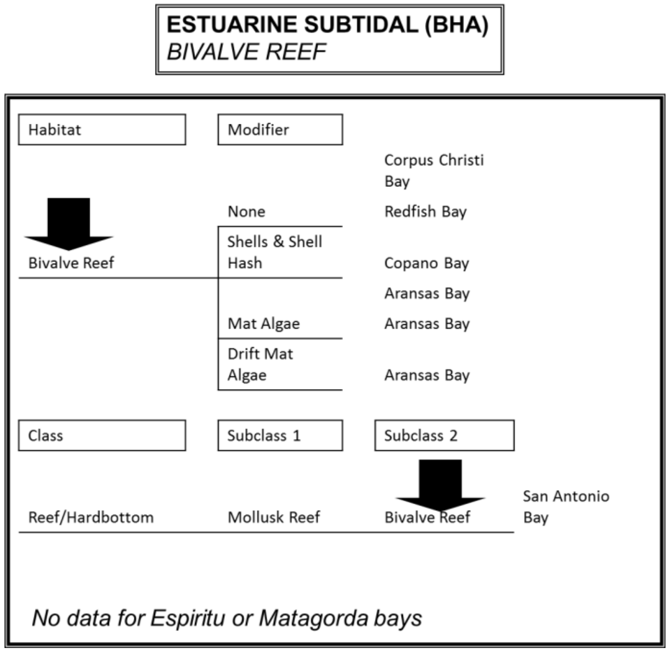


Figure 9. Hierarchical organization among NOAA Benthic Habitat Atlas database for bivalve reef (oyster).

Objective 2 Current Conservation Needs for Whooping Cranes

Current conservation maps are defined for this project as a map that shows the distribution of habitat types used by a species based on their distribution range and habitat use patterns. It shows the arrangement and distribution of habitat types within and outside the species current distribution (in case of Whooping Cranes) so that within the species range it represents areas actually or potentially used by a species and outside its current range represents areas of potential use only. For example, potential use areas would be expected to become current use if a species or population increases or there is a shift in distribution.

Significant information on Whooping Crane habitat use patterns was available from Whooping Crane survey data conducted by USFWS biologists from 1950-2011. Census flights were conducted regularly either weekly or biweekly throughout winter seasons from November through April following a standard methodology (Stehn and Taylor 2008). The survey data was digitized by FWS Region 2 Inventory & Monitoring Program in 2012 and provided for limited use in this GCPLCC pilot project. Associated information, such as weather, time of day, and general habitat type at each crane location, were also included in the attribute table when noted in raw data. Each point recorded on surveys and later digitized represented a single crane or multiple cranes in close proximity to each other. For this study, we used point data for the wintering seasons 2004-2005 through 2010-2011. This range of years corresponds chronologically with the most recent habitat type data used in this study and also represents the years with the largest crane populations.

Spatially explicit data related to location and distribution of individuals or flocks of birds, or even more general species distribution data were not available, for most species considered in this project. Because data of this type did exist for the Whooping Crane, an overlay analysis could be conducted by performing a spatial join between the Whooping Crane sightings dataset and the CHTD. This enables highly specific information related to the use of particular habitat types by individual birds to be developed. Habitat type attributes were assigned to each point, and a summary table based on habitat type use was generated. The table included total number of points coinciding with each habitat type, and number of adult and total number of Whooping Cranes by habitat type. The proportion of sightings in each habitat type was calculated, and the habitat types were classified according to their percent use. At the mesohabitat level, those habitat types comprising >50% of use locations by Whooping Cranes were given an index of 3, or High Use; habitat types between 10%-49% of crane sightings were considered low use and given an index of 2, or Low Use; and, habitat types overlain by <10% of birds were given an index of 1, or Incidental Use. Habitat types not overlain by any of the points and points that did not correspond to CHTD polygons were not indexed.

In the overlay analysis described above, when a point overlays a habitat type that type is selected as potential habitat throughout the data extent. However, if additional characteristics refine the level of use by a particular species, then further analysis is needed to calculate potential habitat use. For example, for the Whooping Crane, survey points may overlay Estuarine Open Water habitat type within the estuarine marsh complex, but not in deeper water offshore from the marsh/bay interface. If the entire coverage of Estuarine Open Water was included in the area calculations for potential use, the extent of potential habitat would be overestimated. Similarly, if Estuarine Open Water was omitted from the calculations, an important habitat type for Whooping Crane use would be excluded from consideration for conservation.

Whooping Cranes forage in Estuarine Open Water to depths no greater than 0.3 m at mean sea level (MSL); we also factored in a decrease in water levels during seasonal low tides in winter of 0.3 m. We used a NOAA estuarine bathymetric DEM developed from hydrographic field data with a 30-m resolution and a stated 0.2 m accuracy for depths shallower than 20 m (Appendix A). Each 30 m resolution raster was then adjusted to reflect elevations relative to Mean Sea Level from the NOAA standard Mean Lower Low Water, which was achieved by retrieving tide gauge data from the Texas Coastal Ocean Observation Network (https://www.cbi.tamucc.edu/TCOON/). The difference between MLLW and MSL was calculated for each gauge within each bay system (3 gauges in Matagorda Bay and 2 gauges each in all other bays) and averaged to obtain a single conversion factor for each bay. The conversion factor for each bay system was subtracted from each cell of the dataset for each bay. The resulting values reflected elevations relative to MSL instead of MLLW. All rasters were then mosaicked to make a continuous raster dataset of estuarine bathymetry. The mosaic was then reclassified into two classes- depths greater than 0.66 m and depths shallower than 0.66 m. The shallower depths were given a value of NoData, resulting in a raster dataset representing only estuarine depths greater than 0.66 m. This raster dataset was then converted to a polygon feature class.

The CHTD was clipped to this “Deep Water” polygon. Then, mesohabitat types that would likely actually exist in “Deep” water were selected (e.g. Estuarine and Marine Open Water, Estuarine Aquatic Bed). All other mesohabitat types were deleted from this clipped CHTD dataset. Micro- and Mesohabitat type names were then appended with the word “Deep” at the end. (e.g. Estuarine Open Water Deep) This clipped CHTD polygon dataset was then re-added to the original CHTD dataset using the “Update” tool, which erases parts of the CHTD overlain by the “Deep” dataset and replaces it with the “Deep” dataset. Whooping crane observation points could then be overlain on the new CHTD Deep dataset and a frequency analysis could be undertaken that would accurately reflect the aerial coverage of estuarine and marine habitat types actually used by the whooping crane.

Objective 3 Selected Avian Species

This project initially was intended to focus on Whooping Cranes but ultimately included an evaluation of five other bird species. Originally we expected to include a group of species selected based on representation from different groups, assemblages, and/or guilds. We used the first stakeholder workshop to help us define the list to a manageable number. However, as the interest of the stakeholder group was varied we ended up with a large number of species and not one but several species in different groups, assemblages or potential guilds. We originally included all species proposed during the stakeholder workshop, despite the fact that some species had minor connections to the study area or that have such wide ranging distribution or habitat type use that our study area was only a small fraction of its normal range.

We attempted to narrow the list of species by considering an evaluation of potential guild association and determining whether we could use surrogate species, whether we could infer the potential effects on one species to be the same on one or more other closely related species. However, upon closer examination of different potential guilds identified, and because of the finer scale resolution of habitat type classes used, it was determined that this was not a feasible nor realistic alternative. For example, if we look at the wading birds as a guild and try to find one species that may represent the entire group we were unable to do so. The sympatry in wading birds has to do with the fact that they are able to partition the habitat and/or food resources. Among sympatric species with similar morphologies, differences in resource use could result from differences in: 1) habitat, 2) diet, or 3) temporal activity patterns (Pianka 1994). Among competing wading bird species high overlap in one resource gradient (e.g., food) generally results in low overlap in a second resource (e.g., habitat) (DuBowy 1988, Ramo and

Busto 1993, Chavez-Ramirez and Slack 1995). So based on similar evaluations for different related potential species groups we decided to treat each species individually for this project.

For all species in our final list we conducted a literature review in order to gather as much information on the species distribution, relative to our study area, and as much habitat requirements and documented habitat type use as available. For all species we began our search with the Birds of North America species accounts (bna.birds.cornell.edu/bna/). For those species whose accounts had not been updated in the last 5 years we then conducted a more detailed search for other published information.

We applied the habitat selection ordering scheme to each species as a way of classifying the quality of the data available for that species for the study area or similar area. So for each species account and maps we will denote the level of habitat selection that the data provides. For example, if a species is known to occur in our GCPLCC pilot project area because its distribution range overlaps in some way that is considered a first order selection process. If we have sufficient information to differentiate whether a species utilizes specific habitat type categories of our CHTD differently we may be able to reach second order selection for those species. At a most basic level we may be able to understand that a species will use grasslands but not wetlands (macrohabitat types) for example, or is present in saltmarsh but not upland grasslands. If we have sufficient information to determine how a species uses different habitat type patches (or mesohabitats) we could determine level three selection processes. For example, if a grassland species uses patches that have been grazed or burned (mesohabitat types) versus the natural tall dense grassland vegetation more often this would be a third order selection process. Reaching this level of resolution would normally require a quantitative evaluation or analysis that numerically differentiates the use of different habitat types by a species. Fourth order selection would require us to understand the species use of specific patches, for example where (microhabitat type) and what kind of food items are taken in a habitat type, or what habitat type it uses for loafing, or drinking water etc.

The CHTD and the matrix developed in the species data review both used similar habitat type descriptors. The species matrix was joined to the CHTD according to this description, giving a spatial dimension to the habitat needs and uses shown in the matrix. The CHTD would then be symbolized according to the habitat use indices for each species (High = 3, Low = 2, Incidental =1) using information from the literature and expert knowledge, resulting in separate current conservation needs maps for each species. These maps show the potential extent of bird use within its current range.

Our habitat use index is a theoretical representation of an expected third order habitat selection process. Habitat types where assigned a value of 3, representing high use, if the species was expected to be encountered in a patch of that type with high frequency and/or in greater abundance. Habitat types were assigned a value of 2, low use, if the species was expected to be found in that habitat type patch in low frequency and/or low abundance. A value of 1 was assigned to habitat types that were expected to receive only occasional and irregular use by a species.

The CHTD was used to calculate areal extent of habitat types described for all selected avian species as used by the species literature sources. In addition, masks were created for several species where use was limited to a particular water depth (e.g., Black Skimmer, bay shoreline to 20 cm depth; Aplomado Falcon habitat types within 1 mi of forest or woodland excluded) and habitat extent recalculated. Summary tables were constructed to provide areal extent (ac) by each habitat type and by use index for each species and habitat use maps created for entire GCPLCC pilot project area.

At the macrohabitat level we can estimate the amount of area currently available for each habitat type with the CHTD map. Potential changes in different habitat types are available for all selected avian species. Because it is known that most species do not use smaller patches (meso- and microhabitats) equally within any specific macrohabitat, using total acreages of a macrohabitat as available to birds can be misleading, in most cases overestimating the amount of areas of use or potentially used habitat types. So for most species we developed potential habitat use index maps. Since there were no quantitative data that could be used to mathematically define high vs low use (as we did with Whooping Cranes) we used our field experience and species' expert opinions to help us develop the habitat use index for different species.

For species with spatially explicit information (i.e. known territory size, or species density) and actual or theoretical third order habitat selection known, we can estimate the number of individuals potentially present in a landscape based on habitat type extent present. For our selected species we found values for territory size (Le Conte's Sparrow, Loggerhead Shrike) or density (Northern Bobwhite) which were used to estimate potential number of territories or individuals that could use the estimated spatial extent calculated for different habitat types. It should be noted that territory size and density are variables that could change depending on time and space, such as local habitat conditions or amount of rainfall in different years. For example, Le Conte's sparrow was previously studied along the Texas coast in Brazoria NWR and there was information on their winter home range size (Baldwin et al. 2010). We used the 95% probability home range of 62.8 ac (25.4 ha) and the 50% probability home range of 14.8 ac (6 ha) to estimate the number of birds that could be supported in the current conditions CHTD acreages. We use both values to estimate a possible range when reporting in results section.

To determine what specific changes the predicted land cover habitat types might have for a species or population in the future we need to understand issues related to the species distribution and dispersion patterns in the landscape as described above. In addition to variables such as density, territory size, and social behavior we tried to determine if a species had a minimum habitat patch size requirement to further refine their potential dispersion patterns on the landscape. To consider the possible effect of habitat type patch size and potential landscape fragmentation we attempted to find information on the species' minimum patch size if available.

Knowing the minimum patch could allow us to determine which patch size could be considered potential habitat in the future and which patches of potentially suitable habitat types are too small to be utilized by a species. For our selected species the minimum patch size, however, is only available for some grassland bird species. However, in some cases for some species, management and conservation plans call for a patch size to be considered from a management perspective and we have used this management patch size to depict those patches in some of the species maps.

A proposed management patch size was reported for the Seaside Sparrow at 10,000 ac (>4,050 ha) and for Le Conte's sparrow of >200 ha (500 ac) by the Gulf Coast Joint Venture. We referred to the reported values as management patch size as they were proposed for areas of conservation and/or restoration and they did not represent true biological minimum patch sizes from the bird species perspective. However, for this project we used these management patch sizes to identify the number and location of relevant patches within our study area and created maps with only relevant patches.

Suitable habitat types for the Le Conte's and Seaside Sparrows is related to not only the specific potential habitat type of an area, but to the spatial configuration of that area. For example, a management patch size of 500 ac has been determined for the Le Conte's Sparrow. A map depicting potential habitat for the Le Conte's Sparrow would show potential high and low use habitat types specific to that species, but only those continuous (within 50 m of each other) polygons which make up 500 ac would be included as good potential habitat. Smaller or disconnected portions of otherwise potential high or low use habitat would be excluded. To achieve this, all polygons of microhabitats determined to be high and low use for the specific species were selected and exported as a separate feature class. The aggregate polygons tool was then used to aggregate all high and low use polygons within 50 m of each other. The aggregate polygons tool was used again with an aggregation distance of 500 ac to achieve the final patches of potential habitat.

Objective 4 Future Conservation Needs for Whooping Cranes and Selected Avian Species

Whooping Cranes

The Sea Level Affecting Marshes Model (SLAMM) was used for predicting effects of sea level rise on potential Whooping Crane habitat. The SLAMM is a dynamic model that takes into account the dominant process in wetland change due to sea level rise including inundation, erosion, overwash, saturation, and accretion. These inputs were used, along with various sea level rise rates, to determine the effect of sea level rise on wetland habitats in and around the Aransas National Wildlife Refuge. The SLAMM model outputs are in raster format, with each raster given a value that corresponds with a model-derived wetland type. Wetland types are based on the National Wetlands Inventory, and resulting habitat types are comparable to NWI habitat types.

Future potential habitat use maps were created for the Whooping Crane by combining the habitat use ranks to the initial and future scenario habitat type rasters from the SLAMM outputs. Rasters were first converted to vector, or polygon, feature datasets. A new attribute ("UseRank") was added, and then populated with ranks 0-3 corresponding with the habitat type associated with each rank. The dataset was then symbolized according to the use index. Additional layers included in the map were the Estuarine Open Water habitat type from SLAMM, and an overlying open water polygon derived from the NWI. This symbolization showed the inundation of open water onto what was initially upland or estuarine marsh habitat in future SLAMM scenarios. Acreages of High Use habitat type categories were then calculated and areal extent mapped for infrequently and frequently flooded marsh for initial conditions and all scenarios. Areal extent was compared among the four SLAMM scenarios at initial, 2075 and 2100 to assess potential changes in habitat availability for potential High Use habitat type categories for Whooping Cranes.

At the request of the reviewers, we also created a separate supplemental document that provides the material related to the development of the CHTD and results of each objective for the Whooping Crane. By restructuring the information, the information gained from this project can be used in conservation planning and implementation for this species.

Selected Avian Species

The effect of habitat type shifts as a result of the sea level rise on the selected bird species can be best evaluated based on changes of the aerial extent of different habitat types. Generally, we estimate the amount of change of different habitat types from the current baseline. For species where we only have first and second order habitat selection (Appendix A) information that means we can only determine whether there may be a positive (increase in habitat types used) or negative (decrease in habitat types used) impact on their habitat in the future.

From the macrohabitat type category perspective we could group the species in our list as upland group (i.e., grassland, grassland-savannah, freshwater wetland) and estuarine intertidal (saltmarsh, estuarine open water, estuarine reef). Because part of our analysis was to evaluate what changes will occur in habitat type categories in the future we can make a general assessment in regards to broad habitat type categories. For example, while changes may not be specifically related to a particular species we could surmise that grassland species will be negatively affected overall if grassland extent is expected to decrease under future sea level rise scenarios. Similarly, we could conclude that estuarine intertidal species would be positively affected overall if there are net increases predicted to the extent of acres of the intertidal zone under future sea level rise scenarios.

At the mesohabitat type, we can use the species from which we had the most spatial information and represent the diversity of microhabitat types as well: Loggerhead Shrike (primarily upland shrubland), Aplomado Falcon, Bobwhite Quail, and Le Conte's Sparrow (primarily upland grassland). In the estuarine macrohabitat, Seaside Sparrow was selected as its use of recently established mangroves differentiates the otherwise similar microhabitat uses of the Whooping Crane. For our selected species we have an estimated or assumed territory size or density we can then determine the potential effect of habitat changes by estimating how many acres and therefore how many individuals or home ranges are potentially affected in future habitat type shift scenarios.

A high resolution digital elevation model (DEM) was developed for the entire study area for the purpose of examining sea level rise scenarios in portions of the study area not covered by the SLAMM. Bare earth DEMs tiles developed by FEMA and the USGS covering each county in the study area were provided by the Texas Natural Resource Information System (TNRIS). Each tile covered ¼ of a Digital Orthographic Quarter Quad (DOQQ), with a cell size of 1.4m. The study area is intersected by 212 DOQQs, and the total number of DEM tiles used numbered close to 800. The tiles were joined using the mosaic function in ArcMap to make a single DEM covering the entire LCC project area. The DEM was then clipped to the extent of the study area, removing jagged lines along the study area boundaries. The DEM was used for a variety of purposes, including a comparison with the DEM used to develop the SLAMM model in order to evaluate possible sources of error in SLAMM outputs, development of contour lines and elevation intervals for habitat analysis, and visualization of maps.

County- wide DEMs at 5m resolution were provided by TNRIS were also used in this project, mosaicked, and clipped to the study area according to the process above. This DEM was then used to develop 1- and 2- meter contours to assist in evaluating potential sea level rise scenarios in areas not covered by the SLAMM model run. A low-pass filter was first applied to the DEM to remove any major outliers within the elevation raster. The DEM was then reclassified according to elevation, separating the DEM into 4 classes: minimum elevation up to 0 m, between 0 m and 1m, between 1 m and 2 m, and above 2 m. This reclassified raster was then converted to a polygon feature class. Polygons representing 0-1 m and 1 – 2 m were then exported separately, and these were used as 1 and 2 meter elevation contour lines. For examining the potential changes to land-cover types under various sea level rise scenarios, the 1- and 2- meter polygons were used as clipping masks to separate the CHTD into elevation classes for further analysis.

The Whooping Crane data from census surveys provided spatial relationships to the habitat types at various levels; we used the high use index to further evaluate potential changes in habitat availability from relative sea-level rise. For the other selected species, we used published literature and professional opinion to categorize habitat use. Therefore, we used both high and low use indices to assess habitat loss only from sea-level rise. This approach is pertinent for upland species as only loss will occur from this type of climate change. For the Seaside Sparrow, loss of upland habitat will be partially compensated for gains in estuarine habitats and results for Whooping Cranes will be valuable for assessing those compensations. For each species, we selected for high and low use habitat types, and clipped that areal extent from the CHTD 1- and 2-m contour datasets, recalculated area and created maps to identify key areas of habitat loss for each species by geomorphic landforms.

Maps showing protected and non-protected potential habitat for Whooping Crane, Seaside Sparrow, Le Conte's Sparrow, Northern Bobwhite, Loggerhead Shrike, and Aplomado Falcon were developed using the current potential habitat map data for each species. Each habitat map was then overlain by all available spatial data delineating conserved lands within the study area, sourced from online data provided by The Nature Conservancy, the National Gap Analysis Program (United States Geological Survey), and The Natural Resources Conservation Service (United States Department of Agriculture). The map was then symbolized according to habitat use and conservation status (protected, not protected) and summary acreage presented by protected, non-protected, and total available for each species.

Objective 5 Future Recommendations for Conservation Design

As this is a pilot project we present an evaluation of the processes, approach, and methods used for this project from its inceptions. In addition, we present an evaluation in reference to the availability or lack thereof of needed information, identification of actual or potential problems with information and data available, as well as techniques and methods. We attempt to identify all sources of information and other resources available and highlight the nonexistence or gaps of specific items that we have encountered. Recommendations and lessons learned are based on results obtained and will be presented in detail and summarized in the discussion sections.

At the request of the reviewers, we also created a separate supplemental document for Whooping Crane, Aplomado Falcon, Northern Bobwhite, Loggerhead Shrike, Le Conte's Sparrow, and Seaside Sparrow that provides the material related to the development of the CHTD and results of each objective for each species. By restructuring the information, the information gained from this project can be used in conservation planning and implementation for each of these species.

RESULTS

GCPLCC Pilot Project Area

The LCC project area was defined by the inland boundary of storm surge inundation from a "worst case scenario" direct hit of a category 5 hurricane in Matagorda Bay, Texas, at high tide (Figure 10). The final boundaries of the area encompassed 1.744 million acres (2,725 mi^2, 7,058.87 $km^{2)}$. The area covered all or portions of eight counties: Matagorda, Wharton, Jackson, Victoria, Calhoun, Refugio, Aransas, and San Patricio.

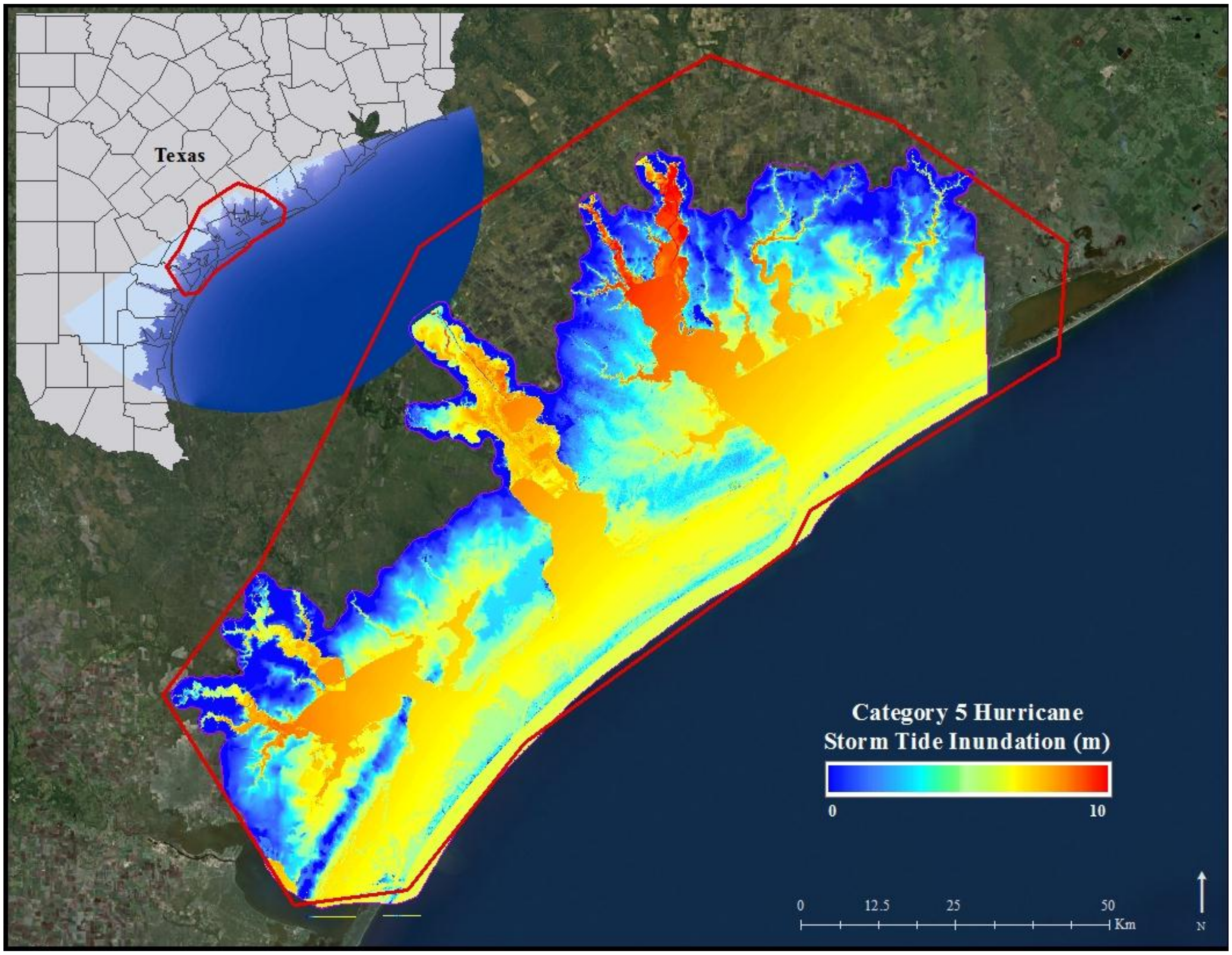


Figure 10. Initial model of potential inundation of storm surge model targeted at Matagorda Bay, Texas (above), and resulting LCC project area boundary after clipping northeastern and southwestern extent.

Objective 1 Composite Habitat Types Dataset

GIS Data Assessment

A total of sixteen databases were assessed that included two state-developed elevation databases, five federal and one state land cover database, one federal and two state land use database, and two federal and two commercial model output types (Appendix A). Twelve of the sixteen databases initially assessed were removed from consideration for one or more of the following reasons: data did not meet the desired spatial or thematic resolution; data coverage did not extend over the entire study area; age of data; known issues with accuracy of data in the area of interest; or lack of availability of commercially-produced model outputs.

A single database that accurately depicts all land cover types would be preferable, for the purposes of consistency across the entire study area. The Texas Ecological Systems Database (TESD) was reviewed first for several reasons. First, this was the most recently developed dataset, having been completed in 2010, and encompassed the entire project area (Figure 11a). Second, this dataset was developed from 30-m resolution Landsat imagery and refined through analysis of aerial photos to a spatial resolution of 10 m, thus creating a dataset suitable for small- or large-scale analyses. The purpose of the development of the Texas Parks and Wildlife Ecological Systems Classification was to create a high resolution (spatially and thematically) land cover classification system particular to the environments of Texas, explicitly incorporating vegetation dynamics to better facilitate ecological interpretations.

The development of the TESD was based on a semi-automated process starting with 30-m Landsat imagery, then using ortho-imagery from the National Agricultural Imagery Program (NAIP) from 2010 at 10-m resolution, county soil maps, and 10-m digital elevation models from the National Elevation Dataset. Land cover types were determined through an automated decision-tree system, and then verified on the ground where possible. Vegetation type descriptions were modified from NatureServ classifications (http://www.natureserve.org/explorer). Limitations of the dataset include inconsistencies between counties in county-level soil maps used for general ecological systems characteristics, problems arising from merging 30-m imagery with 10-m imagery, and inconsistencies among various observers' opinions of vegetation cover in field verification operations (TPWD Texas Ecological Systems Phase 1 Interpretive Guide). Upon discussion with several subject experts familiar with our study area, observations were made that wetland and intertidal habitats were not consistently mapped and these areas would require much more ground verification and correction before the TESD would be useful in wetland habitats within our study area at the level we required.

The US Fish and Wildlife Service National Wetlands Inventory (NWI) was chosen for use in intertidal and inland wetland habitats primarily because it was the only detailed, wetland database to cover the entire LCC project area (Figure 11b). Additionally, the Cowardin classification scheme (Cowardin et al. 1979) is used both nationally and crosswalks and tools

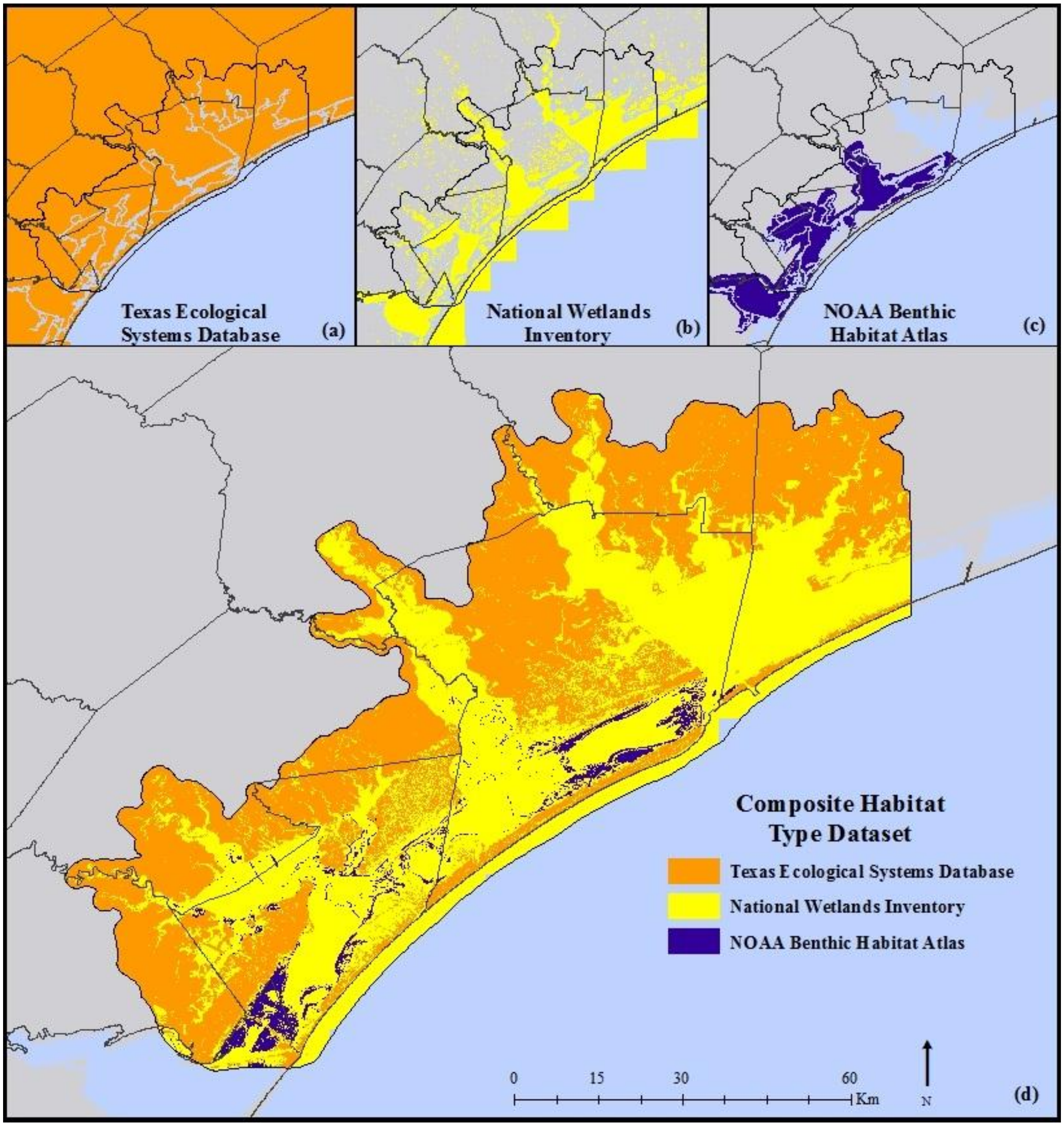


Figure 11. Three spatial databases used to construct the Composite Habitat Type Dataset: a) Texas Ecological Systems Database covered the entire LCC project area with high spatial and thematic resolution and hierarchically-defined habitat types for upland, wetland, and aquatic systems; b) National Wetlands Inventory database provided coverage throughout the entire LCC project area: c) NOAA Benthic Habitat Atlas database encompassed all bay systems except portions of Espiritu Santo and Matagorda bays; and, d) Composite Habitat Type Dataset constructed from the three land cover databases that provides full coverage across the entire study area with most relevant data for upland, wetland/intertidal and benthic environments.

have already been developed to translate NWI classifications to other classification schemes. The Cowardin classification is hierarchical, allowing users to group or split habitat types depending on level of detail necessary. Many users are already familiar with the NWI dataset, and data are available for wetlands across the entire United States. Additionally, the Sea Level Affecting Marshes Model (SLAMM) used in many sea level rise projections also uses habitat classifications that are based on the NWI. Some data coverage for mangrove was included in the National Wetlands Inventory database, but experts with knowledge of the LCC project area reported that the extent of mangrove mapped in the NWI was not comprehensive. In addition, subtidal wetlands, oyster reefs and seagrass are not adequately represented in the database, as the aquatic system requires specialized analyses and groundtruthing.

The NOAA Benthic Habitat Atlas (BHA) was developed in 2004-2007 to delineate polygons of various benthic habitat types including oyster reefs, black mangrove, intertidal marshes, and patchy or continuous submerged rooted vegetation (seagrass) to support the Texas Seagrass Monitoring effort. One-m resolution digital multi-spectral imagery was used in a semi-automated image processing effort with extensive field validation to delineate benthic habitats in sub- and intertidal areas. The benthic habitat atlas has a 10-m spatial resolution. The BHA does not, however, encompass the entire LCC project area, omitting Matagorda Bay system and oyster reefs in Espiritu Santo Bay (Figure 11c).

The Composite Habitat Type Database (CHTD) combines land cover classifications from three sources: the TESD, NWI, and BHA. The stated accuracy of TESD was 72% accurate in terms of land cover, 68% accurate at the ecological system level, and 60% accurate at the level of mapped vegetation type. The level of accuracy for this particular geographic area was lower than in other regions of Texas due to the relative difficulty in ground-truthing model outputs. Additional sources of error for the TESD include inaccurate county-level soil maps used in the development of the Ecological Systems Classification and Mapping System, wide natural variation in shrubland types, and minor coverage of urban areas. For BHA, a contract standard accuracy of 80% was required and overall thematic map deterministic accuracy was 90% for this area, except emergent marsh (76%). Accuracy of the NWI data was not possible to ascertain, as the NWI data within the study area was compiled and revised by several researchers in sections using historic wetland maps and aerial imagery from the 1950's up to 2008. All reports associated with NWI data acknowledge a continuing need for revision of NWI data as new imagery and data becomes available. All land cover datasets, including the CHTD developed for this project, should include field verification of mapped land cover types.

Development of Composite Habitat Type Dataset (CHTD)

Following the crosswalk levels defined for each dataset used to construct the CHTD, the hierarchical organization included seven macrohabitats [Upland and Barren (Figure 12), Estuarine (Figure 13), Palustrine (Figure 14), Lacustrine and Riverine (Figure 15), Marine (Figure 16)] with 29 mesohabitats, and 107 microhabitat types. The TESD database was utilized in four macrohabitats (Upland, Estuarine, Palustrine, and Barren), 14 mesohabitat Types, and 66 microhabitat types. TESD microhabitat types provide a comprehensive description of vegetation types within the upland areas and provide complete coverage of the GCPLCC pilot project area. In addition, more coverage is afforded in both the estuarine and wetland areas by filling in with TESD data.

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Upland	Upland Grassland	Coastal and Sandsheet: Deep Sand Grasslands	TESD
		Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	TESD
		Coastal Plain: Terrace Sandyland Grassland	TESD
		Gulf Coast: Coastal Prairie	TESD
		Gulf Coast: Salty Prairie	TESD
		Post Oak Savanna: Savanna Grassland	TESD
		South Texas: Sandy Mesquite Savanna Grassland	TESD
		Texas Coast Dune and Coastal Grassland Active Dune	TESD
	Upland Shrub	Coastal and Sandsheet: Deep Sand Live Oak Shrubland	TESD
		Coastal and Sandsheet: Deep Sand Shrubland	TESD
		Gulf Coast: Salty Shrubland	TESD
		Invasive: Evergreen Shrubland	TESD
		Native Invasive: Baccharis Shrubland	TESD
		Native Invasive: Huisache Woodland or Shrubland	TESD
		Native Invasive: Mesquite Shrubland	TESD
		Non-native Invasive: Saltcedar Shrubland	TESD
		Post Oak Savanna: Live Oak Shrubland	TESD
		South Texas: Clayey Blackbrush Mixed Shrubland	TESD
		South Texas: Clayey Mesquite Mixed Shrubland	TESD
		South Texas: Sandy Mesquite Dense Shrubland	TESD
	Upland Woodland/Shrub	Non-Native Invasive: Chinese Tallow Forest, Woodland, or Shrubland	TESD
		South Texas: Sandy Mesquite Woodland and Shrubland	TESD

Figure 12. Hierarchical organization of the Composite Habitat Type Dataset within the Upland and Barren macrohabitat types developed to access avian habitat coverage and location in the Gulf Coast Prairie Landscape Conservation Cooperative pilot project area (continued).

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Upland	Upland Woodland	Coastal and Sandsheet: Deep Sand Live Oak / Mesquite Woodland	TESD
		Coastal and Sandsheet: Deep Sand Live Oak Forest and Woodland	TESD
		Native Invasive: Deciduous Woodland	TESD
		Post Oak Savanna: Live Oak Motte and Woodland	TESD
		Post Oak Savanna: Live Oak Slope Forest	TESD
		Post Oak Savanna: Oak / Hardwood Slope Forest	TESD
		Post Oak Savanna: Post Oak / Live Oak Motte and Woodland	TESD
		Post Oak Savanna: Post Oak / Live Oak Slope Forest	TESD
		Post Oak Savanna: Post Oak / Yaupon Motte and Woodland	TESD
		Post Oak Savanna: Post Oak Motte and Woodland	TESD
		South Texas: Clayey Live Oak Motte and Woodland	TESD
		South Texas: Sandy Live Oak Motte and Woodland	TESD
		South Texas: Sandy Mesquite / Evergreen Woodland	TESD
	Upland Row Crop	Row Crops	TESD
	Upland Developed	Urban High Intensity	TESD
		Urban Low Intensity	TESD
Barren	Barren	Barren	TESD

Figure 12. Hierarchical organization of the Composite Habitat Type Dataset within the Upland and Barren macrohabitat types (continued).

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Estuarine	Estuarine Unv Flats	Coastal: Beach	TESD
		Coastal: Tidal Flat	TESD
		Estuarine Intertidal Aquatic Bed Reg Fl	NWI
		Estuarine Intertidal Uncons Shore Irreg Exp	NWI
		Estuarine Intertidal Uncons Shore Irreg Fl	NWI
		Estuarine Intertidal Uncons Shore Reg Fl	NWI
		South Texas: Algal Flats	TESD
		South Texas: Wind Tidal Flats	TESD
	Estuarine Veg Marsh	Coastal: Borrichia Flats	TESD
		Coastal: Salt and Brackish High Tidal Marsh	TESD
		Coastal: Salt and Brackish Low Tidal Marsh	TESD
		Estuarine Intertidal Emerg Marsh Irreg Exp	NWI
		Estuarine Intertidal Emerg Marsh Irreg Fl	NWI
		Estuarine Intertidal Emerg Marsh Reg Fl	NWI
	Estuarine Veg Shrub	Coastal: Mangrove Shrubland	TESD
		Coastal: Salt and Brackish High Tidal Shrub Wetland	TESD
		Estuarine Intertidal Scrub-Shrub (blev) Irreg Fl	NWI
		Estuarine Intertidal Scrub-Shrub (blev) Reg Fl	NWI
		Mangroves	BHA
	Estuarine Veg Seagrass	Continuous SRV	BHA
		Estuarine Intertidal Aquatic Bed Irreg Exp	NWI
		Estuarine Subtidal Aquatic Bed	NWI
		Patchy SRV	BHA
	Estuarine Reef	Bivalve Reef	BHA
	Estuarine Open Water	Estuarine Subtidal Unconsolidated Bottom	NWI
		Open Water	BHA

Figure 13. Hierarchical organization of the Composite Habitat Type Dataset within the Estuarine macrohabitat types.

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Palustrine	Palustrine Unveg	Gulf Coast: Coastal Prairie Pondshore	TESD
		Palustrine Uncons Shore Artif/Seas/Temp Fl	NWI
	Palustrine Veg Marsh	Coastal and Sandsheet: Deep Sand Live Oak Swale Marsh	TESD
		Coastal Bend: Floodplain Grassland	TESD
		Coastal Bend: Floodplain Herbaceous Wetland	TESD
		Coastal Bend: Riparian Grassland	TESD
		Coastal Bend: Riparian Herbaceous Wetland	TESD
		Marsh	TESD
		Palustrine Emerg Marsh Intermit Fl	NWI
		Palustrine Emerg Marsh Mix Fl Tidal	NWI
		Palustrine Emerg Marsh Seas Fl	NWI
		Palustrine Emerg Marsh Semiperm Fl	NWI
		Palustrine Emerg Marsh Temp Fl	NWI
		Palustrine Farmed	NWI
	Palustrine Veg Marsh/Veg Shrub	Palustrine Emerg Marsh/Scrub-Shrub (mix) Interm/Tem/Seas Fl	NWI
	Palustrine Veg Shrub/Veg Marsh	Palustrine Scrub-Shrub/Emerg Marsh Mix Temp/Seas/Semiperm Fl	NWI
	Palustrine Veg Shrub	Coastal Bend: Floodplain Deciduous Shrubland	TESD
		Coastal Bend: Floodplain Evergreen Shrubland	TESD
		Coastal Bend: Riparian Deciduous Shrubland	TESD
		Coastal Bend: Riparian Evergreen Shrubland	TESD
		Native Invasive: Common Reed	TESD
	Palustrine Veg Woodland/Veg Shrub	Palustrine Forested/Scrub-Shrub Mix Seas Fl	NWI
		Palustrine Forested/Scrub-Shrub Mix Temp Fl	NWI
		Palustrine Forested/Shrub-Scrub Mix Semiperm Fl	NWI
	Palustrine Veg Woodland	Coastal Bend: Floodplain Hardwood Forest	TESD
		Coastal Bend: Floodplain Live Oak / Hardwood Forest	TESD
		Coastal Bend: Floodplain Live Oak Forest	TESD
		Coastal Bend: Riparian Hardwood Forest	TESD
		Coastal Bend: Riparian Live Oak / Hardwood Forest	TESD
		Coastal Bend: Riparian Live Oak Forest	TESD

Figure 14. Hierarchical organization of the Composite Habitat Type Dataset within the Palustrine MacroHabitat Types.

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Palustrine	Palustrine Veg Aquatic	Palustrine Aquatic Bed Float/Rooted SemiPerm/Perm Fl	NWI
	Palustrine Open Water	Palustrine Uncons Bottom Artif/Sermiperm/Perm Mix Fl	NWI

Figure 14. Hierarchical organization of the Composite Habitat Type Dataset within the Palustrine macrohabitat types (continued).

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Lacustrine	Lake Aquatic Bed	Lacustrine Aquatic Bed Perm Fl	NWI
	Lake Open Water	Lacustrine Uncons Bottom Perm, Semiperm Fl	NWI
	Lake Unv Flats	Lacustrine Uncons Shore Mixed Fl	NWI
Riverine	Riverine Open Water	Riverine Uncons Bottom Perm Fl	NWI
		Riverine Uncons Bottom Perm Fl Tidal	NWI
	Riverine Unveg	Riverine Streambed Seas Fl	NWI

Figure 15. Hierarchical organization of the Composite Habitat Type Dataset within the Lacustrine and Riverine macrohabitat types.

Macrohabitat	Mesohabitat Type	Microhabitat Type	Source
Marine	Marine Open Water	Marine Uncons Bottom	NWI
	Marine Rocky Shore	Marine Intertidal Rocky Shore Rubble Irreg Fl	NWI
	Marine Unv Shore	Marine Intertidal Uncons Shore Irreg Fl	NWI
		Marine Intertidal Uncons Shore Reg Fl	NWI

Figure 16. Hierarchical organization of the Composite Habitat Type Dataset within the Marine macrohabitat types developed to access avian habitat coverage and location in the Gulf Coast Prairie Landscape Conservation Cooperative pilot project area.

The NWI encompassed five of the seven macrohabitats (Riverine, Palustrine, Lacustrine, Estuarine, and Marine) 20 of the mesohabitats, and 38 microhabitat types (reduced from 128 originally). Microhabitat types were useful to differentiate among grouped hydrologic modifiers, and mesohabitat types were used when specifically quantifying areal extent in areas where hydrologic modifers were not consistent (i.e., Estuarine Intertidal Emergent Marsh regularly or irregularly flooded or irregularly exposed). The BHA contributed to Estuarine macrohabitat type, providing updated information on three key microhabitat types: mangrove, seagrass, and bivalve reefs. In addition, coverage of open water areas was completed using spatial information from the BHA data (see Figure 11c).

Once the habitat types from each database were identified for inclusion into the CHTD, the databases were clipped to the extent of their intended use and merged to form a continuous dataset with as complete coverage as possible across the entire study area including benthic, wetland/intertidal, and upland habitats (see Figure 11d). The resulting CHTD includes a combination of 107 habitat types, near-comprehensive coverage over the entire study area, and covers habitat types from subtidal seagrass beds to uplands. This dataset can be queried for generalized habitat type, or for various more detailed modifiers carried over from its parent databases.

A total of 107 microhabitat, 26 mesohabitat, and 7 macrohabitat types encompassed 1,741,337 ac of the GCPLCC pilot project (Table 1). The most abundant macrohabitat type was Upland, comprising about 44% of the total area. The largest mesohabitat within the Upland category was Upland Grassland (47% of Upland), and within Upland Grassland, Gulf Coast: Coastal Prairie was the most abundant microhabitat type (about 40% of the total area). Estuarine was the second most abundant macrohabitat (about 40% of total area) (Table 2). Within the Estuarine macrohabitat, the most extensive mesohabitat by far was Estuarine Open Water (covering about 71% of all Estuarine area), with microhabitat Estuarine Subtidal Unconsolidated Bottom taking up the vast majority of that mesohabitat (94%).

Palustrine Wetland was the third most extensive macrohabitat (11% of total area) (Table 3). Palustrine Wetland mesohabitat type Wetland Vegetated Marsh covered the most Palustrine Wetland area (63%), and the most common microhabitat type within Wetland Vegetated Marsh was Palustrine Emergent Marsh Temporarily Flooded. Palustrine Emergent Marsh, Seasonally Flooded microhabitat type was also quite prevalent (33% of Wetland Vegetated Marsh).

Marine, Lacustrine, Riverine, and Barren macrohabitat comprised the remainder of habitat types within the study area (Table 4). Within Marine, Marine Open Water was the most prevalent mesohabitat (97% of all Marine habitat types), including just a single microhabitat- Marine Unconsolidated Bottom. Marine Unconsolidated Bottom comprises the portion of the Gulf of Mexico as most seaward extent of the study area, excluding the shoreline.

Table 1. Sources, patch number and areal extent of habitat types by Upland macrohabitat type in the Composite Habitat Type Dataset within the pilot project area of the Gulf Coast Prairie Landscape Conservation Cooperative program area.

Macrohabitat Type Mesohabitat Type *Microhabitat Type*	Source *TESD*	*NWI*	*BHA*	*No. Patches*	Total Sum (ac) by Level
Macrohabitat: Upland					**761,799**
Mesohabitat: Upland Developed					28,033
Urban High Intensity	*1*			*903*	*5,700*
Urban Low Intensity	*1*			*2646*	*22,333*
Mesohabitat Type: Upland Grassland					360,242
Coastal and Sandsheet: Deep Sand Grasslands	*1*			*1714*	*39,848*
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	*1*			*786*	*1,873*
Coastal Plain: Terrace Sandyland Grassland	*1*			*70*	*947*
Gulf Coast: Coastal Prairie	*1*			*3302*	*210,801*
Gulf Coast: Salty Prairie	*1*			*1810*	*106,625*
Post Oak Savanna: Savanna Grassland	*1*			*7*	*15*
South Texas: Sandy Mesquite Savanna Grassland	*1*			*8*	*38*
Texas Coast Dune and Coastal Grassland Active Dune	*1*			*49*	*92*
Mesohabitat Type: Upland Row Crop					192,800
Row Crops	*1*			*975*	*192,800*
Mesohabitat Type: Upland Shrub					106,678
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	*1*			*1954*	*20,221*
Coastal and Sandsheet: Deep Sand Shrubland	*1*			*1668*	*4,731*
Gulf Coast: Salty Shrubland	*1*			*1892*	*10,192*
Invasive: Evergreen Shrubland	*1*			*2479*	*15,192*
Native Invasive: Baccharis Shrubland	*1*			*1776*	*5,406*
Native Invasive: Huisache Woodland or Shrubland	*1*			*1252*	*6,963*
Native Invasive: Mesquite Shrubland	*1*			*2611*	*19,327*
Non-native Invasive: Saltcedar Shrubland	*1*			*278*	*463*
Post Oak Savanna: Live Oak Shrubland	*1*			*501*	*4,165*
South Texas: Clayey Blackbrush Mixed Shrubland	*1*			*419*	*1,891*
South Texas: Clayey Mesquite Mixed Shrubland	*1*			*1496*	*17,879*
South Texas: Sandy Mesquite Dense Shrubland	*1*			*120*	*242*
Mesohabitat Type: Upland Woodland					65,812
Coastal and Sandsheet: Deep Sand Live Oak / Mesquite Woodland	*1*			*187*	*313.53*
Coastal and Sandsheet: Deep Sand Live Oak Forest and Woodland	*1*			*1518*	*20,081*
Native Invasive: Deciduous Woodland	*1*			*2992*	*19,448*
Post Oak Savanna: Live Oak Motte and Woodland	*1*			*1742*	*18,369*
Post Oak Savanna: Live Oak Slope Forest	*1*			*6*	*3*

Macrohabitat Type		Source			
Mesohabitat Type				*No.*	Total Sum (ac)
Microhabitat Type	*TESD*	*NWI*	*BHA*	*Patches*	by Level
Post Oak Savanna: Oak / Hardwood Slope Forest	*1*			*5*	*2*
Post Oak Savanna: Post Oak / Live Oak Motte and Woodland	*1*			*62*	*159*
Post Oak Savanna: Post Oak / Live Oak Slope Forest	*1*			*1*	*0.26*
Post Oak Savanna: Post Oak / Yaupon Motte and Woodland	*1*			*26*	*39*
Post Oak Savanna: Post Oak Motte and Woodland	*1*			*193*	*1,242*
South Texas: Clayey Live Oak Motte and Woodland	*1*			*680*	*4,084*
South Texas: Sandy Live Oak Motte and Woodland	*1*			*483*	*1,921*
South Texas: Sandy Mesquite / Evergreen Woodland	*1*			*52*	*147*
Mesohabitat Type: Upland Woodland/Shrub					8,231
Non-Native Invasive: Chinese Tallow Forest, Woodland, or Shrubland	*1*			*643*	*1,976*
South Texas: Sandy Mesquite Woodland and Shrubland	*1*			*853*	*6,255*

Table 2. Sources, patch number and areal extent of habitat types by Estuarine macrohabitat type in the Composite Habitat Type Dataset within the pilot project area of the Gulf Coast Prairie Landscape Conservation Cooperative program area.

Macrohabitat Type Mesohabitat Type *Microhabitat Type*	Source *TESD*	 *NWI*	 *BHA*	*No.* *Patches*	Total Sum (ac) by Level
Macrohabitat Type: Estuarine					**691,419**
Mesohabitat Type: Estuarine Open Water					490,085
Estuarine Subtidal Unconsolidated Bottom		*1*		*4671*	*486,875*
Open Water			*1*	*718*	*3,210*
Mesohabitat: Estuarine Reef[a,b]					6,771[a,b]
Bivalve Reef[a,b]			*1*	*2302*	*6,771*[a,b]
Mesohabitat: Estuarine Unvegetated Flats					31,626
Coastal: Beach	*1*			*43*	*1,039*
Coastal: Tidal Flat	*1*			*1122*	*3,107*
Estuarine Intertidal Aquatic Bed Regularly Flooded		*1*		*299*	*250*
Estuarine Intertidal Unconsolidated Shore Irregularly Exposed		*1*		*1576*	*5,347*
Estuarine Intertidal Unconsolidated Shore Irregularly Flooded		*1*		*2740*	*8,216*
Estuarine Intertidal Unconsolidated Shore Regularly Flooded		*1*		*3029*	*12,968*
South Texas: Algal Flats	*1*			*143*	*257*
South Texas: Wind Tidal Flats	*1*			*126*	*437*
Mesohabitat Type: Estuarine Vegetated Marsh					104,439
Coastal: Borrichia Flats	*1*			*1387*	*6,125*
Coastal: Salt and Brackish High Tidal Marsh	*1*			*3002*	*20,018*
Coastal: Salt and Brackish Low Tidal Marsh	*1*			*1368*	*2,894*
Estuarine Intertidal Emergent Marsh Irregularly Exposed		*1*		*563*	*1,723*
Estuarine Intertidal Emergent Marsh Irregularly Flooded		*1*		*3062*	*30,930*
Estuarine Intertidal EmergentMarsh Regularly Flooded		*1*		*4325*	*42,748*
Mesohabitat Type: Estuarine Vegetated Seagrass[a]					51,980[a]
Continuous Submergent Rooted Vegetation[a]			*1*	*5018*	*34,196*[a]
Estuarine Intertidal Aquatic Bed Irregularly Exposed		*1*		*1087*	*1,373*
Estuarine Subtidal Aquatic Bed		*1*		*548*	*9,474*
Patchy Submergent RootedVegetation[a]			*1*	*9905*	*6,935*[a]
Mesohabitat Type: Estuarine Vegetated Shrub[a]					6,516[a]
Coastal: Mangrove Shrubland	*1*			*46*	*93*
Coastal: Salt and Brackish High Tidal Shrub Wetland	*1*			*803*	*1,373*
Estuarine Intertidal Scrub-Shrub (broad-leaved evergreen) Irregularly Flooded		*1*		*130*	*363*
Estuarine Intertidal Scrub-Shrub (broad-leaved evergreen) Regularly Flooded		*1*		*320*	*401*
Mangroves[a]			*1*	*2514*	*4,285*[a]

[a]does not include Matagorda Bay

[b]does not include Espiritu Santo Bay

Table 3. Sources, patch number and areal extent of habitat types by Palustrine macrohabitat type in the Composite Habitat Type Dataset within the pilot project area of the Gulf Coast Prairie Landscape Conservation Cooperative program area.

Macrohabitat Type Mesohabitat Type *Microhabitat Type*	*TESD*	Source *NWI*	*BHA*	*No. Patches*	Total Sum (ac) by Level
Macrohabitat: Palustrine Wetland					**184,874**
Mesohabitat Type: Wetland Open Water					3,450
Palustrine Unconsolidated Bottom Artificially/Sermipermanently/Permanently Mixed Flooded		*1*		*3002*	*3,450*
Mesohabitat Type: Wetland Unvegetated					4,568
Gulf Coast: Coastal Prairie Pondshore	*1*			*792*	*3,701*
Palustrine Uncons Shore Artificially/Seasonally/Temporarily Flooded		*1*		*492*	*867*
Mesohabitat Type: Wetland Veg Aquatic					693
Palustrine Aquatic Bed Float/Rooted Semipermanently/ Permanently Flooded		*1*		*358*	*693*
Mesohabitat Type: Wetland Veg Marsh					116,852
Coastal and Sandsheet: Deep Sand Live Oak Swale Marsh	*1*			*430*	*1,161*
Coastal Bend: Floodplain Grassland	*1*			*472*	*7,974*
Coastal Bend: Floodplain Herbaceous Wetland	*1*			*409*	*1,925*
Coastal Bend: Riparian Grassland	*1*			*664*	*3,615*
Coastal Bend: Riparian Herbaceous Wetland	*1*			*54*	*73*
Marsh	*1*			*5*	*6*
Palustrine Emergent Marsh Intermittently Flooded		*1*		*327*	*5,920*
Palustrine Emergent Marsh Mix Flooded Tidal		*1*		*65*	*1,205*
Palustrine Emergent Marsh Seasonally Flooded		*1*		*6190*	*38,995*
Palustrine Emergent Marsh Semipermanently Flooded		*1*		*2285*	*5,949*
Palustrine Emergent Marsh Temporarily Flooded		*1*		*5686*	*48,095*
Palustrine Farmed		*1*		*132*	*1,929*
Mesohabitat Type: Wetland Veg Marsh/Vegetated Shrub					6,482
Palustrine Emergent Marsh/Scrub-Shrub (mix) Intermittent /Temporarily/Seasonally Flooded		*1*		*437*	*6,482*
Mesohabitat Type: Wetland Veg Shrub					17,652
Coastal Bend: Floodplain Deciduous Shrubland	*1*			*696*	*2,907*
Coastal Bend: Floodplain Evergreen Shrubland	*1*			*463*	*1,070*
Coastal Bend: Riparian Deciduous Shrubland	*1*			*285*	*479*
Coastal Bend: Riparian Evergreen Shrubland	*1*			*159*	*230*
Native Invasive: Common Reed	*1*			*1504*	*12,965*
Mesohabitat Type: Wetland Veg Shrub/Vegetated Marsh					1,278
Palustrine Scrub-Shrub/Emergent Marsh Mix Temporarily/ Seasonally/Semipermanently Flooded		*1*		*134*	*1,278*
Mesohabitat Type: Wetland Vegetated Woodland					15,661

Macrohabitat Type Mesohabitat Type *Microhabitat Type*	Source *TESD*	 *NWI*	 *BHA*	*No.* *Patches*	Total Sum (ac) by Level
Coastal Bend: Floodplain Hardwood Forest	*1*			*769*	*9,890*
Coastal Bend: Floodplain Live Oak / Hardwood Forest	*1*			*720*	*2,612*
Coastal Bend: Floodplain Live Oak Forest	*1*			*609*	*1,911*
Coastal Bend: Riparian Hardwood Forest	*1*			*373*	*777*
Coastal Bend: Riparian Live Oak / Hardwood Forest	*1*			*108*	*131*
Coastal Bend: Riparian Live Oak Forest	*1*			*189*	*337*
Mesohabitat Type: Wetland Vegetated Woodland/ Vegetated Shrub					18,233
Palustrine Forested/Scrub-Shrub Mix Seasonally Flooded		*1*		*388*	*3,294*
Palustrine Forested/Scrub-Shrub Mix Temporarily Flooded		*1*		*1279*	*14,365*
Palustrine Forested/Shrub-Scrub Mix Semipermanently Flooded		*1*		*73*	*573*

Table 4. Sources, patch number and areal extent of habitat types by Marine, Lacustrine, Riverine, and Barren macrohabitat types within the Composite Habitat Type Dataset within the pilot project area of the Gulf Coast Prairie Landscape Conservation Cooperative program area.

Macrohabitat Type Mesohabitat Type *Microhabitat Type*	Source *TESD*	 *NWI*	 *BHA*	*No. Patches*	Total Sum (ac) by Level
Macrohabitat: Marine					80,668
Mesohabitat Type: Marine Open Water					78,244
Marine Unconsolidated Bottom		*1*		*2*	*78,244*
Mesohabitat Type: Marine Rocky Shore					7
Marine Intertidal Rocky Shore Rubble Irregularly Flooded		*1*		*2*	*7*
Mesohabitat Type: Marine Unvegetated Shore					2,416
Marine Intertidal Unconsolidated Shore Regularly Flooded		*1*		*12*	*517*
Marine Intertidal Unconsolidated Shore Irregularly Flooded		*1*		*6*	*1,899*
Macrohabitat: Lacustrine					*18,657*
Mesohabitat: Lake Aquatic Bed					1,362
Lacustrine Aquatic Bed Permanently Flooded		*1*		*24*	*1,362*
Mesohabitat Type: Lake Open Water					15,089
Lacustrine Unconsolidated Bottom Permanently, Semipermanently Flooded		*1*		*81*	*15,089*
Mesohabitat Type: Lake Unvegetated Flats					2,205
Lacustrine Unconsolidated Shore Mixed Flooded		*1*		*35*	*2,205*
Macrohabitat: Riverine					**2,744**
Mesohabitat Type: Riverine Open Water					2,690
Riverine Unconsolidated Bottom Permanently Flooded		*1*		*35*	*2,116*
Riverine Unconsolidated Bottom Permanently Flooded Tidal		*1*		*10*	*574*
Mesohabitat Type: Riverine Unvegetated					53
Macrohabitat Type: Barren					1,172
Mesohabitat Type: Barren					1,172
Barren	1			340	1,172
Riverine Streambed Seasonally Flooded		*1*		*7*	*53*

[a]does not include Matagorda Bay

[b]does not include Espiritu Santo Bay

Within Lacustrine mesohabitat Lake Open Water (1.1% of total area), the microhabitat Lacustrine Unconsolidated Bottom Permanently and Semipermanently Flooded (81%) was most prevalent. Again, this result would be expected, as the other microhabitat types refer to aquatic beds and unvegetated flats within the Lacustrine environment.

The vast majority of the Riverine macrohabitat (0.16% of total area) was classified as belonging to the Riverine Open Water mesohabitat (98% of Riverine habitat types), and specifically the microhabitat Riverine Unconsolidated Bottom Permanently Flooded (78% of Riverine Open Water). Lastly, the Barren classification (macro-, meso-, and microhabitat level) was the least prevalent habitat type classification, consisting of less than 1% of the total study area (0.067%).

Objective 2 Current Conservation Needs for Whooping Crane

Whooping Crane Habitat Selection

A total of 6,492 data points, representing 15,112 Whooping Cranes, were used to determine habitat type selection of Whooping Crane in their wintering grounds in the San Antonio Bay system (Figure 17). The large amount of information available for depicting Whooping Crane habitat use patterns allowed us to quantify not only habitat use but also habitat selection. Habitat selection of Whooping Crane was determined with an overlay analysis approach and provided a spatial linkage and quantification between the Whooping Crane census data from 2004-2010 to CHTD habitat type use categories within the LCC project area. Frequency and relative frequency values calculated between crane locations and mesohabitat data were ranked to the Habitat Use levels (Table 5). High use habitats covered 104,438 ac, low use 54,468 ac, and incidental use 531,881 ac. About 50% of crane observations occurred in High Use habitats, which is the value we will further evaluate for assessing conservation success in the pilot project area. This method provided the quantitative information to develop the current potential habitat map at three levels of use within the LCC project area (Figure 18). Based on the habitat selection definitions this is considered a third-order habitat selection process.

In the model, the third order habitat selection depicted from Whooping Crane survey points indicates that this species is selecting the Estuarine Vegetated Marsh mesohabitat type as its primary winter habitat. The potential habitat type map provides the coverage of those habitat types throughout the pilot project area. The habitat types defined as High Use include macrohabitat Estuarine, mesohabitat Estuarine Vegetated Marsh, and microhabitat types covering Intertidal Emergent Marsh regularly and irregularly flooded and irregularly exposed. As the Whooping Crane population continues to increase it is very likely that those areas of potential high use (highlighted in purple, Fig. 18) will be occupied by new territorial breeding pairs. As young have shown high fidelity to their first winter territory, the area most likely to be used the earliest will be those in close proximity to the current wintering range (Stehn and Johnson 1987). Potential high use is limited to fringing estuarine vegetated marshes along the lee side of barrier islands and surrounding peninsulas, as well as in coastal river deltas. Low use areas encompass similar areas, defining shallow Estuarine Open Water (unvegetated coastal ponds, tidal creeks, and flats) within the estuarine marsh mosaic. Incidental use broadly covers the upland landscape encompassing fringing shorelines, palustrine marshes and excavated tanks, and grassland/shrubland.

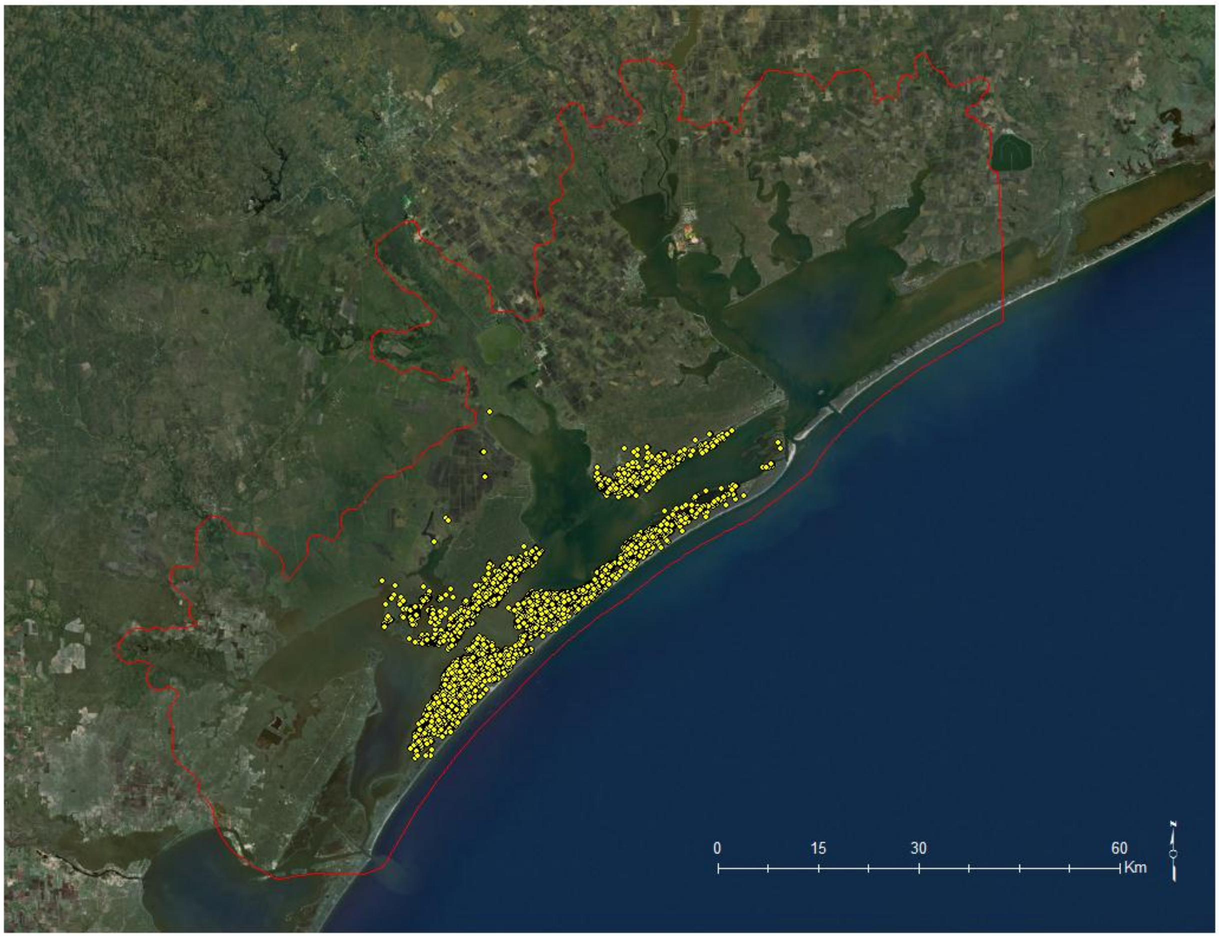


Figure 17. Representation of Whooping Crane locations collected from aerial surveys from winter 2004-2005 through 2010-2011 within the project area.

Table 5. Potential Use Index (3 – High, 2 – Low, 1 – Incidental) at mesohabitat level for Whooping Crane derived by linking habitat data at micro-, meso-, and macrohabitat levels to Whooping Crane census (2004-2010). Potential microhabitat availability is presented by patch number and extent in pilot project area.

Microhabitat	Patch #	Extent (Acres)	Cranes #	Mesohabitat	Macrohabitat	Micro-habitat Use (Rel Freq)	Meso-habitat Use (Rel Freq)	Use Index
Estuarine Intertidal Emergent Marsh Regularly Flooded	4325	42,748	5908	Estuarine Vegetated Marsh	Estuarine	39.09	50.4	3
Estuarine Intertidal Emergent Marsh Irregularly Flooded	3062	30,930	901	“	“	5.96		
Estuarine Intertidal Emergent Marsh Irregularly Exposed	563	1,723	425	“	“	2.81		
Coastal: Salt and Brackish High Tidal Marsh	3002	20,018	224	“	“	1.48		
Coastal: Salt and Brackish Low Tidal Marsh	1368	2,894	94	“	“	0.62		
Coastal: Borrichia Flats	1387	6,125	61			0.40		
Estuarine Subtidal Unconsolidated Bottom	4665	88,067	2518	Estuarine Open Water	Estuarine	16.82	16.9	2
Open Water	717	3,176	18	“	“	0.12		
Continuous Submerged Root Vegetation[a]	5018	34,196	864	Estuarine Vegetated Seagrass	Estuarine	5.72	13.0	2
Estuarine Subtidal Aquatic Bed	539	8,788	762	“	“	5.04		
Estuarine Intertidal Aquatic Bed Irregularly Exposed	1087	1,373	217	“	“	1.44		
Patchy Submerged Root Vegetation[a]	9905	6,935	119	“	“	0.79		
Estuarine Intertidal Unconsolidated Shore Regularly Flooded	3029	12,968	643	Estuarine Unvegetated Flats	Estuarine	4.25	8.2	1
Estuarine Intertidal Unconsolidated Shore Irregularly Exposed	1576	5,347	349	“	“	2.31		
Estuarine Intertidal Unconsolidated Shore Irregularly Flooded	2740	8,216	156	“	“	1.03		
Estuarine Intertidal Aquatic Bed Regularly Flooded	299	250	71	“	“	0.47		
South Texas: Algal Flats	143	258	22	“	“	0.15		
Coastal: Tidal Flat	1122	3,107	5			0.03		
Coastal and Sandsheet: Deep Sand Grasslands	1714	39,848	561	Upland Grassland	Upland	3.71	5.7	1
Gulf Coast: Salty Prairie	1810	106,625	232	“	“	1.54		

“ “

“ “

Microhabitat	Patch #	Extent (Acres)	Cranes #	Mesohabitat	Macrohabitat	Micro-habitat Use (Rel Freq)	Meso-habitat Use (Rel Freq)	Use Index
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	786	1,873	66	Upland Grassland	Upland	0.44		
Gulf Coast: Coastal Prairie	3302	210,801	7	“	“	0.05		
Palustrine Emergent Marsh Temp Flooded	5686	48,095	278	Wetland Vegetated Marsh	Freshwater Wetland	1.84	2.8	1
Palustrine Emergent Marsh Seas Flooded	6190	38,995	104	“	“	0.69		
Palustrine Emergent Marsh Semipermanently Flooded	2285	5,949	25	“	“	0.17		
Palustrine Emergent Marsh Intermit Flooded	327	5,920	12	“	“	0.08		
Coastal and Sandsheet: Deep Sand Live Oak Swale Marsh	786	1,873	5	“	“	0.03		
Palustrine Emergent Marsh Mix Flooded Tidal	65	1,205	3	“	“	0.02		
Coastal and Sandsheet: Deep Sand Shrubland	1668	4,731	105	Upland Shrub	Upland	0.69	1.5	1
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	1954	20,221	96	“	“	0.64		
Native Invasive: Baccharis Shrubland	1776	5,407	20	“	“	0.13		
Gulf Coast: Salty Shrubland	1892	10,192	2	“	“	0.01		
Native Invasive: Common Reed	1504	12,965	35	Wetland Vegetated Shrub	Freshwater Wetland	0.23	0.23	0
Coastal and Sandsheet: Deep Sand Live Oak Forest and Woodland	1518	20,081	15	Upland Woodland	Upland	0.10	0.10	0
Mangroves[a]	2514	4,285	11	Estuarine Vegetated Shrub	Estuarine	0.07	0.09	0
Estuarine Intertidal Scrub-Shrub (broad-leaved evergreen) Irregularly Flooded	130	363	3	“	“	0.02		
Palustrine Unconsolidated Bottom Artificially/Sermiperm-anently/Permanently Mixed Flooded	3002	3,450	10	Wetland Open Water	Freshwater Wetland	0.07	0.07	0
Bivalve Reef[a]	2302	6,771	10	Estuarine Reef	Estuarine	0.07	0.07	0
Palustrine Forested/Scrub-Shrub Mix Temporarily Flooded	1279	14,365	4	Wetland Vegetated Woodland/ Vegetated Shrub	Freshwater Wetland	0.03	0.03	0

Microhabitat	Patch #	Extent (Acres)	Cranes #	Mesohabitat	Macrohabitat	Micro-habitat Use (Rel Freq)	Meso-habitat Use (Rel Freq)	Use Index
Palustrine Unconsolidated Shore Artificially/Seasonally/ Temporarily Flooded	492	867	3	Wetland Unvegetated	Freshwater Wetland	0.02	0.02	0
Palustrine Aquatic Bed Float/Rooted Semipermanently/ Permanently Flooded	358	694	3	Wetland Vegetated Aquatic	Freshwater Wetland	0.02	0.02	0
Palustrine Emergent Marsh/Scrub-Shrub (mix) Intermittent/Temporarily/ Seasonally Flooded	437	6,482	3	Wetland Vegetated Marsh/ Vegetated Shrub	Freshwater Wetland	0.02	0.02	0

[a] Incomplete coverage

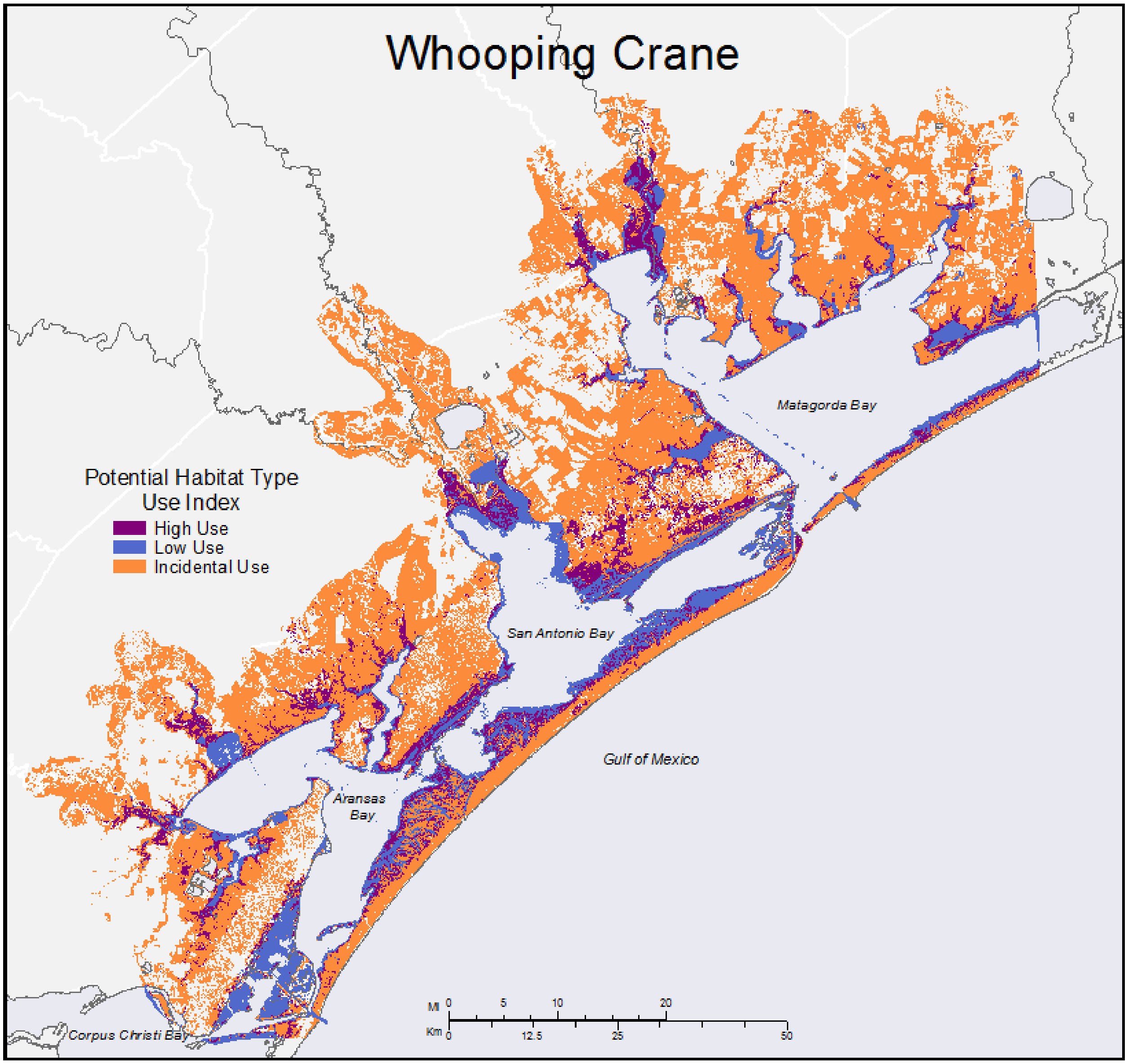


Figure 18. Distribution of potential Whooping Crane habitat type use in the LCC project area, under current conditions.

Objective 3 Selected Avian Species

Additional Coastal Avian Species

As a result of stakeholder workshops and project team assessment a total of 25 avian species were selected for inclusion in our analysis that encompassed the following habitat types: grassland savannah birds (4 species), grassland birds (3 species), palustrine wetland (4 species), shore and bare ground birds (4 species), salt marsh (3 species), estuarine open water (shallow) (6 species) and estuarine reef (1 species) (Table 6). Priority for conservation can be evaluated at many different levels and may include more than one criterion. If the priority involves identifying species that are totally dependent on habitat types within the pilot project area, then one species, the Whooping Crane, fits this criterion. Two species, White-tailed Hawk and Mottled Duck, are partially dependent and one species, Aplomado Falcon, has been reintroduced into the area. Thirteen species are present year round, nine species in winter only, two species pass through on migration, and one species has individuals that are present year round with some only during winter. Population numbers of eleven species are decreasing, five species are stable, six species are increasing, two species are fluctuating, and one species' population trend is unknown. Two species are currently listed as endangered, one species threatened, one species highly imperiled, and twelve species under concern. Twenty-four species are negatively affected by some form of habitat change (e.g., loss, modification, alteration, fragmentation) and one species by high predation rates. Eighteen species are included in at least one conservation plan during some portion of their overall range.

The data available for most species relevant to our study area was primarily a distributional type or first order habitat selection level. That is, the study area is known to be within the species distribution range at least during a portion of one or more phases of their yearly life cycle. There were no species, besides the Whooping Crane, with quantitative data from which to determine habitat selection below a second order level. That is there is no information available on the dispersion patterns in the landscape within our project area to define habitat selection patterns based on the CHTD. However, there was nesting location data for the reintroduced Aplomado Falcon population which were used to help refine the habitat type use index. Habitat types with greater than 50% of nests were considered high use (index 3), those with >10% and < 50% nest location were considered low use (index 2). For all other species we used published descriptions of habitat use. For all selected species we used expert opinion and personal experience to define a theoretical third order selection process based on using a habitat use index approach.

Habitat descriptions for all species were found in different literature sources, however, in most cases it was not possible to equate the habitat definition or description from literature sources to the specific mesohabitat or microhabitat type classes as defined by the CHTD land cover classification schemes we used, but primarily to the macrohabitat type level. The primary reason for this difference is that in most cases bird habitats can be defined from a functional

Table 6. Summary of selected coastal avian species whose habitat use was delineated in LCC project area.

Species	Range Within Project area	Resident Status	Population Trend	Conservation Status	Conservation Issues	Conservation Plan[a]
Grassland Savannah						
Aplomado Falcon	inclusive	year round	increasing	Endangered/ introduced	high predation rates	AFRP
White-tailed hawk	Partial	year round	Stable to increasing		Habitat loss	
Loggerhead Shrike	marginal	Year round/ winter	decreasing	concern	Habitat loss	PIF and GCJV landbird
Northern Bobwhite	marginal	year round	decreasing		habitat modifications	PIF and GCJV Landbird
Grassland						
Upland Sandpiper	marginal	Migratory	stable to decreasing		habitat loss	
Le Conte's Sparrow	marginal	Winter	stable to increasing	concern	habitat fragmentation	PIF Landbird, GCJV
Long-billed Curlew	marginal	Winter	deceasing	highly imperiled	habitat loss	USSCP (HI), GCJV-fall
Palustrine wetland						
Black Rail	marginal	Winter	decreasing	concern	habitat loss	GCJV, NAWCP (HC)
Northern Pintail	marginal	Winter	fluctuating		habitat alteration	GCJV
Mottled Duck	Partial	year round	stable to decreasing	concern	habitat alteration	GCJV-MDCP, USFWS
Little Blue Heron	marginal	year round	decreasing	concern	habitat loss	GCJV
Shore and Bare Ground						
Western Sandpiper	marginal	Winter	stable		habitat alteration	GCJV-fall
Hudsonian Godwit	marginal	Migratory	stable		habitat alteration	USSCP (HC), GCJV-fall
Wilson's Plover	marginal	Winter	decreasing	concern	habitat loss	USSCP(HC), GCJV-fall
Piping Plover	marginal	Winter	decreasing	threatened	habitat alteration	PPRP, USSCP (HI),
Salt Marsh						
Whooping Crane	inclusive	Winter	increasing	endangered	habitat alteration	WCRP

Species	Range Within Project area	Resident Status	Population Trend	Conservation Status	Conservation Issues	Conservation Plan[a]
Clapper rail	marginal	year round	unknown?	concern	habitat loss/ fragmentation	
Seaside Sparrow	marginal	year round	decreasing	concern	habitat loss	PIF and GCJV Landbird
Estuarine Open Water (shallow)						
Tricolored Heron	marginal	year round	increasing		habitat alteration	
Reddish Egret	marginal	year round	stable	concern	habitat alteration	PIF and GCJV Landbird, REEG CAP
Sandwich Tern	marginal	year round	stable to increasing		habitat alteration	
Royal Tern	marginal	year round	stable		habitat alteration	
Black Skimmer	marginal	year round	decreasing	concern	habitat loss	GCJV
Redhead	marginal	Winter	stable Fluctuating	concern	habitat loss	GCJV
Estuarine Reef						
American Oystercatcher	marginal	year round	stable	concern	habitat alteration	USSCP (HC)

[a]APRP = Aplomado Falcon Recovery Plan; PIF = Partners in Flight; GCJV = Gulf Coast Joint Venture; USSCP = US Shorebird Conservation Plan; NAWCP = North American Waterfowl Conservation Plan; GCJV-MDCP = Mottled Duck Conservation Plan; WCRP = Whooping Crane Recovery Plan.

perspective while land cover classes are primarily classified from a geo-physical and or plant physiognomy perspective.

Species Accounts

A brief species account was developed for all species that included a potential habitat type use summary table and a current conservation map depicting the distribution of the potential habitat type use. Most species did not have significant spatial information that could be used to evaluate management and conservation strategies. However, this information on potential habitat use information is not depicted in general range maps. Therefore, we created species account maps and information for each species selected by stakeholders in Appendix B, and used the following species as examples of spatial assessment of potential habitat use and conservation strategies.

A distribution map of the species for North America, from the Birds of North America accounts, is presented as in inset in the current conservation map, in an effort to represent the species entire range relative to our project area. The distribution maps depict whether the species is year round, summer, or winter resident or if it only migrates through our project area. When evaluating potential impacts of sea level rise on species or species population the extent to which the species relies on or is limited by its use of coastal edge habitat types will determine the likely severity of effects. The species descriptions include any conservation or management plan where the species is listed as of interest or concern. It was from the management and conservation plans where we obtained management patch sizes proposed for some species and depicted in additional maps where appropriate.

The habitat type availability and potential use index table represents a summary of potential habitat use by the species within our project area. The number of microhabitat patches and their extent within our project area are represented, as well as to which meso- and macrohabitat category each microhabitat belongs to. As not all microhabitats are used to the same extent by a species, the index represents the actual or theoretical expected use of the different microhabitats by the species categorized as high use (3), low use (2), and incidental use (1). In the case of some species there was insufficient information to determine differential use of microhabitat to develop a habitat use index for that species and therefore the index value for all microhabitats potentially used were assigned the intermediate value of 2. For species with known minimum patch size requirements or for those where a minimum management patch size is suggested an additional table summarizing the number of patches and their extent is presented.

Current conservation maps are a visual representation of the habitat type availability and potential use index table. The maps represent the location and extent of the different microhabitats potentially used by the species within our project area. They also identify areas of high use microhabitats, low use and incidental use. For a few species, as described in methods, we developed an additional map to depict potential habitat type availability and use under different conditions such as distance from wooded patches (Aplomado Falcon), or only patches of a minimum size (Le Conte’s and Seaside Sparrow) etc. For those species with known minimum patch size requirements or for those where a management patch size is recommended a separate map was generated highlighting the appropriate patches in green. These patches can consist of any microhabitat types categorized as high and low use by the species. Incidental use indexed microhabitat types are not included in the estimation of patches as they are not considered to be primary areas of distribution and or use. Only patches equal to or greater than the minimum patch size recommendations are included in the final maps.

In the case of Piping Plover and American Oystercatcher (Appendix B) we present additional maps to show a close-up of a portion of the project area. Because the patches used by these species are small in our CHTD and sometimes linear they are difficult to observe in our maps covering the entire project area. The additional close-up maps give a better idea and represent the potential habitat use information in a more realistic fashion. In the case of the American Oystercatcher (Appendix B), it must be kept in mind that the oyster reefs are not mapped for our entire project area and therefore acreage estimates and actual representation on the map are conservative estimates of actual potential habitat available.

To determine what specific changes the predicted land cover habitat types might have for a species or population in the future we need to understand issues related to the species distribution and dispersion patterns in the landscape. So we searched for variables such as density, territory size, and social behavior to gain insight into the different species dispersion patterns on the landscape. To consider the possible effect of habitat type patch size and potential landscape fragmentation we attempted to find information on the species minimum patch size if available. Knowing the minimum patch can allow us to determine which patch size could be considered potential habitat in the future and which patches of potentially suitable habitat types are too small to be utilized by a species. It is not known if the salt marsh dependent species such as Seaside Sparrow have a biological minimum patch size requirement. However, in some cases and for some species, management and conservation plans call for a patch size to be considered from a management perspective and we have used this management patch size to depict those patches in some of the species maps.

Aplomado Falcon

The Aplomado Falcon population in our study area is the result of reintroduction efforts conducted in the area over many years. However, there is now a nesting population in the area. This species is a grassland-savannah specialist and the habitat use index ranks depict that (Table 7, Figure 19). The high use habitat types (359,188 ac) in the project area for Aplomado Falcon included coastal and salty prairies. To a lesser extent several shrubland habitat types are considered of low (133,827 ac) and intermittent use (19,924 ac). Over 70% (102) of the nest sites were located within Coastal and Sandsheet: Deep Sand Grasslands. While significant potential high and low use habitat is available in the project area (Figure 19), because proximity (within 1 mile) to a wooded area is considered detrimental due to predation, the actual potential area available is reduced by more than 90% (Table 8, Figure 20). This is an extreme example of how a large proportion of potentially usable habitat becomes unsuitable due to a biological limitation. High use habitats using the 1-mi buffer scenario covered 41,754 ac, low use 9,478 ac, with all incidental use habitat types removed from area.

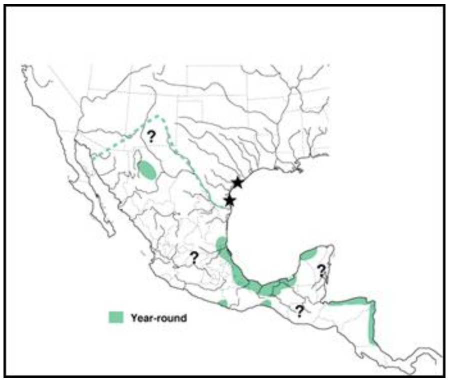
The Aplomado's range is primarily south starting in Mexico to South America. In the US the species occurs naturally in west Texas. In the project pilot area, this species is been reintroduced, but has been able to persist along Matagorda Island primarily. A savannah and grassland specialist, it occupies the coastal prairie and shrubland (Figure 19). Because of predation from Great Horned Owl it does better at least 1 mi from wooded areas (Figure 20). The Aplomado Falcon Recovery Plan outlines the approach to downlist/delist this species.

Table 7. Habitat type availability and potential use index for Aplomado Falcon (no buffer).

Microhabitat	Patch #	Mesohabitat	Macrohabitat	Extent (acres)	Index
Gulf Coast: Coastal Prairie	3,302	Upland Grassland	Upland	210,802.2	3
Gulf Coast: Salty Prairie	1,810	Upland Grassland	Upland	106,625.4	3
Coastal and Sandsheet: Deep Sand Grasslands	1,714	Upland Grassland	Upland	39,848.6	3
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	786	Upland Grassland	Upland	1,873.1	3
South Texas: Sandy Mesquite Savanna Grassland	8	Upland Grassland	Upland	38.6	3
Coastal: Salt and Brackish High Tidal Marsh	3,002	Estuarine Vegetated Marsh	Estuarine	20,018.4	2
Palustrine Emergent Marsh Temp Flooded	5,686	Palustrine Vegetated Marsh	Freshwater Wetland	48,095.4	2
Native Invasive: Common Reed	1,504	Palustrine Vegetated Shrub	Freshwater Wetland	12,965.3	2
Urban Low Intensity	2,646	Upland Developed	Upland	22,333.4	2
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	1,954	Upland Shrub	Upland	20,221.8	2
Gulf Coast: Salty Shrubland	1,892	Upland Shrub	Upland	10,193.0	2
Invasive: Evergreen Shrubland	2,479	Upland Shrub	Upland	15,192.2	1
Coastal and Sandsheet: Deep Sand Shrubland	1,668	Upland Shrub	Upland	4,731.4	1

Table 8. Habitat type availability and potential use index for Aplomado Falcon >1.0 mi from wooded habitat types.

Microhabitat	Patch #	Mesohabitat	Macrohabitat	Extent (ac)	Index
Coastal and Sandsheet: Deep Sand Grasslands	150	Upland Grassland	Upland	11,497.3	3
Gulf Coast: Coastal Prairie	135	Upland Grassland	Upland	12,601.9	3
Gulf Coast: Salty Prairie	415	Upland Grassland	Upland	17,654.8	3
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	110	Upland Shrub	Upland	705.5	2
Coastal and Sandsheet: Deep Sand Shrubland	146	Upland Shrub	Upland	1,243.1	2
Coastal: Salt and Brackish High Tidal Marsh	786	Estuarine Vegetated Marsh	Estuarine	3,257.6	2
Gulf Coast: Salty Shrubland	147	Upland Shrub	Upland	473.0	2
Invasive: Evergreen Shrubland	15	Upland Shrub	Upland	58.7	2
Native Invasive: Common Reed	116	Palustrine Vegetated Shrub	Freshwater Wetland	559.9	2
Palustrine Emerg Marsh Temp Flooded	448	Palustrine Vegetated Marsh	Freshwater Wetland	2,676.1	2
Urban Low Intensity	125	Upland Developed	Upland	503.9	2



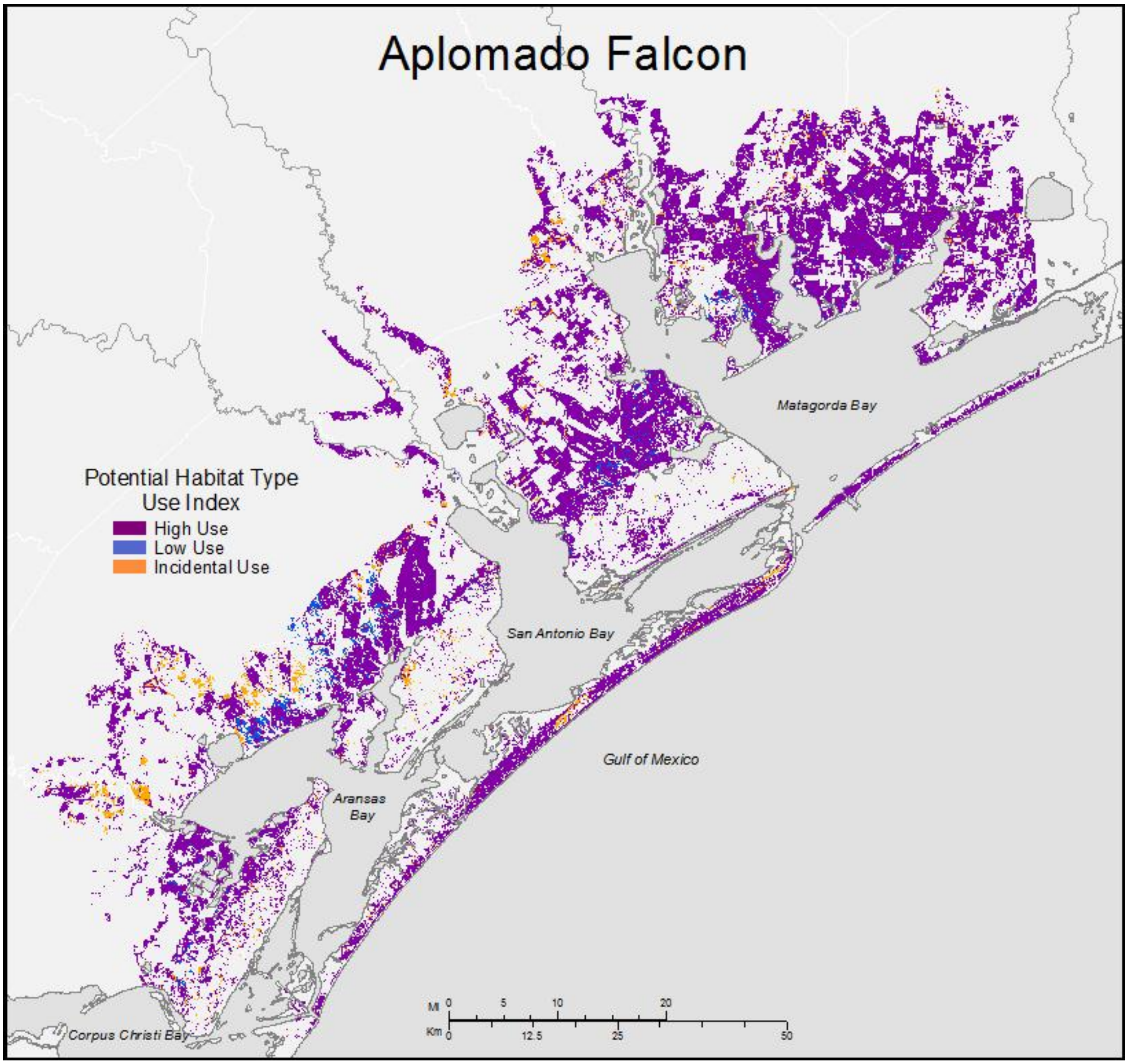


Figure 19. Current conservation map based on potential habitat use and habitat type availablity within the project area for Aplomado Falcon. All suitable habitat types are shown regardless of distance from wood areas.

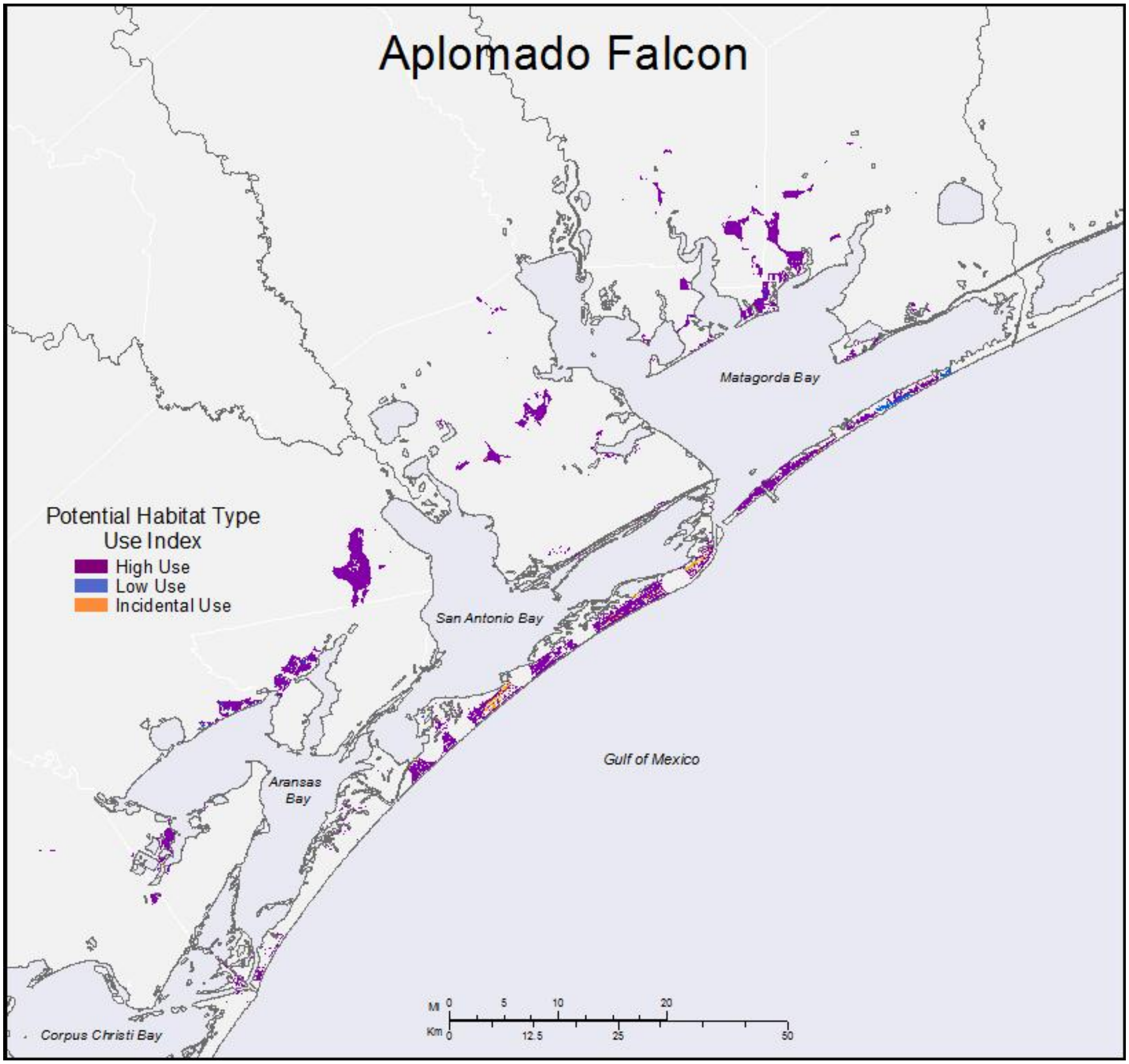


Figure 20. Current conservation map based on potential habitat use and habitat type availablity greater than 1 mile from wooded areas within the project area for Aplomado Falcon.

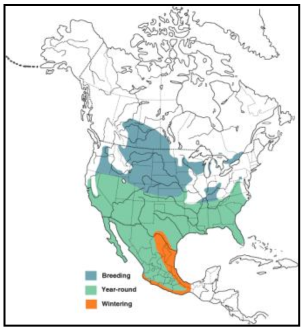
Loggerhead Shrike

Loggerhead Shrikes in the project area consist of both nesting residents and wintering migrants. While the species is decling rangewide some areas of Texas still maintain significant numbers, particularly in the winter. Shrikes use a wide range of habitat types including grasslands with woody structure to urban and suburban parks and significant acreages of high (51,244 ac), low (278,832 ac) and incidental (92,076 ac) use habitat types are present in the project area (Table 9, Figure 21). If we assume 19.8 (8 ha) territory size for resident birds as many as 16,771 territories are potential within the acreage of high and low uses habitat types. If we assume 5 acre (2 ha) as an average territory size, as is suggested for wintering migrants (GCJV landbird plan), more than 66,415 territories are possible. However, the interaction between resident and migratory birds is not clear and so it is not known if territory size for resident birds become smaller or shift during the non-breeding season when wintering birds arrive.

Loggerhead Shrikes are a widespread species found throughout the US and Canada; in the pilot project area, this species both year-round breeding resident and winter migrant. Many northern breeding birds migrate and spend the winter months overlapping with resident birds. Shrikes use a variety of open grassland habitats with scattered perches, including urban parks, roadsides, and different grasslands and savannahs (Figure 21). Not a coastal dependent species but found in high densities in coastal and salty prairies. The Loggerhead Shrike is included as a species of concern, USFWS, PIF and GCJV landbird programs.

Table 9. Habitat type availability and potential use index for Loggerhead Shrike.

Microhabitat	Patch #	Mesohabitat	Macrohabitat	Extent (acres)	Index
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	1,954	Upland Shrub	Upland	20,221.80	3
Native Invasive: Mesquite Shrubland	2,611	Upland Shrub	Upland	19,327.20	3
Native Invasive: Huisache Woodland or Shrubland	1,252	Upland Shrub	Upland	6963.6	3
Coastal and Sandsheet: Deep Sand Shrubland	1,668	Upland Shrub	Upland	4,731.40	3
Coastal Bend: Floodplain Deciduous Shrubland	696	Palustrine Vegetated Shrub	Freshwater Wetland	2,907.40	2
Coastal Bend: Floodplain Evergreen Shrubland	463	Palustrine Vegetated Shrub	Freshwater Wetland	1,070.30	2
Urban Low Intensity	2,646	Upland Developed	Upland	22,333.30	2
Gulf Coast: Coastal Prairie	3,302	Upland Grassland	Upland	210,801.40	2
Coastal and Sandsheet: Deep Sand Grasslands	1,714	Upland Grassland	Upland	39,848.40	2
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	786	Upland Grassland	Upland	1,873.10	2
Palustrine Emerg Marsh Temp Flooded	5,686	Palustrine Vegetated Marsh	Freshwater Wetland	48,095.20	1
Palustrine Emerg Marsh Intermit Flooded	327	Palustrine Vegetated Marsh	Freshwater Wetland	5,920.10	1
Gulf Coast: Salty Prairie	1,810	Upland Grassland	Upland	106,625	1
South Texas: Sandy Mesquite Savanna Grassland	8	Upland Grassland	Upland	38.6	1
Invasive: Evergreen Shrubland	2,479	Upland Shrub	Upland	15,192.10	1
Gulf Coast: Salty Shrubland	1,892	Upland Shrub	Upland	10,192.90	1
Non-Native Invasive: Chinese Tallow Forest, Woodland, or Shrubland	643	Upland Woodland/Shrub	Upland	1,976.10	1



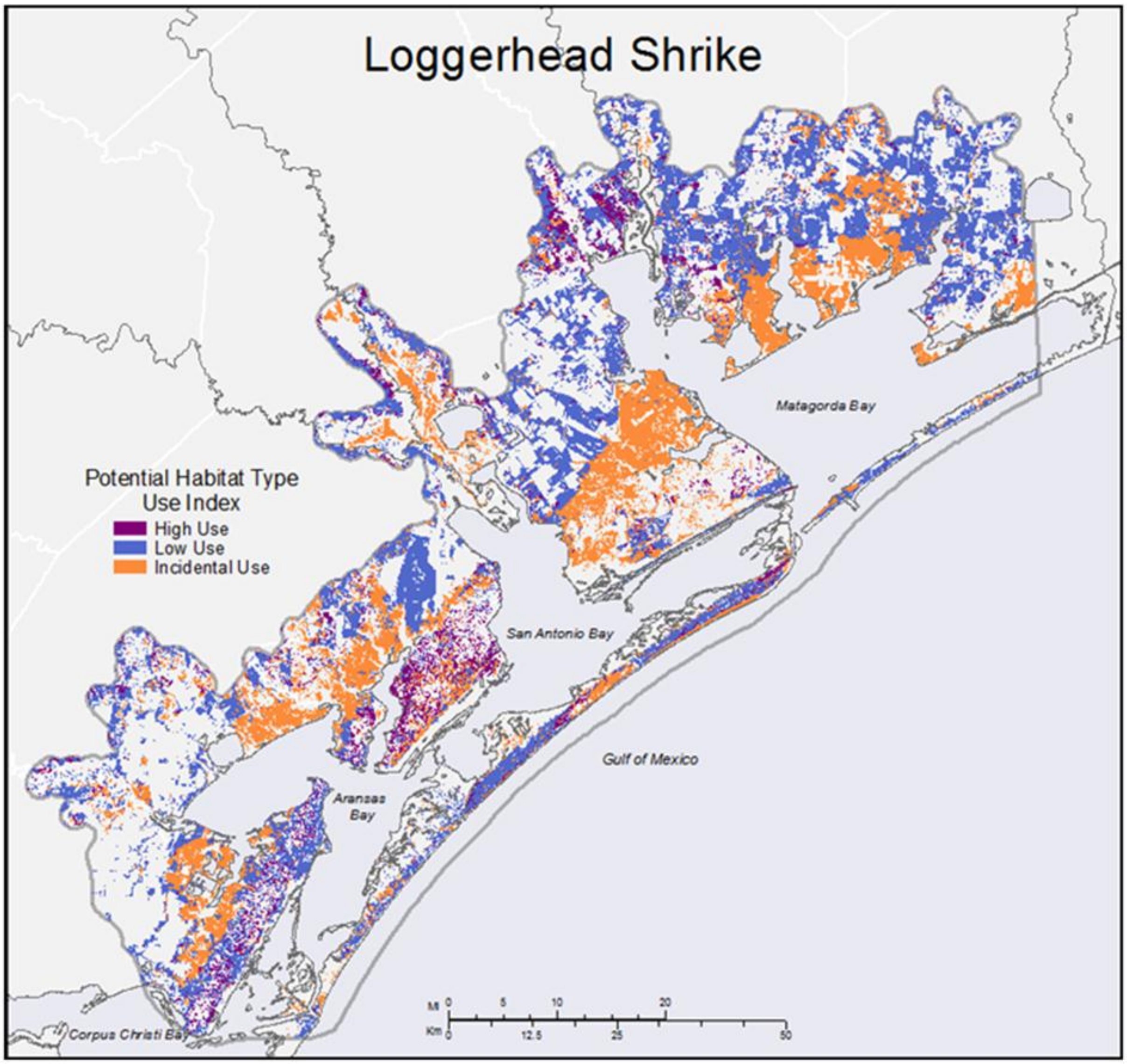


Figure 21. Current conservation map based on potential habitat use and habitat type availability within the project area for Loggerhead Shrike.

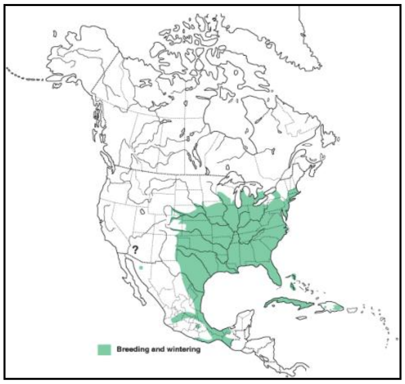
Northern Bobwhite

The Northern Bobwhite quail is a common year-round resident of the project area. It is a ground-dwelling species which only rarely takes flight. It occupies a wide range of habitat types, including most grassland and shrubland habitat types (Table 10, Figure 22). High use habitats covered 357,424 ac, low use 38,663 ac, and incidental use 197,965 ac. Varying densities occur depending on the local conditions and management of specific sites. The Northern Bobwhite can reach high densities in the region so it would be possible to support 1 quail per ac in the project area in most habitat types (Anderson pers. comm.) which would mean 396,087 potential quail in acreages of the high and low use habitat types. However, the presence and density of quail in an area is highly dependent on local conditions and can vary greatly from year to year depending on weather conditions and management of a site.

The Northern Bobwhite is a common ground-dwelling bird of the southeastern US and northern Mexico. It is nonmigratory and is found in many habitat types that support grassland and woody cover in early successional stages. Northern Bobwhite occurs in most grassland and shrubland habitat types in our pilot project area (Figure 22) and is not coastal dependent.

Table 10. Habitat type availability and potential use index for Northern Bobwhite.

Microhabitat	Patch #	Mesohabitat	Macrohabitat	Extent (acres)	Index
Gulf Coast: Coastal Prairie	3,302	Upland Grassland	Upland	210802.2	3
Gulf Coast: Salty Prairie	1,810	Upland Grassland	Upland	106625.4	3
Coastal and Sandsheet: Deep Sand Grasslands	1,714	Upland Grassland	Upland	39848.6	3
Texas Coast Dune and Coastal Grassland Active Dune	49	Upland Grassland	Upland	92.7	3
South Texas: Sandy Mesquite Savanna Grassland	8	Upland Grassland	Upland	38.6	3
Post Oak Savanna: Savanna Grassland	7	Upland Grassland	Upland	16.0	3
Coastal Bend: Floodplain Grassland	472	Palustrine Vegetated Marsh	Freshwater Wetland	7974.9	2
Coastal Bend: Riparian Grassland	664	Palustrine Vegetated Marsh	Freshwater Wetland	3615.8	2
Coastal Bend: Riparian Deciduous Shrubland	285	Palustrine Vegetated Shrub	Freshwater Wetland	479.9	2
Coastal Bend: Riparian Evergreen Shrubland	159	Palustrine Vegetated Shrub	Freshwater Wetland	230.2	2
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	1,954	Upland Shrub	Upland	20221.8	2
Coastal and Sandsheet: Deep Sand Shrubland	1,668	Upland Shrub	Upland	4731.4	2
Coastal Plain: Terrace Sandyland Grassland	70	Upland Grassland	Upland	947.5	2
Coastal and Sandsheet: Deep Sand Live Oak / Mesquite Woodland	187	Upland Woodland	Upland	313.5	2
South Texas: Sandy Mesquite / Evergreen Woodland	52	Upland Woodland	Upland	147.6	2
Palustrine Emerg Marsh Temp Flooded	5,686	Palustrine Vegetated Marsh	Freshwater Wetland	48095.4	1
Palustrine Emerg Marsh Seasonally Flooded	6,190	Palustrine Vegetated Marsh	Freshwater Wetland	38995.9	1
Palustrine Emerg Marsh/Scrub-Shrub (mix) Intermittently/Temp/Seas Flooded	437	Palustrine Vegetated Marsh/ Vegetated Shrub	Freshwater Wetland	6482.3	1
Palustrine Emerg Marsh Intermittently Flooded	327	Palustrine Vegetated Marsh	Freshwater Wetland	5920.1	1
Coastal Bend: Floodplain Deciduous Shrubland	696	Palustrine Vegetated Shrub	Freshwater Wetland	2907.4	1
Palustrine Farmed	132	Palustrine Vegetated Marsh	Freshwater Wetland	1929.7	1
Coastal Bend: Floodplain Evergreen Shrubland	463	Palustrine Vegetated Shrub	Freshwater Wetland	1070.3	1
Coastal and Sandsheet: Deep Sand Live Oak Forest and Woodland	1,518	Upland Woodland	Upland	20081.4	1
Native Invasive: Deciduous Woodland	2,992	Upland Woodland	Upland	19448.3	1
Post Oak Savanna: Live Oak Motte and Woodland	1,742	Upland Woodland	Upland	18369.1	1
Invasive: Evergreen Shrubland	2,479	Upland Shrub	Upland	15192.2	1
Gulf Coast: Salty Shrubland	1,892	Upland Shrub	Upland	10193.0	1
South Texas: Clayey Live Oak Motte and Woodland	680	Upland Woodland	Upland	4084.5	1
South Texas: Sandy Live Oak Motte and Woodland	483	Upland Woodland	Upland	1921.2	1
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	786	Upland Grassland	Upland	1873.1	1
Post Oak Savanna: Post Oak Motte and Woodland	193	Upland Woodland	Upland	1242.1	1
Post Oak Savanna: Post Oak / Live Oak Motte and Woodland	62	Upland Woodland	Upland	160.0	1



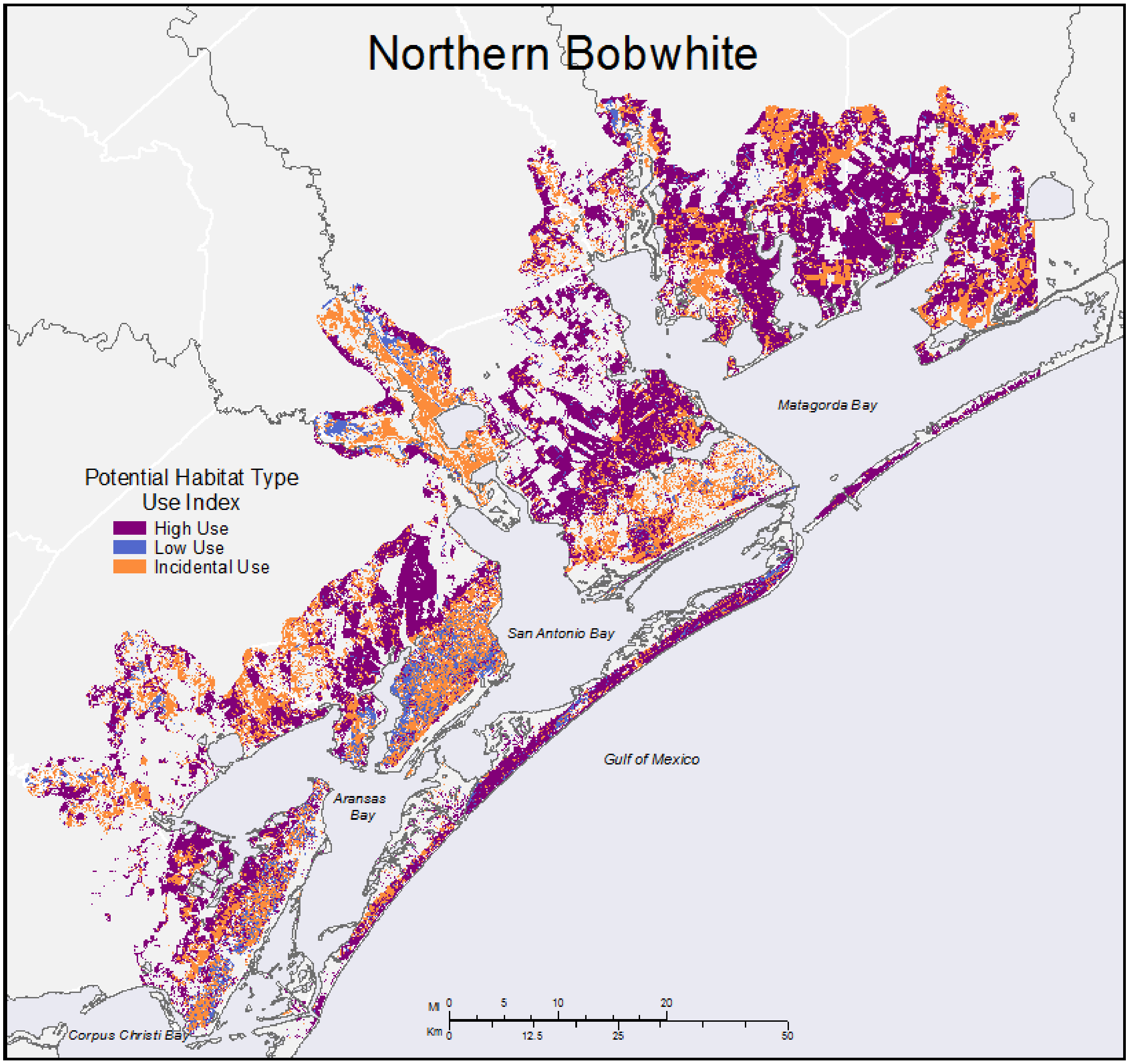


Figure 22. Current conservation map based on potential habitat use and habitat type availability within the project area for Northern Bobwhite.

Le Conte's Sparrow

Le Conte's Sparrow is a grassland species and a winter resident within our project area. It is fairly common in most grasslands throughout the region. Significant acreages of high (41,721 ac), low (264,816 ac) and incidental (108,441 ac) use habitat types are present in the project area (Table 11, Figure 23) These habitats are sufficient to support 12,261 territories assuming a territory size of 25 ac (95% probability of home range 25.4 ac) or more than 51,000 territories assuming a home range of 6 ac (50% probability of home range 6 ac, Baldwin et al. 2010). For Le Conte's Sparrow we generated additional maps showing an analysis of the distribution of patches greater than 500 ac in size as referenced by the GCJV (Table 12, Figure 24). When only patches greater than 500 ac are considered as suitable habitat (high and low use habitat types combined) the total potentially available acreage is reduced by about 60,000 ac.

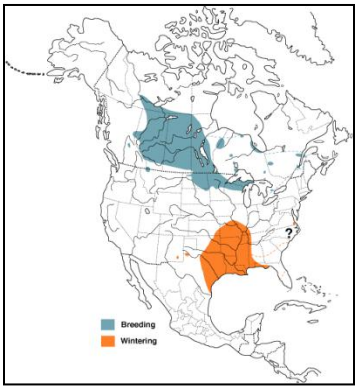
Le Conte's Sparrow is one of the small, secretive grassland birds that breeds in the northern US and large portion of Canada. The species occurs during the winter in our pilot project area where it is found in thick grass in most of our open grassland habitat types except estuarine (Figure 23) and is not coastal dependent. Le Conte's sparrow is included as a species of concern in the PIF and GCJV Landbird plans. Suggested management patch size of 500 ac (Figure 24).

Table11. Habitat type availability and potential use index for Le Conte's Sparrow.

MicroHabitat	Patch #	Mesohabitat	Macrohabitat	Extent (acres)	Index
Coastal and Sandsheet: Deep Sand Grasslands	1,714	Upland Grassland	Upland	39,848.4	3
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	786	Upland Grassland	Upland	1,873.1	3
Palustrine Emergent Marsh Temp Flooded	5,686	Palustrine Vegetated Marsh	Freshwater Wetland	48,095.2	2
Palustrine Emergent Marsh Intermit Flooded	327	Palustrine Vegetated Marsh	Freshwater Wetland	5,920.1	2
Gulf Coast: Coastal Prairie	3,302	Upland Grassland	Upland	210,801.4	2
Estuarine Intertidal Emergent Marsh Irregularly Exposed	563	Estuarine Vegetated Marsh	Estuarine	1,723.4	1
Gulf Coast: Salty Prairie	1,810	Upland Grassland	Upland	106,625.0	1
Texas Coast Dune and Coastal Grassland Active Dune	49	Upland Grassland	Upland	92.7	1

Table 12. Number and extent of patch sizes greater than >500 ac based on high and low use habitat types for Le Conte's Sparrow.

Habitat Patch	Patch #	Extent (acres)	Min. Patch Size	Max. Patch Size	Mean Patch Size	SD
>500 ac	87	246,588.60	534.95	15,524.36	28,34.35	3,575.72



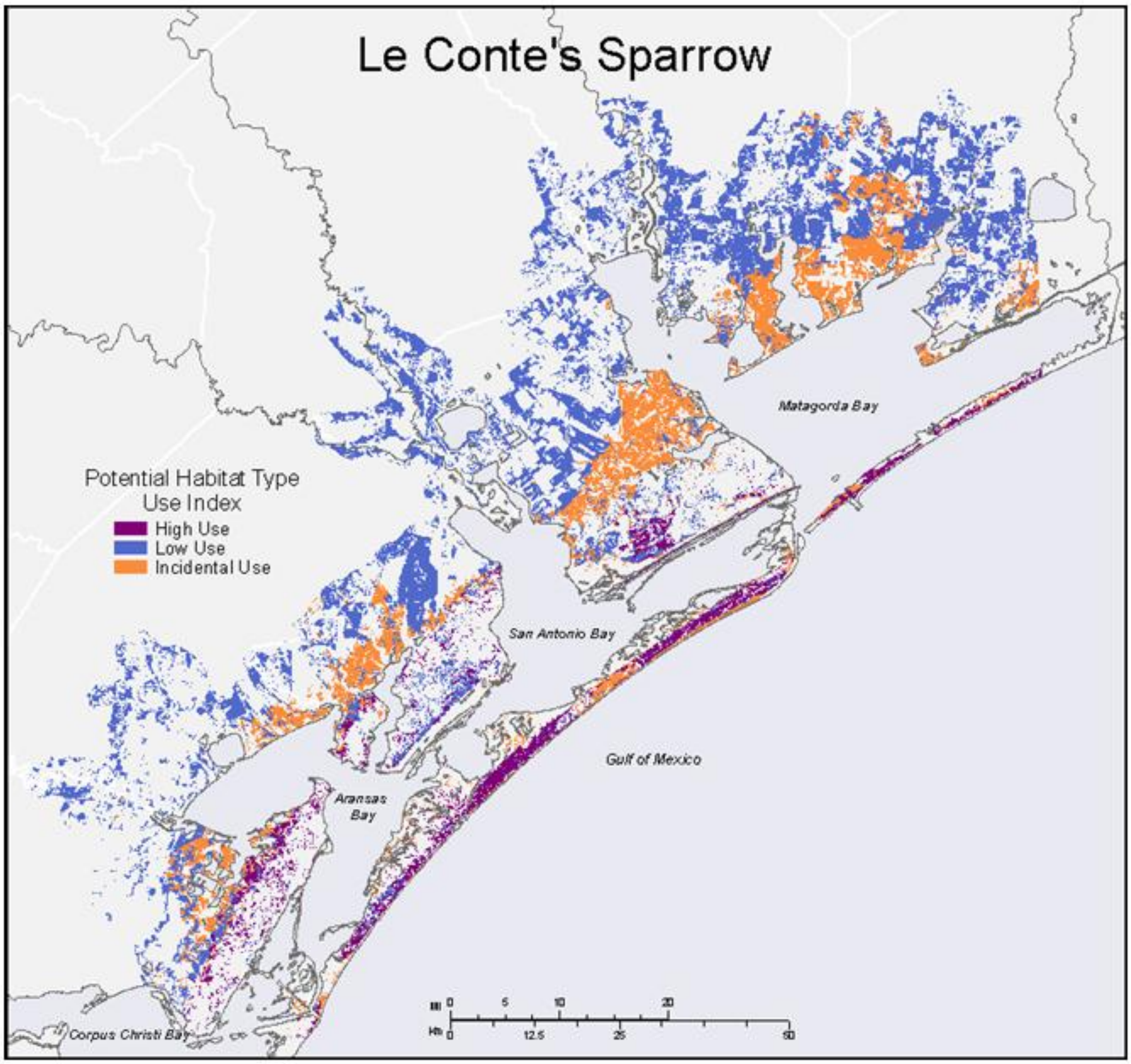


Figure 23. Current conservation map based on potential habitat use and habitat type availability within the project area for Le Conte's Sparrow.

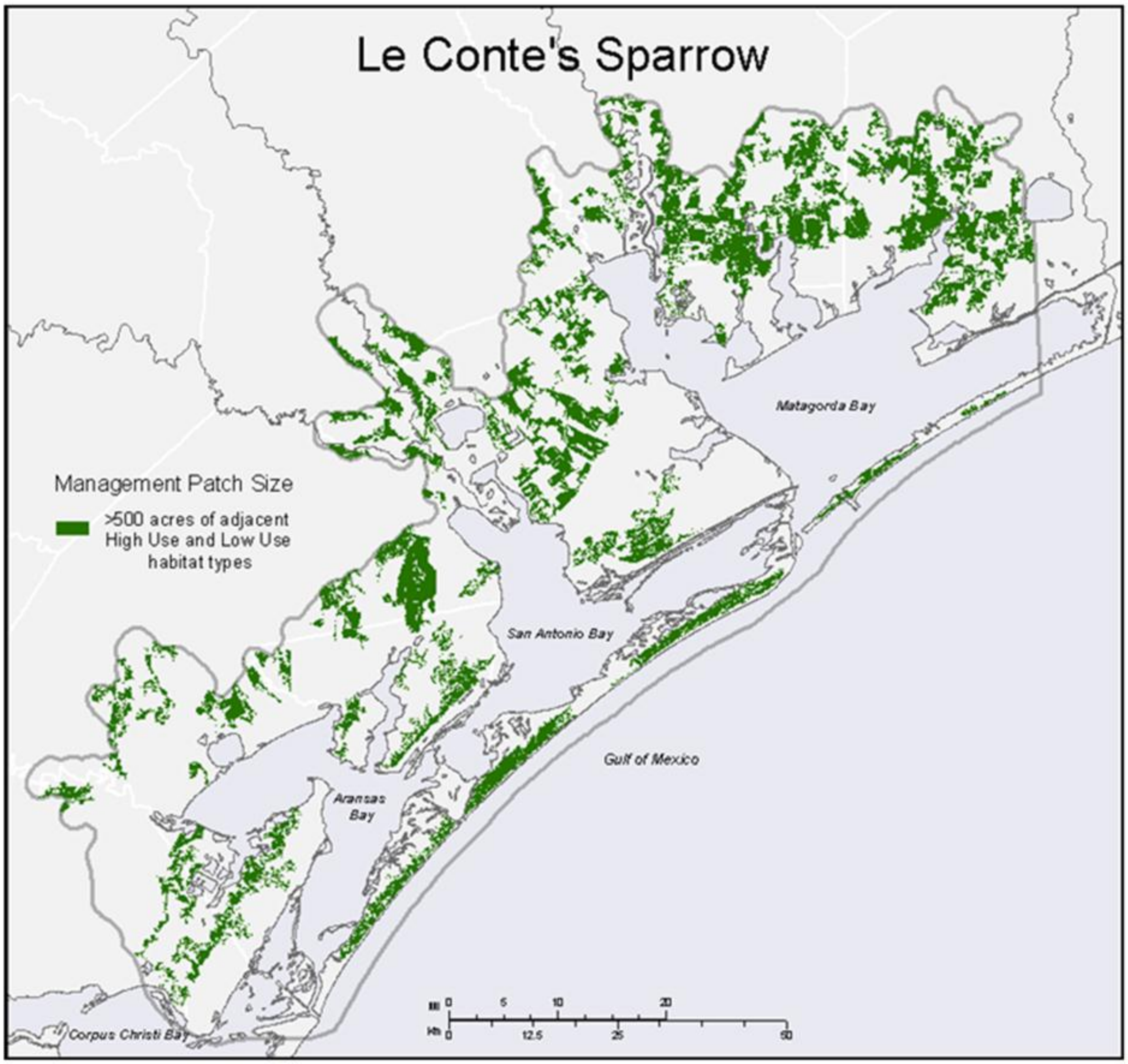


Figure 24. Current conservation map based on potential habitat use and habitat type availability within the project area for Le Conte's Sparrow. Only patches greater than 500 acres are depicted as example of the influence of patch size on habitat type potential use.

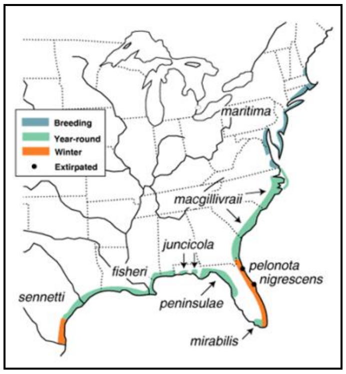
Seaside Sparrow

Seaside Sparrow is a year round resident of the project area and is one of the coastal specialists, not found away from coastal habitat types. High use habitats covered 72,820 ac, low use 4,842 ac, and incidental use 65,735 ac. Considering breeding territories that have been estimated in other areas are relatively small 2.5 ac (< 1 ha), the acreage of high and low use habitat types (Table 13, Figure 25) could support as many as 31.063 Seaside Sparrow territories in the project area. While minimum biological patch is not known for this species, but there is a management patch size proposed of 10,000 ac (GCJV land bird plan). We attempted to generate a map showing the referenced management patch size of greater than 10,000 ac, however, no patches of that size are present within the project area.

As the name implies, this species is found only along coastal marshes that are inundated (Figure 25). It is found year round in coastal areas of the Atlantic and Gulf of Mexico into southern Texas. This is one of few coastal specialists that is likely to significantly be impacted by changes on the coastal areas of the US. Seaside Sparrow is listed in the PIF and GCJV landbird plans.

Table 13. Habitat type availability and potential use index for Seaside Sparrow < 0.6 mi from bay shoreline.

Microhabitat	Patch #	Mesohabitat	Macrohabitat	Extent (Acres)	Index
Estuarine Intertidal Emergent Marsh Regularly Flooded	3,854	Estuarine Vegetated Marsh	Estuarine	38,141.10	3
Estuarine Intertidal Emergent Marsh Irregularly Flooded	2,752	Estuarine Vegetated Marsh	Estuarine	23,658.70	3
Coastal: Salt and Brackish High Tidal Marsh	2,092	Estuarine Vegetated Marsh	Estuarine	8,990.50	3
Coastal: Salt and Brackish Low Tidal Marsh	1,019	Estuarine Vegetated Marsh	Estuarine	2,029.40	3
Mangroves	2,200	Estuarine Vegetated Shrub	Estuarine	4,137.10	2
Estuarine Intertidal Scrub-Shrub (broad leaved evergreen) Regularly Flooded	292	Estuarine Vegetated Shrub	Estuarine	385.3	2
Estuarine Intertidal Scrub-Shrub (broad leaved evergreen) Irregularly Flooded	118	Estuarine Vegetated Shrub	Estuarine	319.4	2
Coastal: Borrichia Flats	776	Estuarine Vegetated Marsh	Estuarine	2,367.90	1
Estuarine Intertidal Emergent Marsh Irregularly Exposed	543	Estuarine Vegetated Marsh	Estuarine	1,657.00	1
Native Invasive: Common Reed	516	Palustrine Vegetated Shrub	Freshwater Wetland	2,773.70	1
Gulf Coast: Salty Prairie	966	Upland Grassland	Upland	37,018.10	1
Gulf Coast: Coastal Prairie	645	Upland Grassland	Upland	21,838.60	1
Texas Coast Dune and Coastal Grassland Active Dune	41	Upland Grassland	Upland	79.4	1



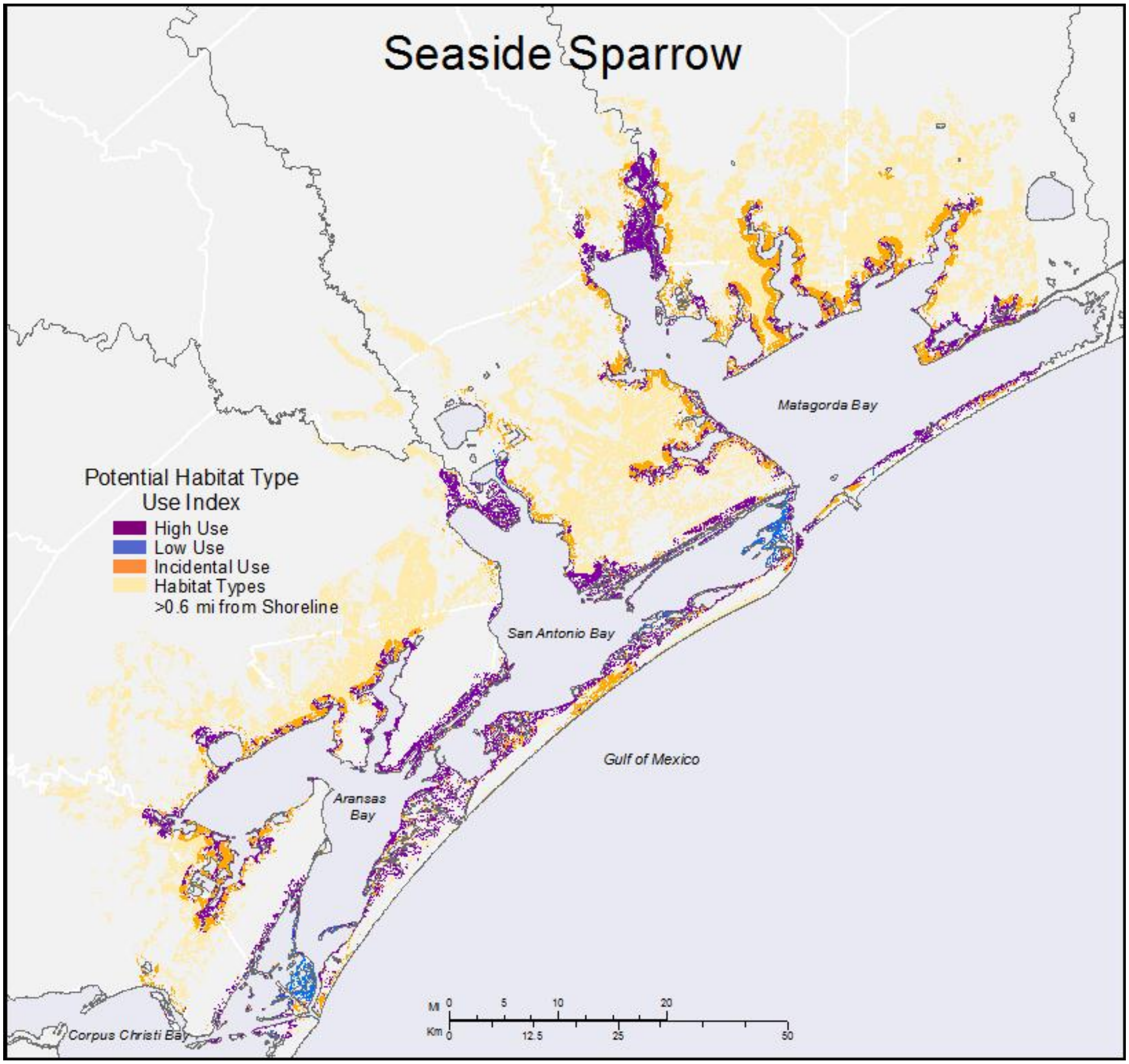


Figure 25. Current conservation map based on potential habitat use and habitat type availability within the project area for Seaside Sparrow.

Objective 4 Future Conservation Needs for Whooping Cranes and Selected Avian Species

Whooping Cranes

The same analysis and ranking of habitat types used in previous species habitat-type use maps were performed to parameterize land cover types to habitat types for the Whooping Crane under initial conditions of the SLAMM. High use categories for this species include Estuarine Emergent Marsh, both irregularly and regularly flooded habitat types, and are essentially the key factor in assessing areal changes in the SLAMM contextual area. Sea-level rise scenarios for the Whooping Crane were generated from SLAMM for the following: IPCC A1B Mean, A1B Maximum, 1-m and 2-m under two time frames (2075 and 2100). The overall interest in generating these various scenarios included determining how the amount and geographic extent of gains or losses of habitat types within the SLAMM contextual area and compare those values to potentially achieving downlisting criteria defined in the Whooping Crane Recovery Plan. We also included a layer to visually depict open water areas <0.6 m deep that presently occur and will develop from what was initially upland or estuarine marsh habitat in current future SLAMM scenarios. The one criterion that emphasizes habitat conservation focuses on ensuring there is at least 125,000 ac of primary coastal wetland habitat in the wintering grounds which include and surround the Aransas National Wildlife Refuge. The 125,000 ac is estimated based on the need for space for 250 breeding pairs for downlisting (CWS and USFWS 2005), at an estimated average territory size of 500 ac per pair. The second conservation interest lies in determining where potential high-use areas will be located as sea-level rise progresses and ensure those areas are secured in a conservation strategy.

The IPCC scenario A1B Mean is the most conservative sea level rise scenario used in the SLAMM. The AIB scenario assumes a climate change situation resulting from a balanced mix of energy from renewable and fossil-fuel sources, rapid economic and efficient technological growth, and population growth that peaks around 2050, then declines. The A1B Mean scenario predicts 0.39 m of sea level rise by 2100. Under initial conditions, the key high use areas encompass the bay side of barrier islands, along the eastern shoreline of Blackjack Peninsula, and localized extents in the Guadalupe and Mission deltas (Figure 26) and cover about 50,000 ac (Figure 27). Under this sea level rise scenario, potential High Use habitat for Whooping Cranes decreases 12% to less than 44,000 ac by 2075 (Figure 28) with the most obvious losses occurring along the bay side of the barrier islands in 2075 (Figure 29). By 2100, the SLAMM projects a total decrease of about 23% of High Use habitat. Highest losses continue to be geographically focused along barrier island marshes and extensive marsh habitat type is predicted as being lost in the southwest corner of Seadrift-Port O-Connor Ridge in the Welder Flats area (Figure 30).

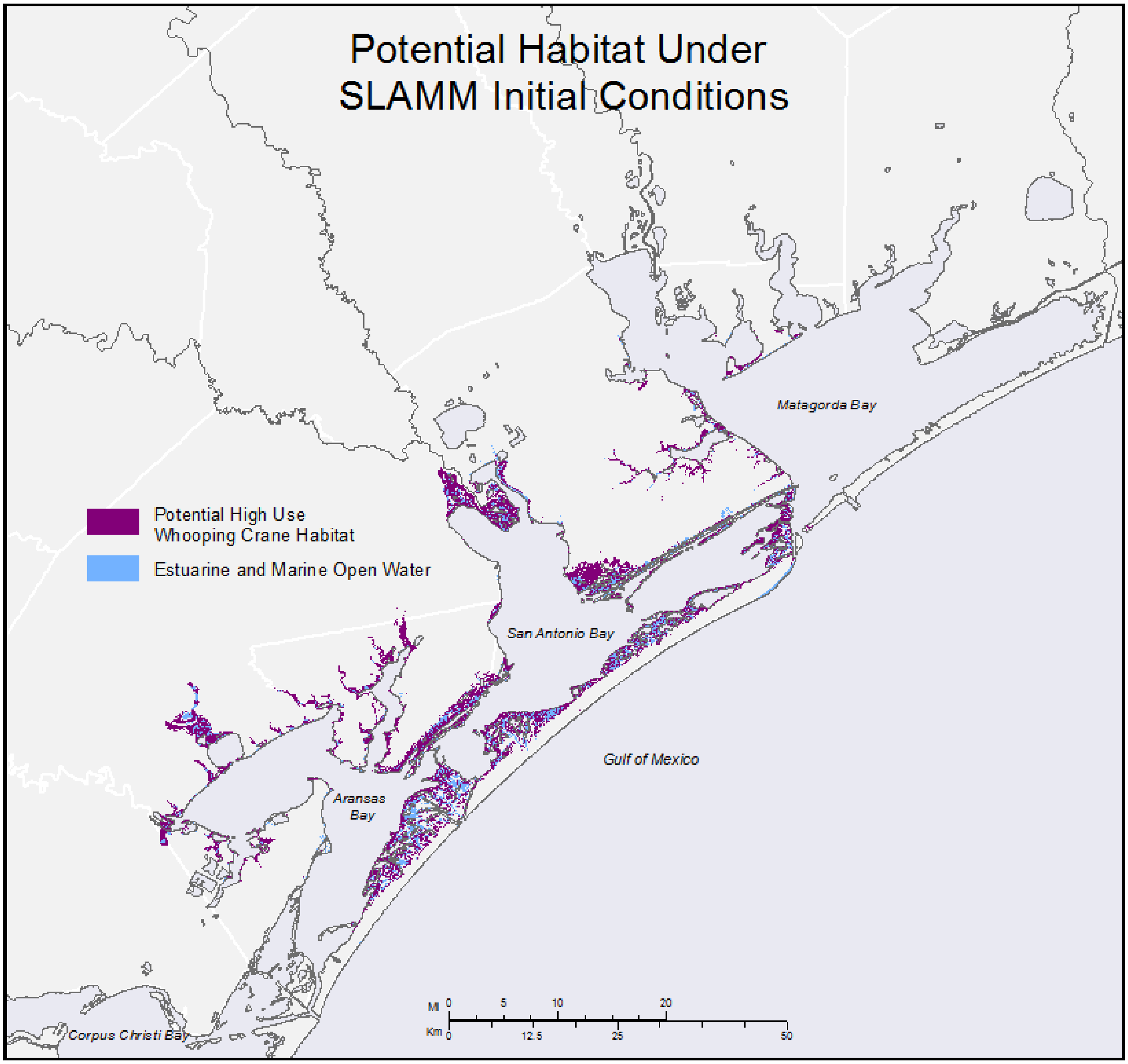
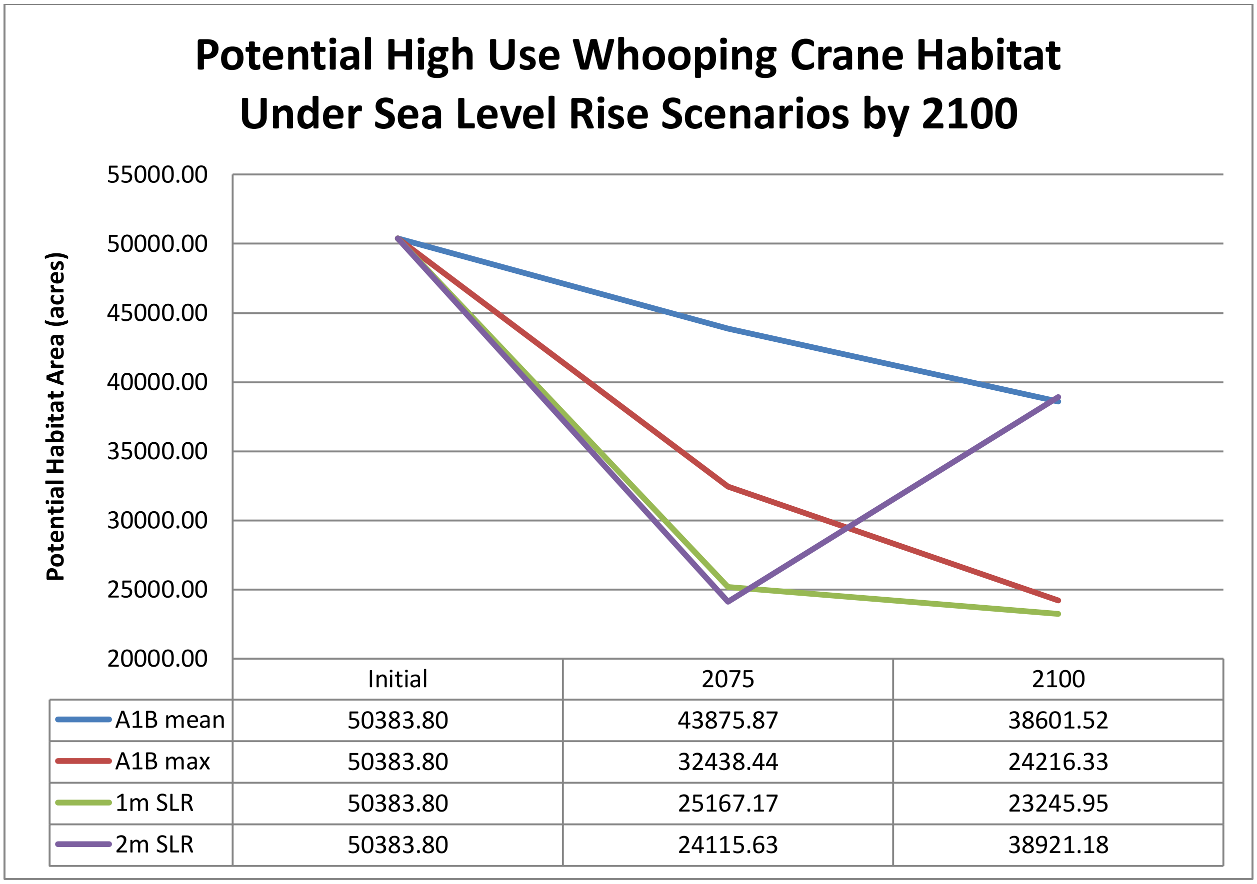
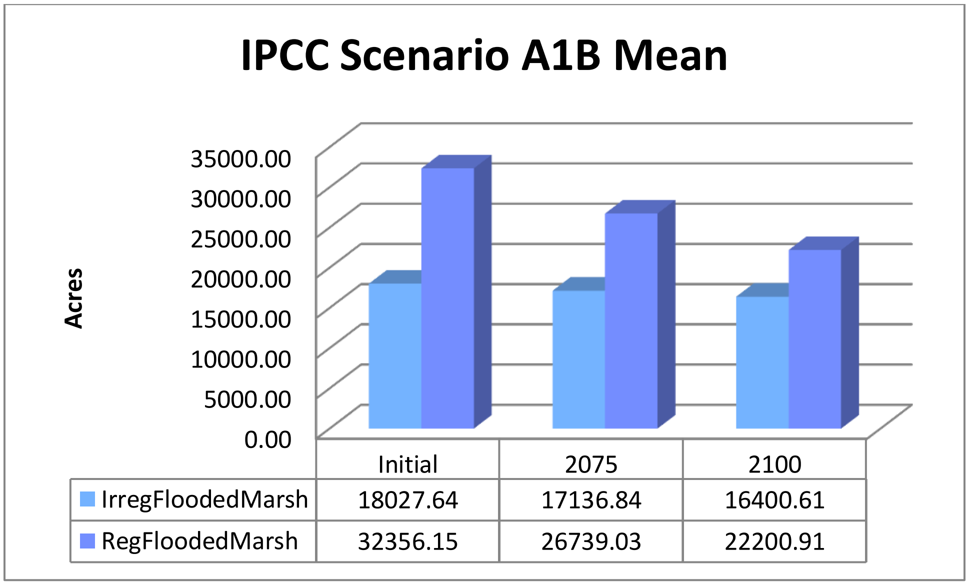


Figure 26. Depiction of the current distribution of Whooping Crane potential High Use habitat types within the SLAMM contextual area.



	Initial	2075	2100
A1B mean	50383.80	43875.87	38601.52
A1B max	50383.80	32438.44	24216.33
1m SLR	50383.80	25167.17	23245.95
2m SLR	50383.80	24115.63	38921.18

Figure 27. Changes in high use Whooping Crane habitat under all sea level rise scenarios.



	Initial	2075	2100
IrregFloodedMarsh	18027.64	17136.84	16400.61
RegFloodedMarsh	32356.15	26739.03	22200.91

Figure 28. Changes in coastal habitat types important to Whooping Crane under the IPCC A1B Mean scenario (~0.4 m rise by 2100).

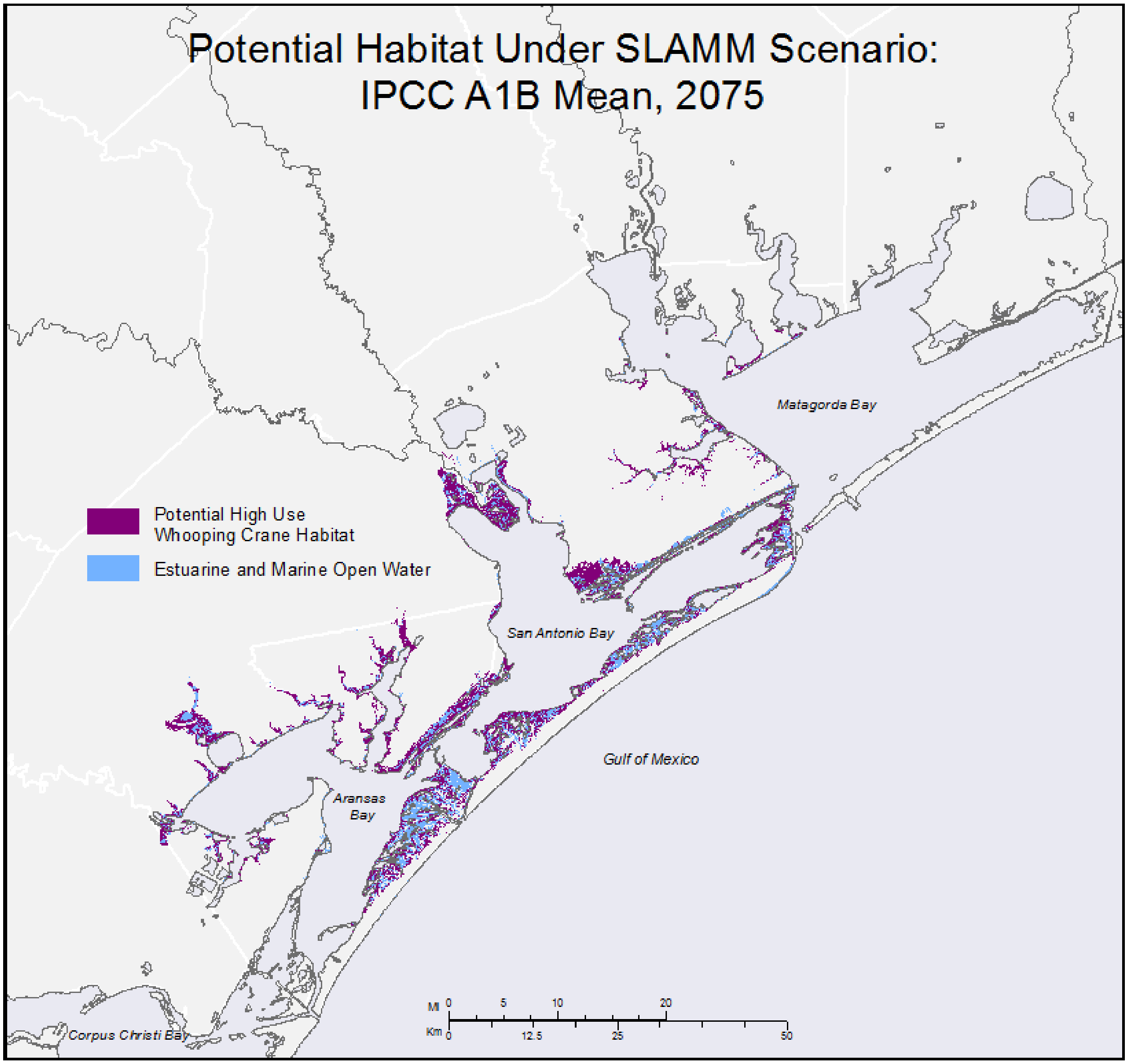


Figure 29. Predicted distribution of future potential Whooping Crane High Use habitat types within the SLAMM contextual area for IPCC A1B Mean at 2075.

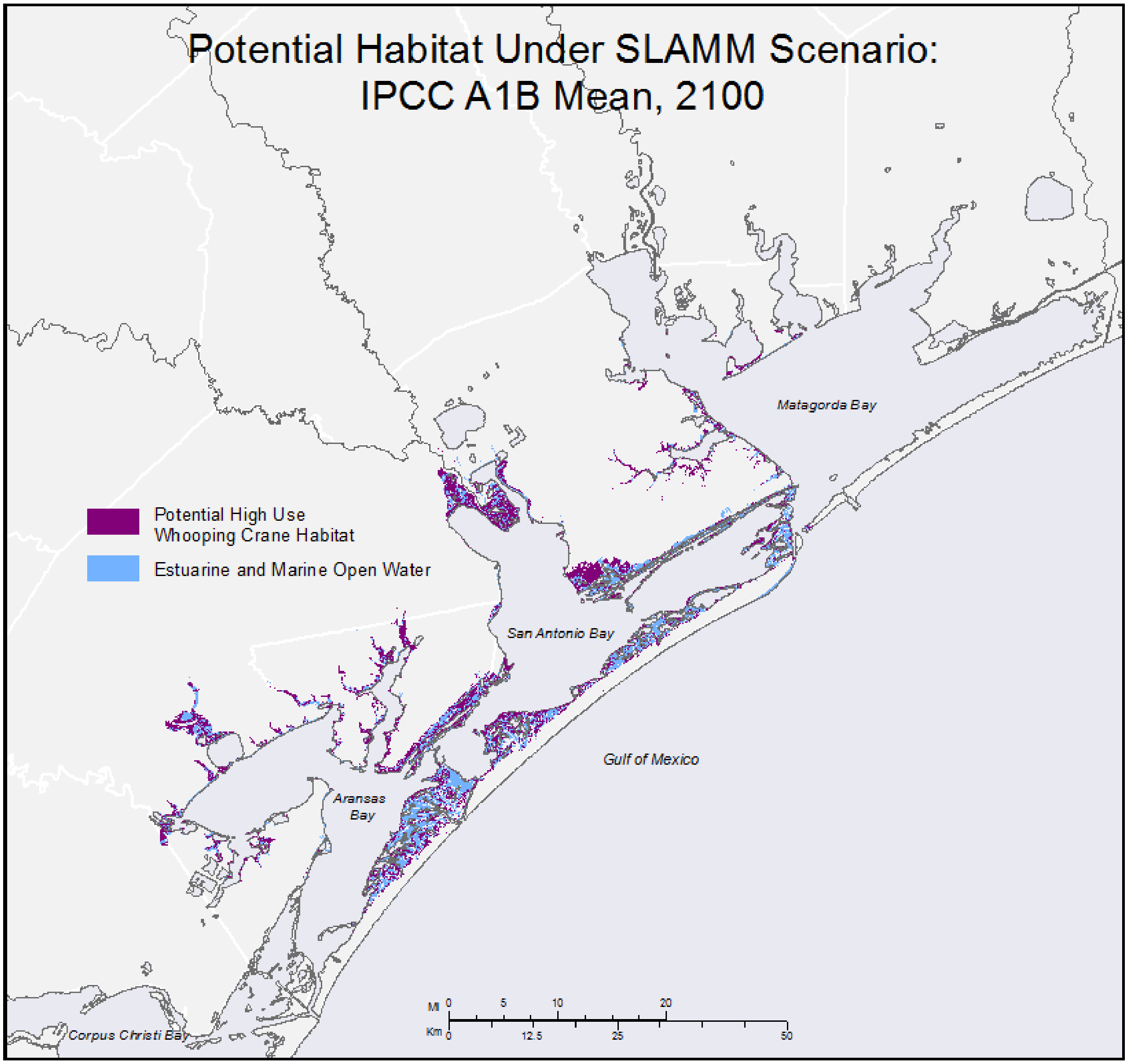


Figure 30. Predicted distribution of Whooping Crane potential High Use habitat within the SLAMM contextual area for IPCC A1B Mean at 2100.

The IPCC scenario A1B Maximum follows the same assumptions about energy use, economic and technological growth, and population growth. The primary difference from the A1B Mean involves utilizing the highest projections for sea level rise under these conditions as 0.69 m by 2100.

Under this scenario, potential High Use habitat type coverage decreases by 36% in 2075 from initial conditions from about 50,000 ac to 32,000 ac (Figure 27). In 2075, much of the high use areas are lost along the bay side of the barrier islands, as well as key areas along the eastern shorelines of the peninsulas and in Mission Delta (Figure 31).

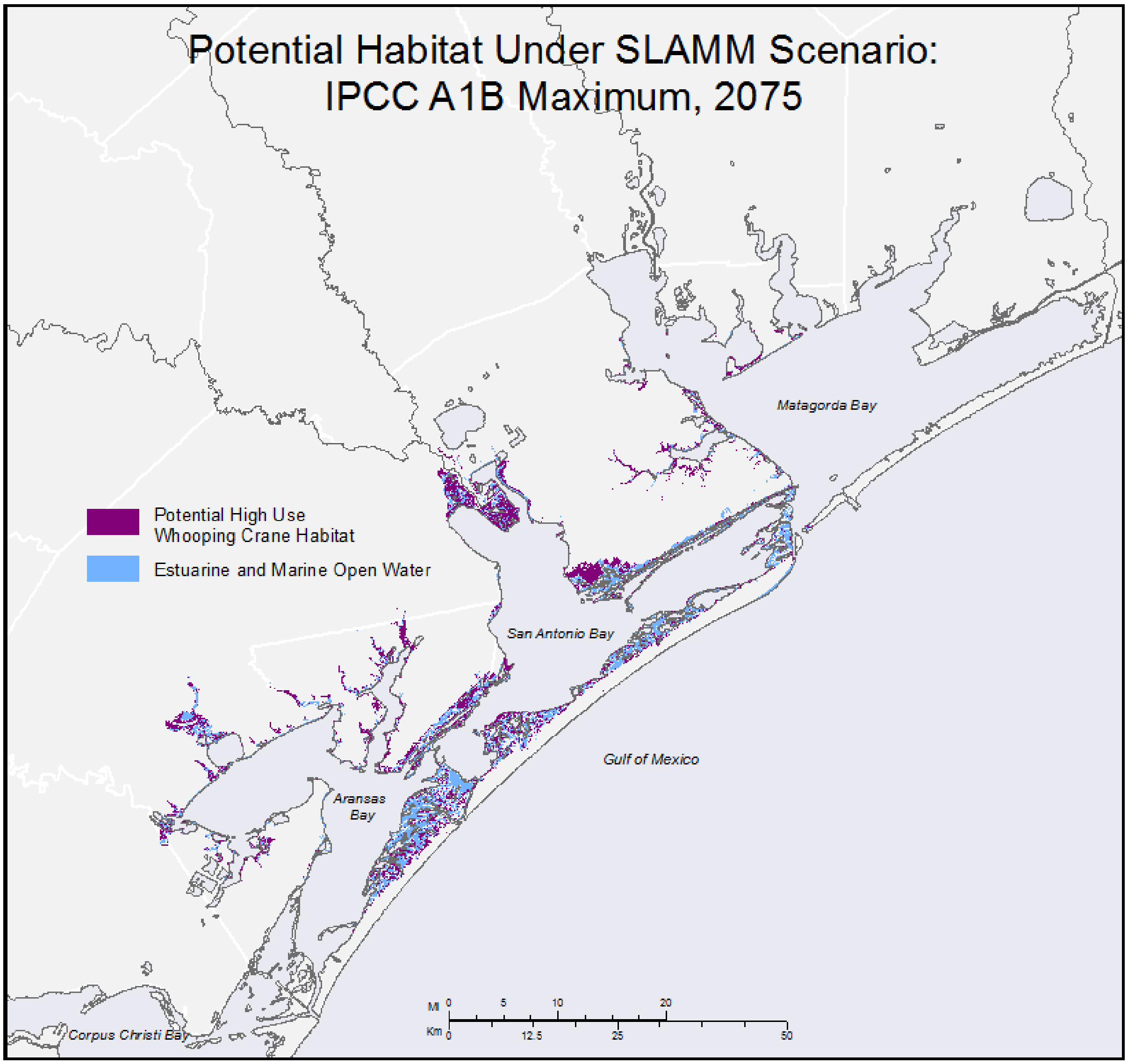


Figure 31. Changes within the SLAMM contextual area for IPCC A1B Maximum at 2075 in various use categories for the Whooping Crane.

By 2100, potential High Use Whooping Crane habitat types decreased by 52% from initial conditions of about 50,000 ac to about 24,000 ac (Figure 27). However, no specific geographic area can be identified where high use areas will be created. The Guadalupe Delta continues to maintain an extensive amount of fragmented habitats and Welder Flats maintain high use areas on the inland side (Figure 32). Regularly Flooded Marsh decreased significantly from initial to 2075, then decreases were more similar to Irregularly Flooded Marsh (Figure 33).

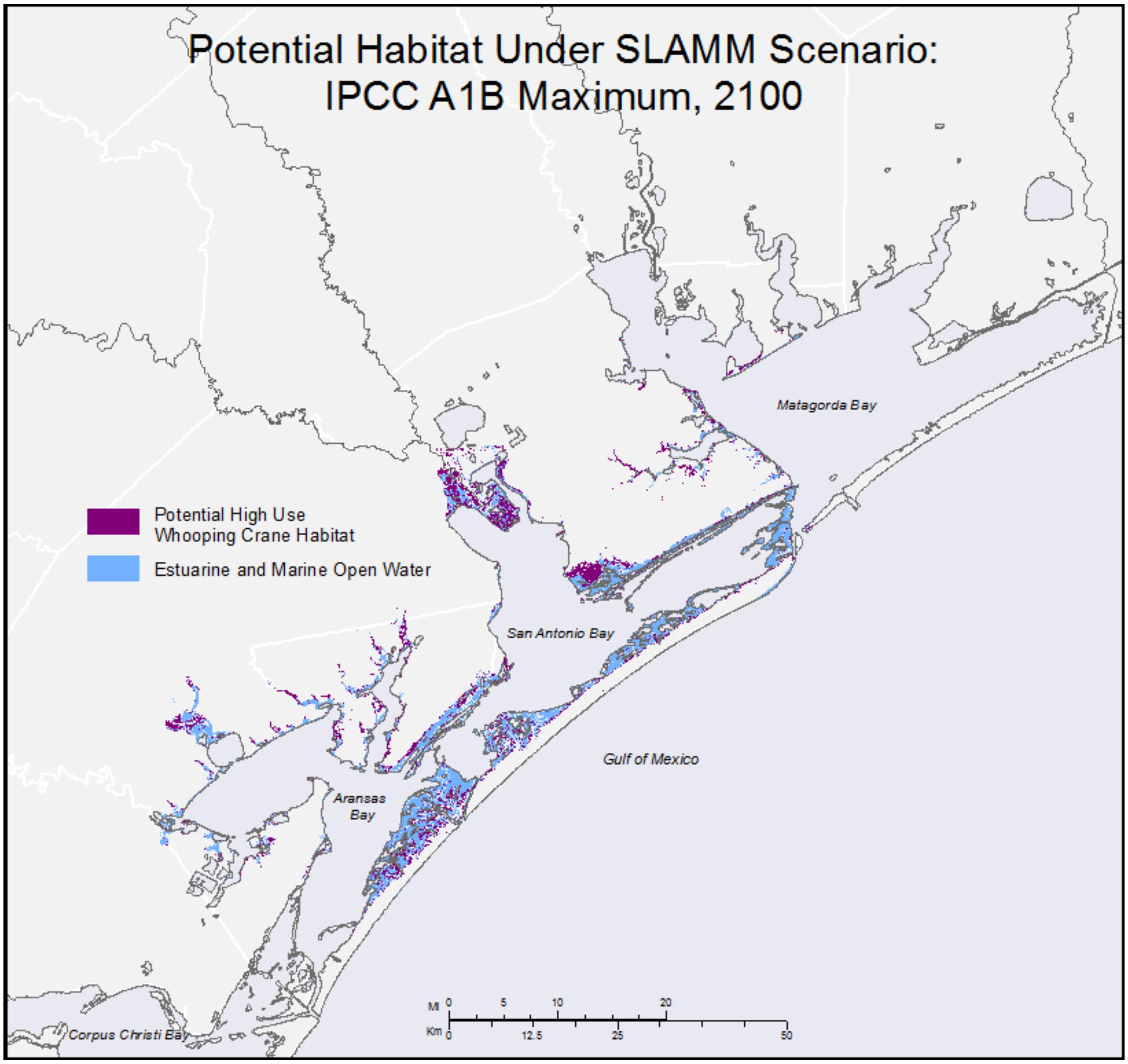
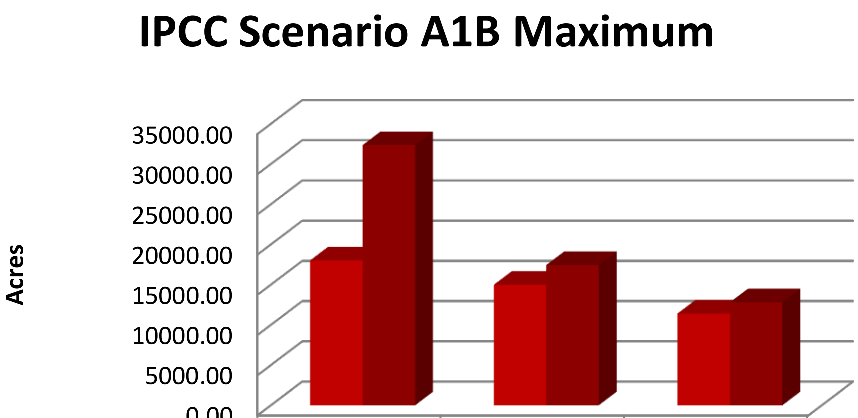


Figure 32. Predicted distribution of Whooping Crane potential High Use habitat types within the SLAMM contextual area for IPCC A1B Max at 2100.



	Initial	2075	2100
IrregFloodedMarsh	18027.64	14988.03	11405.18
RegFloodedMarsh	32356.15	17450.41	12811.15

Figure 33. Changes in coastal habitat types important to Whooping Crane under the IPCC A1B Maximum scenario (~0.69 m rise by 2100).

At 1m sea level rise scenario, about 50% of potential High Use Whooping Crane habitat was lost by 2075, with overall coverage of habitat types at about 25,000 ac. All areas lost extensive High Use marshes, although Guadalupe Delta continued to maintain relatively more continuous patches of High Use area (Figure 34).

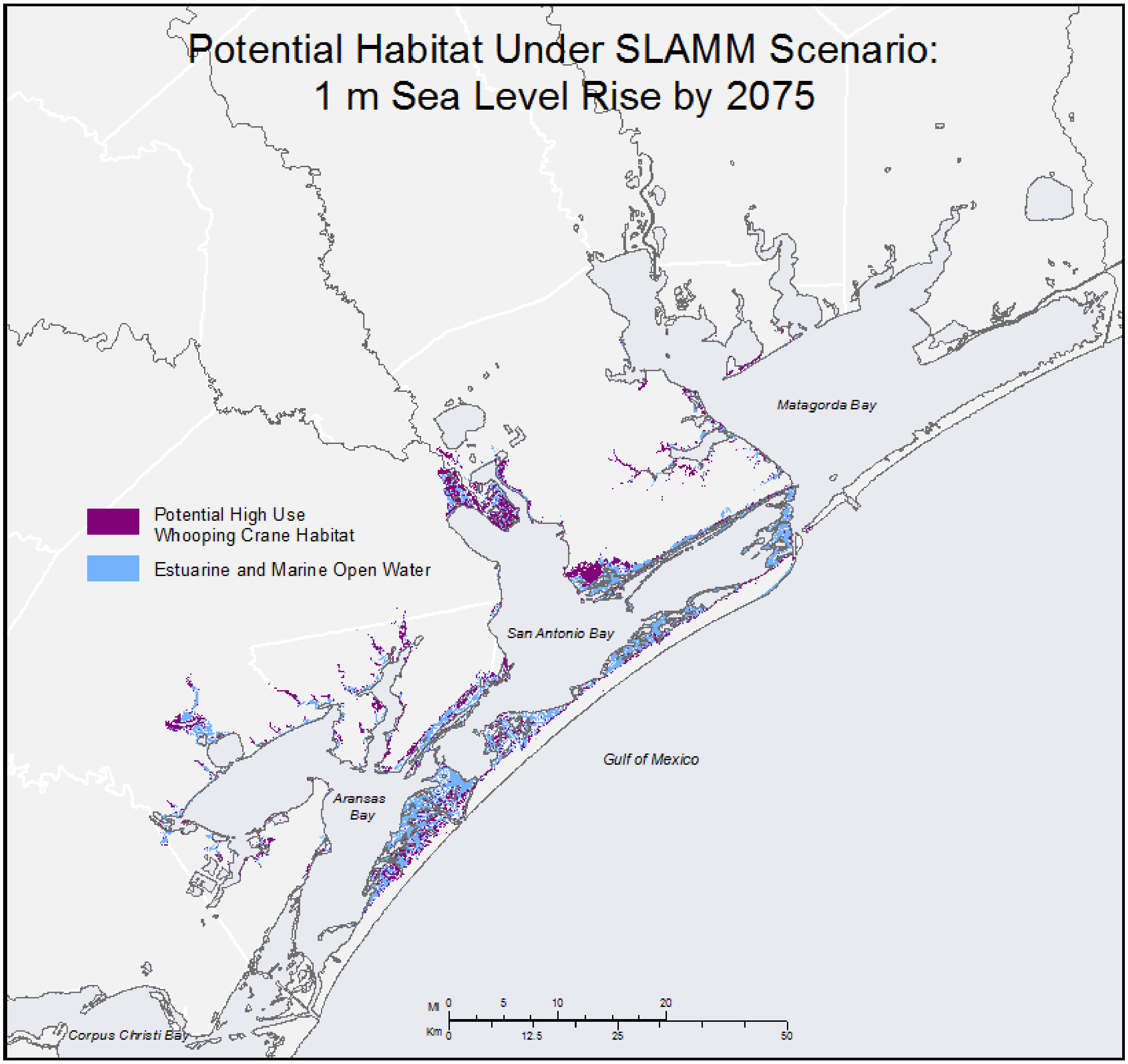


Figure 34. Predicted distribution of potential High Use habitat types for Whooping Crane within the SLAMM contextual area in 2075, under a 1-m sea level rise by 2100.

From initial conditions to 2100, potential High Use habitat for Whooping Cranes decreased by about 54%. Most of the high use marsh areas have been inundated with minor new marsh development in other areas, with the exception of Guadalupe Delta, Welder Flats and western margins of Lamar Peninsula as marsh migrated inland (Figure 35). Regularly flooded emergent marsh was most impacted by sea level rise, decreasing the most between initial conditions and 2075, then increasing by 2100 (Figure 36). Irregularly flooded emergent marsh steadily declined throughout the period.

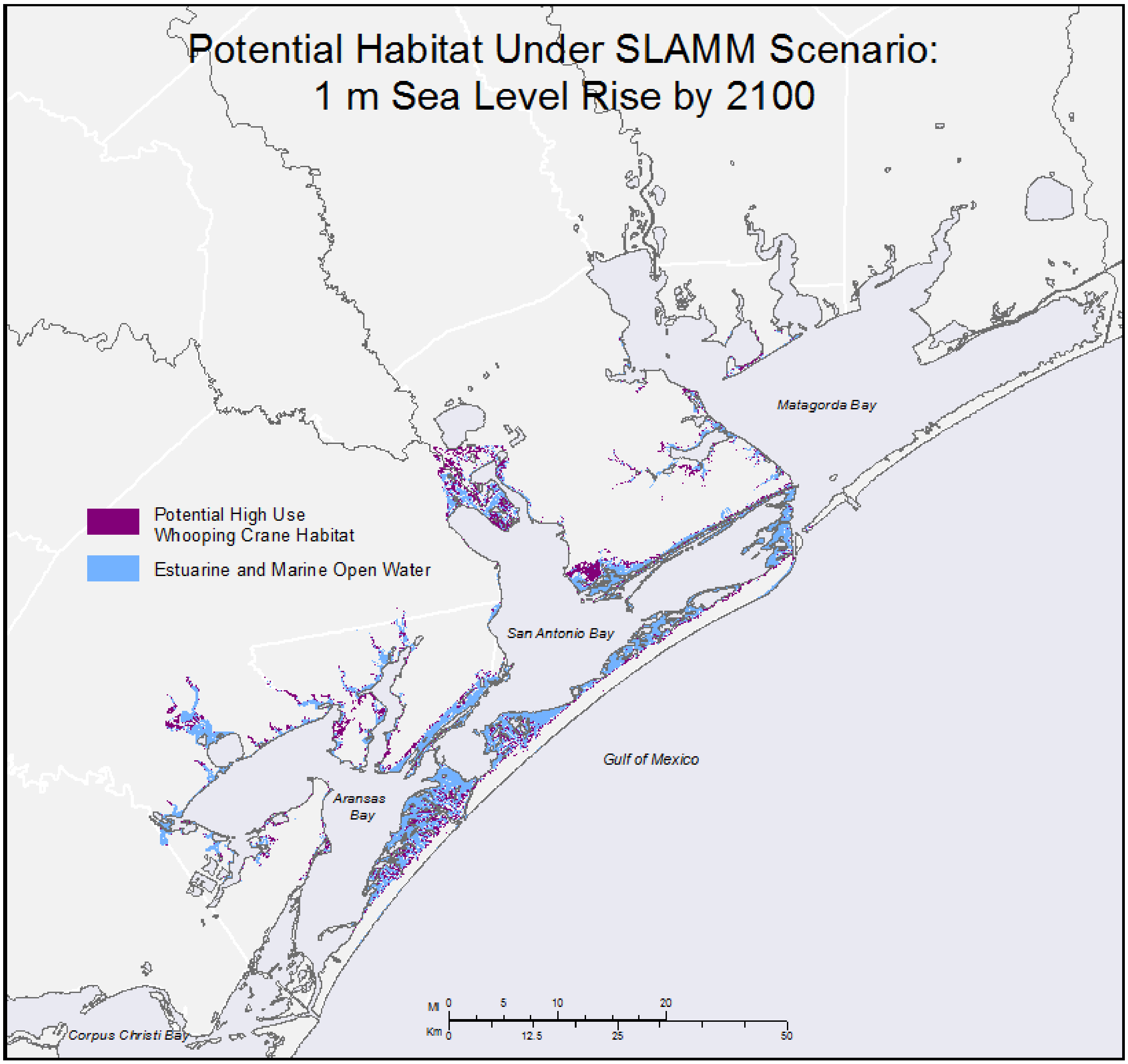
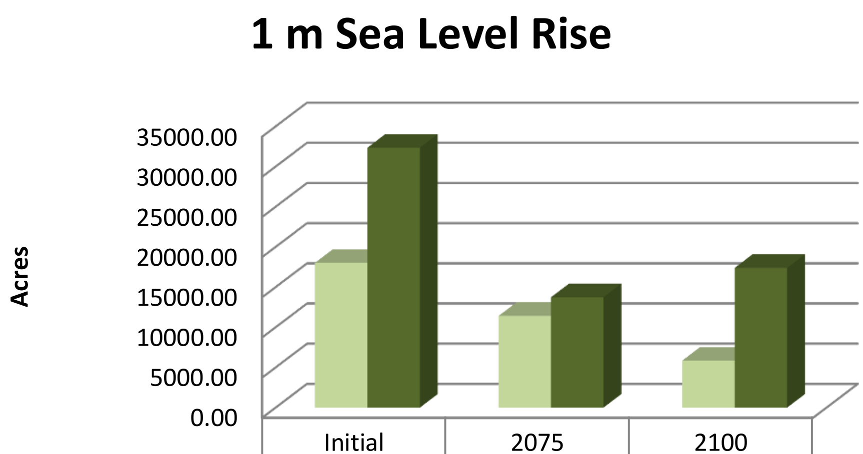


Figure 35. Predicted distribution of potential High Use habitat types for Whooping Crane within the SLAMM contextual area for a 1-m sea level rise by 2100.



	Initial	2075	2100
IrregFloodedMarsh	18027.64	11417.09	5849.38
RegFloodedMarsh	32356.15	13750.07	17396.58

Figure 36. Changes in coastal habitat important to Whooping Crane under the 1-m sea-level rise scenario.

The 2-m sea level rise scenario is the most extreme used by SLAMM, and is considered by some authors to be the upper limit of plausible sea level rise scenarios due to glaciological conditions. With 2 m of projected sea level rise, potential High Use habitat for Whooping Cranes decreases by about 52% by 2075 to about 24,000 ac. An extensive decrease in infrequently flooded marsh occurred during this time. The areas of habitat loss along the bay side of the barrier islands and eastern shoreline of peninsulas are compensated for in the Guadalupe Delta and, to a lesser extent Welder Flats on Seadrift-Port O-Connor Ridge and Copano Bay side of Lamar Peninsula (Figure 35).

With 2-m sea level rise by 2100, area of potential High Use habitat for Whooping Cranes increased from predicted levels for 2075 by about 15,000 ac and overall loss from initial conditions rebounded to about 38,000 ac. Irregularly flooded marsh continued to decrease, whereas substantial increases are evident in regularly flooded marsh. Areas exhibiting most areal extent increases are located throughout the bay shoreline of the barrier islands, along the eastern shoreline of the peninsulas, as well as back bay areas in Powderhorn Lake, Lamar Peninsula, and Port Bay area as well as inland portions of Welder Flats, Guadalupe and Mission river deltas (Figure 37). The 2-m sea level rise scenario at 2100 is the only scenario where high use areas will potentially recover at some level toward initial conditions acreages (Figure 38). However, the increase does not correspond to a recovery of irregularly flooded emergent marsh (Figure 39).

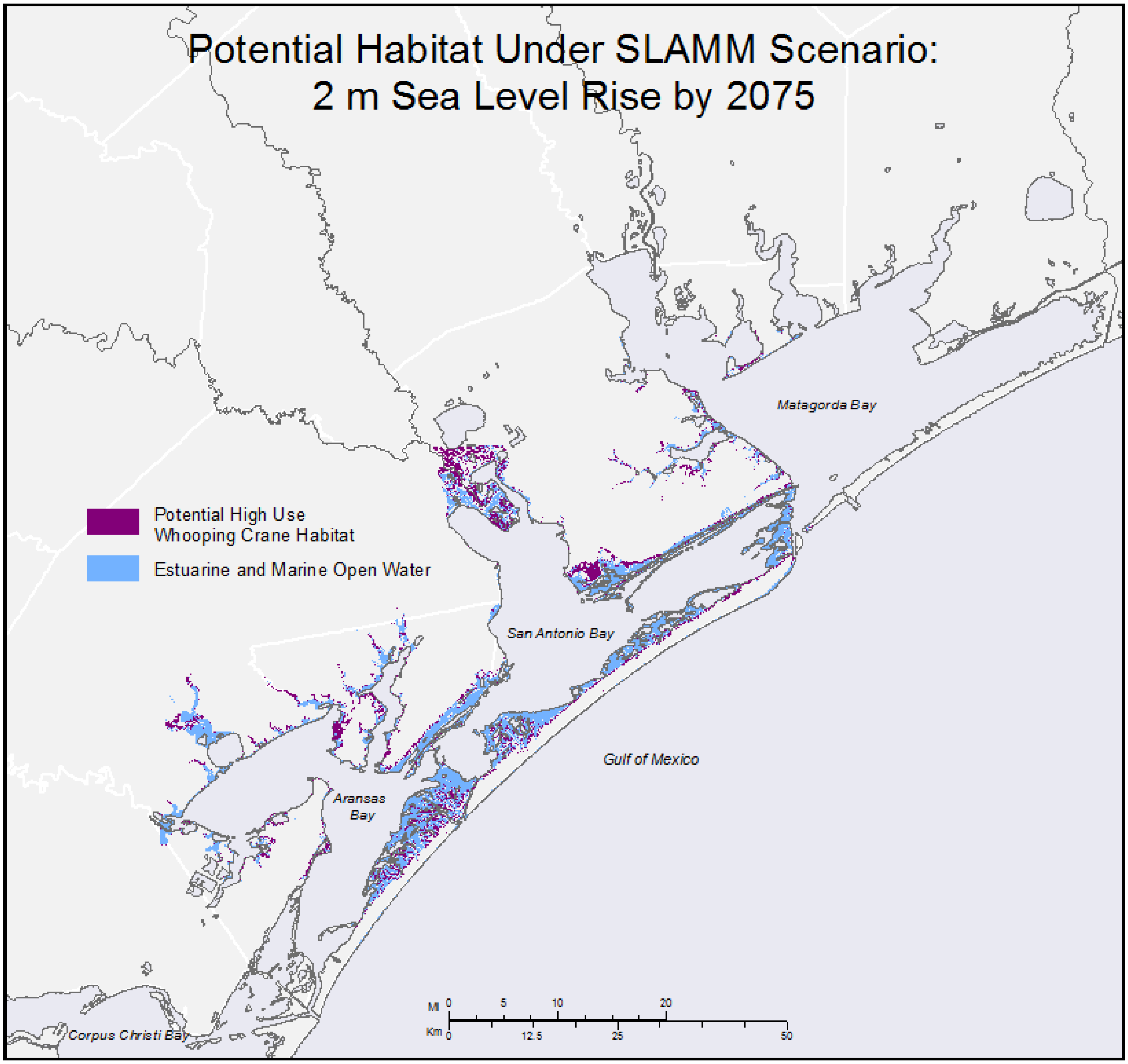


Figure 37. Predicted distribution of High Use habitat types for Whooping Crane within the SLAMM contextual in 2075 for 2-m sea level rise by 2100.

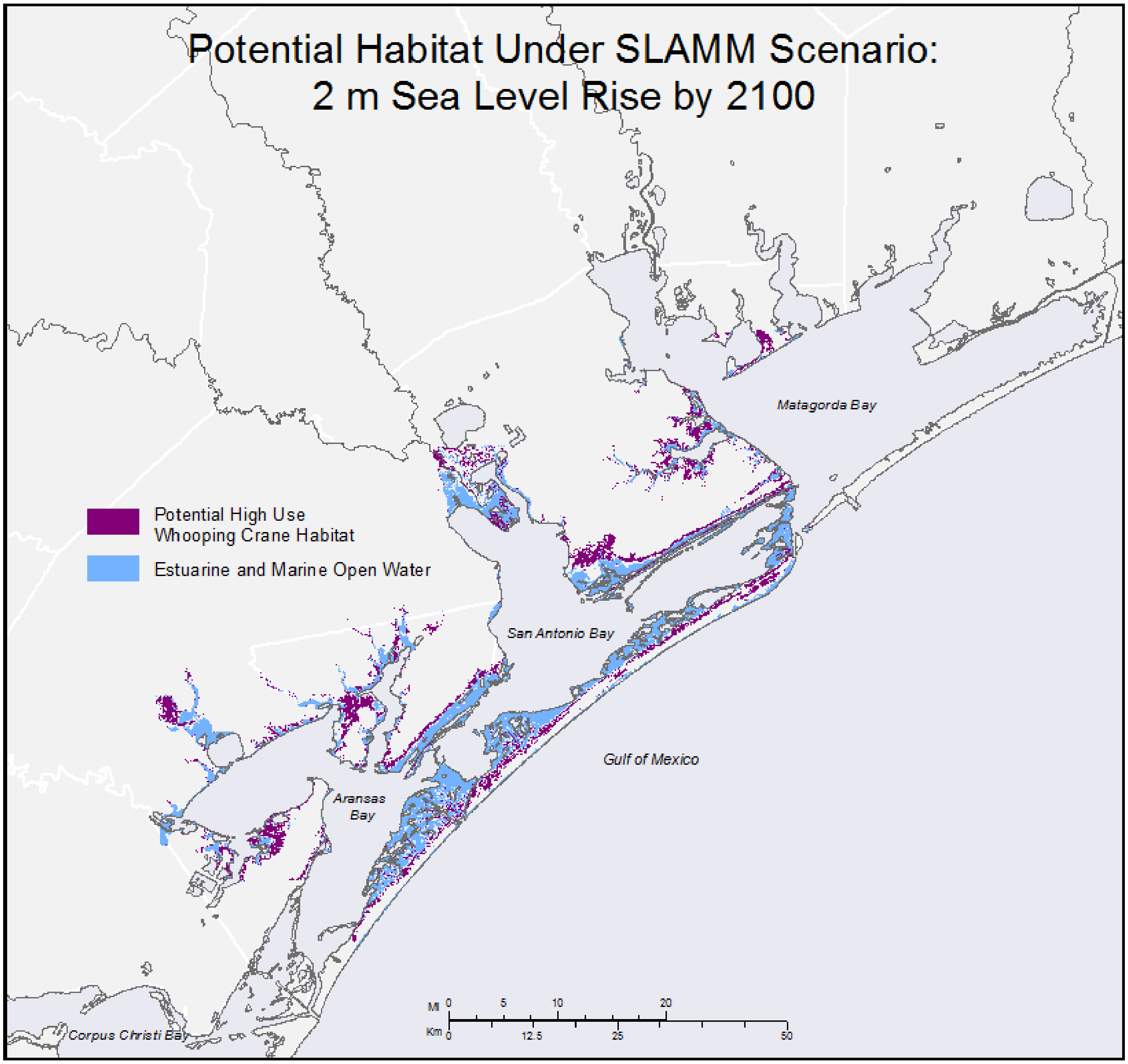
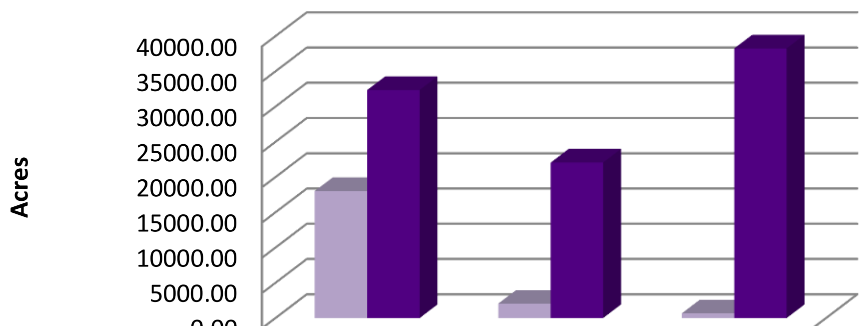


Figure 38. Predicted distribution of potential High Use habitat types for Whooping Crane within the SLAMM contextual area for a 2-m sea level rise by 2100.



	Initial	2075	2100
IrregFloodedMarsh	18027.64	2052.30	667.50
RegFloodedMarsh	32356.15	22063.33	38253.67

Figure 39. Changes in coastal habitat important to the Whooping Crane under the 2-m sea-level rise scenario.

Selected Avian Species

We used an alternate approach to quantify changes on the uplands concomitant with those changes in the estuarine area from projected sea level rise (SLR) throughout the entire LCC pilot project area (Figure 40) because SLAMM does not include upland habitat types. Most areas affected by 0-1 m SLR appear to be located on back-barrier landforms, eastern shorelines of peninsulas, and larger river deltas. At 1-2 m SLR, most of barrier landforms are inundated as well as minor bays extending behind peninsulas and upper reaches of the river floodplains.

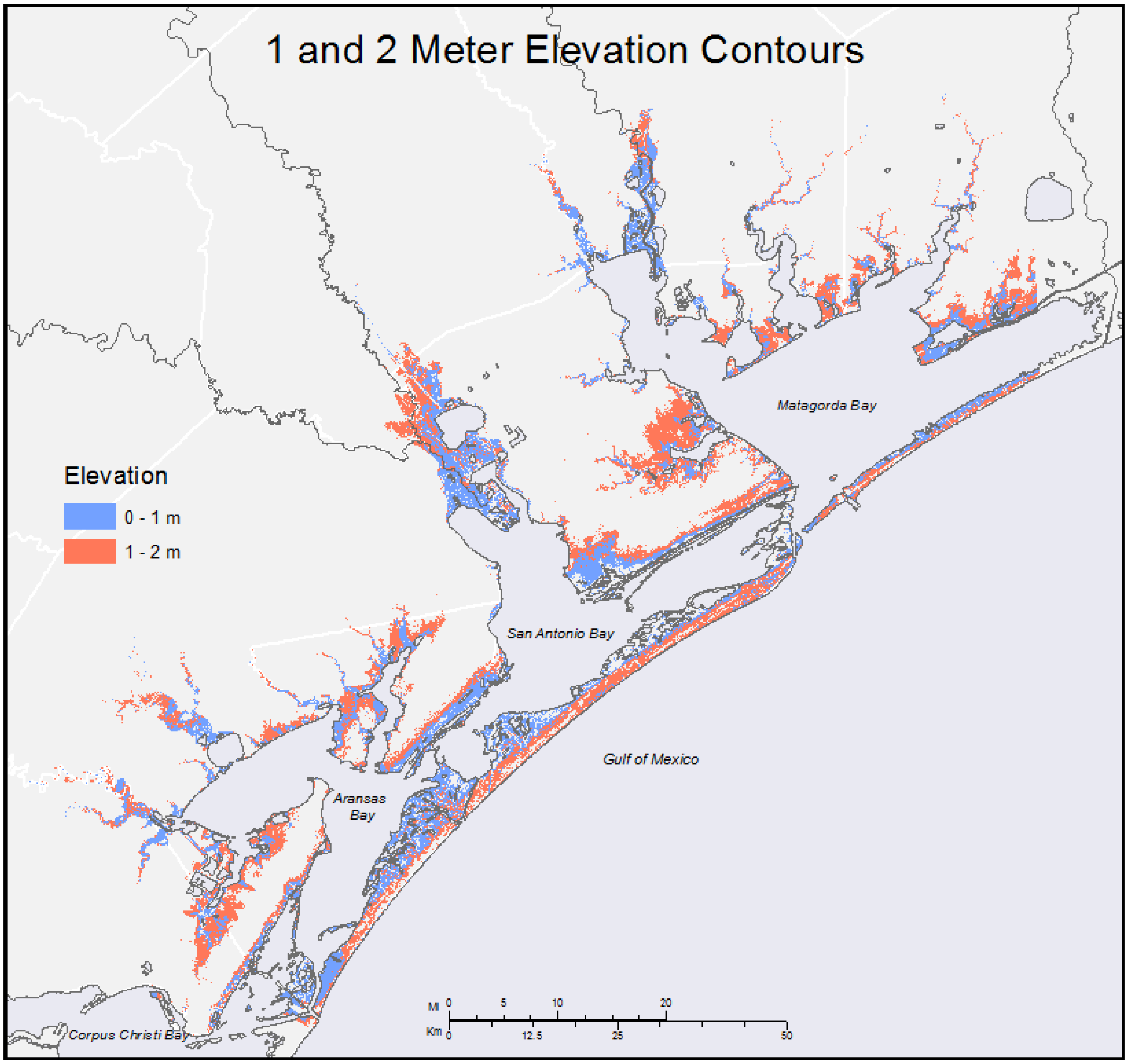


Figure 40. Spatial extent of areas that will be impacted by two sea-level rise scenarios in the GCPLCC pilot project area.

We first examined changes at the landscape level which includes the areal coverage of the SLAMM for macro-, meso-, and microhabitat types. Within the macrohabitat Upland type 1.6% of total area will be lost in 1-m SLR, and an additional 8.4% lost in 2-m SLR, or about 10% of total Upland area in LCC pilot project area (Table 14). Most of the loss (80%) will occur within the grassland mesohabitat, which will primarily affect the grassland birds that depend on Gulf Coast: Salty Prairie and Coastal and Sandsheet: Deep Sand Grassland for both 1- and 2-m SLR losses (Table 15). About 1000 ac of Upland Developed will be lost at 1-m SLR and additional 3,800 ac lost at 2-m SLR, or 18% of total developed area in the LCC pilot project area (see Table 14). A minor amount of Row Crop will be affected by 1-m (24 ac) and 2-m (129 ac) of SLR, which is generally a result that lands within this elevation are not suitable for cultivated crops.

Table 14. Areal extent losses of macro- and mesohabitat types Upland within 0-1 and 1-2 contour areas in LCC pilot project area.

Macrohabitat Type Mesohabitat Type	Current Area (ac)	0-1 m Contour Area (ac) (% loss)	1-2 m Contour Area (ac) (% loss)	Total % Loss 0-2 m	Mesohabitat Loss (%) within Macrohabitat Loss by Contour 0-1 m Contour	1-2 m Contour
Macrohabitat Type: Upland	**761,799**	**11,841** **(1.6)**	**63,697** **(8.4)**	**10.0%**		
Mesohabitat Type: Upland Developed	28,033	1,078 (3.8)	3,845 (13.7)	17.5%	9.1%	6.0%
Mesohabitat: Upland Grassland	360,243	9,529 (2.6)	50,703 (14.1)	16.7%	80.5%	79.6%
Mesohabitat Type: Upland Row Crop	192,801	24 (0.0)	129 (0.1)	0.1%	0.2%	0.2%
Mesohabitat Type: Upland Shrub	106,679	847 (0.8)	6,828 (6.4)	7.2%	7.2%	10.7%
Mesohabitat Type: Upland Woodland	65,812	317 (0.5)	1,785 (2.7)	3.2%	2.7%	2.8%
Mesohabitat Type: Upland Woodland/Shrub	8,232	47 (0.6)	407 (4.9)	5.5%	0.4%	0.6%

Table 15. Areal extent losses for Upland Grassland microhabitat types.

Mesohabitat Type	Current Area (ac)	0-1 m Contour Extent (ac)	1-2 m Contour Extent (ac)	Total Cumulative Loss (ac)
Mesohabitat: Upland Grassland	**761,799**	**9,529**	**50,703**	**60,232**
Coastal and Sandsheet: Deep Sand Grasslands	*39,848*	*3,133*	*16,946*	*20,079*
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	*1,873*	*372*	*627*	*999*
Coastal Plain: Terrace Sandyland Grassland	*947*	*0*	*6*	*6*
Gulf Coast: Coastal Prairie	*210,801*	*244*	*2,293*	*2,537*
Gulf Coast: Salty Prairie	*106,625*	*5,774*	*30,787*	*36,561*
Texas Coast Dune and Coastal Grassland Active Dune	*92*	*6*	*44*	*50*

Within the macrohabitat Estuarine type 13.3% of total area will be lost in 1-m SLR, and an additional 2.5% lost in 2-m SLR, or about 16% of total Estuarine area in LCC pilot project area (Table 16). Most of the loss (80%) will occur within the mesohabitat Estuarine Vegetated Marsh which will primarily affect the birds that depend on Intertidal Emergent Marsh Regularly and Irregularly Flooded (Table 17). Mesohabitat type Estuarine Unvegetated Flats will lose 54.2% under 1-m SLR conditions, and a total of 61.7% at 2-m SLR; gains from upland inundation are not projected under this method (see Table 16). Mangrove microhabitats comprise most of the mesohabitat type Estuarine Vegetated Shrub, 38% of which will be lost at 1-m SLR and total of 47% at combined 1- and 2-m SLR. Since mangrove gains on newly inundated lands are not projected in this method, it is unknown what the overall extent of this estuarine shrub habitat will cover.

At 1-m SLR, 13.0% of total area will be lost within the macrohabitat Palustrine type and an additional 22.9% lost in 2-m SLR, or about 36% of total Palustrine area in LCC pilot project area (Table 18). Highest percentage of losses occur within the mesohabitat Wetland Vegetated Aquatic (33.1%, 1-m SLR;28.7%, 2-m SLR); highest areal extent lost is projected in the Wetland Vegetated Marsh mesohabitat type. Microhabitat types most impacted by 1- and 2-m SLR include those Temporarily Flooded (~24,000 ac total) and Seasonally Flooded (~16,000 ac total) (Table 19). These losses primarily affected freshwater wetland specialists and those species that depend on both freshwater and estuarine wetlands during their residence period in the LCC pilot project area.

Table 16. Areal extent losses of macro- and mesohabitat types for Estuarine within 0-1 and 1-2 contour areas in LCC pilot project area.

Macrohabitat Type Mesohabitat Type	Current Area (ac)	0-1 m Contour Area (ac) (% loss)	1-2 m Contour Area (ac) (% loss)	Total % Loss 0-2 m	Mesohabitat Loss (%) within Macrohabitat Loss by Contour 0-1 m Contour	 1-2 m Contour
Macrohabitat: Estuarine	**691,420**	**92,173**	**17,101**			
		(13.3)	**(2.5)**	**15.8%**		
Mesohabitat Type: Estuarine Open Water	490,086	8,904	1,758		9.7%	10.3%
		(1.8)	(0.4)	2.2%		
Mesohabitat Type: Estuarine Reef[a]	6,771	67	2		0.1%	0.0%
		(1.0)	(0.0)	1.0%		
Mesohabitat Type: Estuarine Unvegetated Flats	31,626	17,128	2,364		18.6%	13.8%
Mesohabitat Type: Estuarine Vegetated Marsh	104,440	60,698	12,275		65.9%	71.8%
Mesohabitat Type: Estuarine Vegetated Seagrass[a]	51,980	2,901	87		3.1%	0.5%
Mesohabitat Type: Estuarine Vegetated Shrub	6,517	2,475 (38.0)	614 (9.4)	47.4%	2.7%	3.6%

[a] Incomplete coverage

Table 17. Areal extent losses for Estuarine Vegetated Marsh microhabitat types.

Mesohabitat Type	Current Area (ac)	0-1 m Contour Extent (ac)	1-2 m Contour Extent (ac)	Total Cumulative Loss (ac)
Mesohabitat Type: Estuarine Vegetated Marsh	104,439	60,698	12,275	72973
Coastal: Borrichia Flats	*6,125*	*506*	*1,108*	*1,614*
Coastal: Salt and Brackish High Tidal Marsh	*20,018*	*3,220*	*5,746*	*8,966*
Coastal: Salt and Brackish Low Tidal Marsh	*2,894*	*1,269*	*826*	*2,095*
Estuarine Intertidal Emerg Marsh Irregularly Exposed	*1,723*	*883*	*1*	*884*
Estuarine Intertidal Emerg Marsh Irregularly Flooded	*30,930*	*23,949*	*3,934*	*27,883*
Estuarine Intertidal Emerg Marsh Regularly Flooded	*42,748*	*30,869*	*657*	*31,526*

Table 18. Areal extent losses of macro- and mesohabitat types for Palustrine within 0-1 and 1-2 contour areas in LCC pilot project area.

Macrohabitat Type Mesohabitat Type	Current Area (ac)	0-1 m Contour Area (ac) (% loss)	1-2 m Contour Area (ac) (% loss)	Total % Loss 0-2 m	Mesohabitat Loss (%) within Macrohabitat Loss by Contour: 0-1 m Contour	Mesohabitat Loss (%) within Macrohabitat Loss by Contour: 1-2 m Contour
Macrohabitat Type: Palustrine Wetland	**184,875**	**24,024 (13.0)**	**42,261 (22.9)**	**35.9**%		
Mesohabitat: Wetland Open Water	3,451	599 (17.4)	579 (16.8)	34.2%	2.5%	1.4%
Mesohabitat Type: Wetland Unvegetated	4,568	312 (6.8)	474 (10.4)	17.2%	1.3%	1.1%
Mesohabitat Type: Wetland Veg Aquatic	694	229 (33.1)	199 (28.7)	61.8%	1.0%	0.5%
Mesohabitat Type: Wetland Vegetated Marsh	116,852	18,874 (16.2)	32,181 (27.5)	43.7%	78.6%	76.1%
Mesohabitat Type: Wetland Vegetated Marsh/Vegetated Shrub	6,482	827 (12.8)	890 (13.7)	26.5%	3.4%	2.1%
MesoHabitat Type: Wetland Vegetated Shrub	17,653	491 (2.8)	2,275 (12.9)	15.7%	2.0%	5.4%
Mesohabitat Type: Wetland Vegetated Shrub/Vegetated Marsh	1,279	62 (4.8)	118 (9.2)	14.1%	0.3%	0.3%
Mesohabitat Type: Wetland Vegetated Woodland	15,662	510 (3.3)	2,037 (13.0)	16.3%	2.1%	4.8%
Mesohabitat Type: Wetland Vegetated Woodland/Vegetated Shrub	18,234	2,119 (11.6)	3,509 (19.2)	30.9%	8.8%	8.3%

Table 19. Areal extent losses for Wetland Vegetated Marsh microhabitat types.

Mesohabitat Type	Current Area (ac)	0-1 m Contour Extent (ac)	1-2 m Contour Extent (ac)	Total Cumulative Loss (ac)
Mesohabitat Type: Wetland Vegetated Marsh		**18,874**	**32,180.6**	**51,054.6**
Coastal and Sandsheet: Deep Sand Live Oak Swale Marsh	*1,161*	*6*	*36*	*42*
Coastal Bend: Floodplain Grassland	*7,974*	*292*	*1,317*	*1,609*
Coastal Bend: Floodplain Herbaceous Wetland	*1,925*	*242*	*292*	*534*
Coastal Bend: Riparian Grassland	*3,615*	*12*	*83*	*95*
Coastal Bend: Riparian Herbaceous Wetland	*73*	*0*	*0.4*	*0*
Marsh	*6*	*0*	*0.3*	*0*
Palustrine Emergent Marsh Intermittently Flooded	*5,920*	*1,304*	*1,957*	*3,261*
Palustrine Emergent Marsh Mixed Flooded Tidal	*1,205*	*910*	*223*	*1,133*
Palustrine Emergent Marsh Seasonally Flooded	*38,995*	*6,416*	*9,759*	*16,175*
Palustrine Emergent Marsh Semipermanently Flooded	*5,949*	*1,413*	*1,808*	*3,221*
Palustrine Emergent Marsh Temp Flooded	*48,095*	*8,259*	*15,556*	*23,815*
Palustrine Farmed	*1,929*	*14*	*1,144*	*1,158*

Within the macrohabitat Marine type 1.8% of total area will be lost in 1-m SLR, and an additional 1.2% lost in 2-m SLR, or about 3.0% of total area in LCC pilot project area (Table 20). Since this method only calculates loss, it is probable that the Marine Unvegetated Shore will prograde inland as sea level rises and habitat will not be lost for birds using this microhabitat type. However, the losses documented for macrohabitat types Lacustrine and Riverine will not be compensated for elsewhere on the landscape as sea level rises. Lacustrine macrohabitat type will lose almost one-quarter of the total areal extent at 2-m SLR, a majority of that in mesohabitat type Lake Open Water at both 1- and 2-m SLR. We project that Riverine macrohabitat type will decrease over one-half of the total extent by 2-m SLR, primarily in Riverine Open Water mesohabitat as estuarine waters inundate these areas during sea-level rise.

Table 20. Areal extent losses of macro- and mesohabitat types for Marine, Lacustrine, and Riverine within 0-1 and 1-2 contour areas in LCC pilot project area.

Macrohabitat Type Mesohabitat Type	Current Area (ac)	0-1 m Contour Area (ac) (% loss)	1-2 m Contour Area (ac) (% loss)	Total % Loss 0-2 m	Mesohabitat Loss (%) within Macrohabitat Loss by Contour 0-1 m Contour	 1-2 m Contour
Macrohabitat: Marine	**80,669**	**1,437**	**959**			
		(1.8)	**(1.2)**	**3.0%**		
Mesohabitat Type: Marine Open Water	78,245	318	8		22.2%	0.9%
		(0.4)	(0.0)	0.4%		
Mesohabitat Type: Marine Rocky Shore	8	4	3		0.3%	0.3%
		(57.1)	(35.2)	92.3%		
Mesohabitat Type: Marine Unvegetated Shore	2,417	1,114	948		77.5%	98.9%
		(46.1)	(39.2)	85.3%		
Macrohabitat Type: Lacustrine	**18,658**	**2,262**	**1,917**			
		(12.1)	**(10.3)**	**22.4%**		
Mesohabitat Type: Lake Aquatic Bed	1,363	78	195		3.4%	10.2%
		(5.7)	(14.3)	20.0%		
Mesohabitat Type: Lake Open Water	15,089	2,049	971		90.6%	50.6%
		(13.6)	(6.4)	20.0%		
Mesohabitat Type: Lake Unvegetated Flats	2,206	136	752		6.0%	39.2%
		(6.2)	(34.1)	40.3%		
Macrohabitat Type: Riverine	**2,744**	**1,020**	**432**			
		(37.2)	**(15.7)**	**52.9%**		
Mesohabitat Type: Riverine Open Water	2,691	1,001	411		98.2%	95.0%
		(37.2)	(15.3)	52.5%		
Mesohabitat: Riverine Unvegetated	53	19	21		1.8%	5.0%
		(35.4)	(40.3)	75.7%		

Impacts on 1- and 2-m sea level rise on all species were not conducted; however, changes at the micro-habitat type level were calculated and summarized in Appendix C. The five species selected to assess the conservation design approach at this level illustrate landscape changes that will occur to species' distribution within the GCPLCC pilot project area.

Aplomado Falcon

The Aplomado Falcon high use habitat areas will be impacted primarily on the barrier Islands (Figure 41). However, 8% of high use habitat types is predicted at 1 m SLR but up to 28% loss of high use habitat types at 2 m SLR (Table 21). This is significant as the barrier islands support the vast majority of the nesting falcons in the project area. Because the distribution of Aplomado Falcons is primarily the result of reintroduction efforts and therefore future location could be influenced, it would be possible to initiate reintroduction efforts in other areas with less susceptibility to loss by sea level rise in the future.

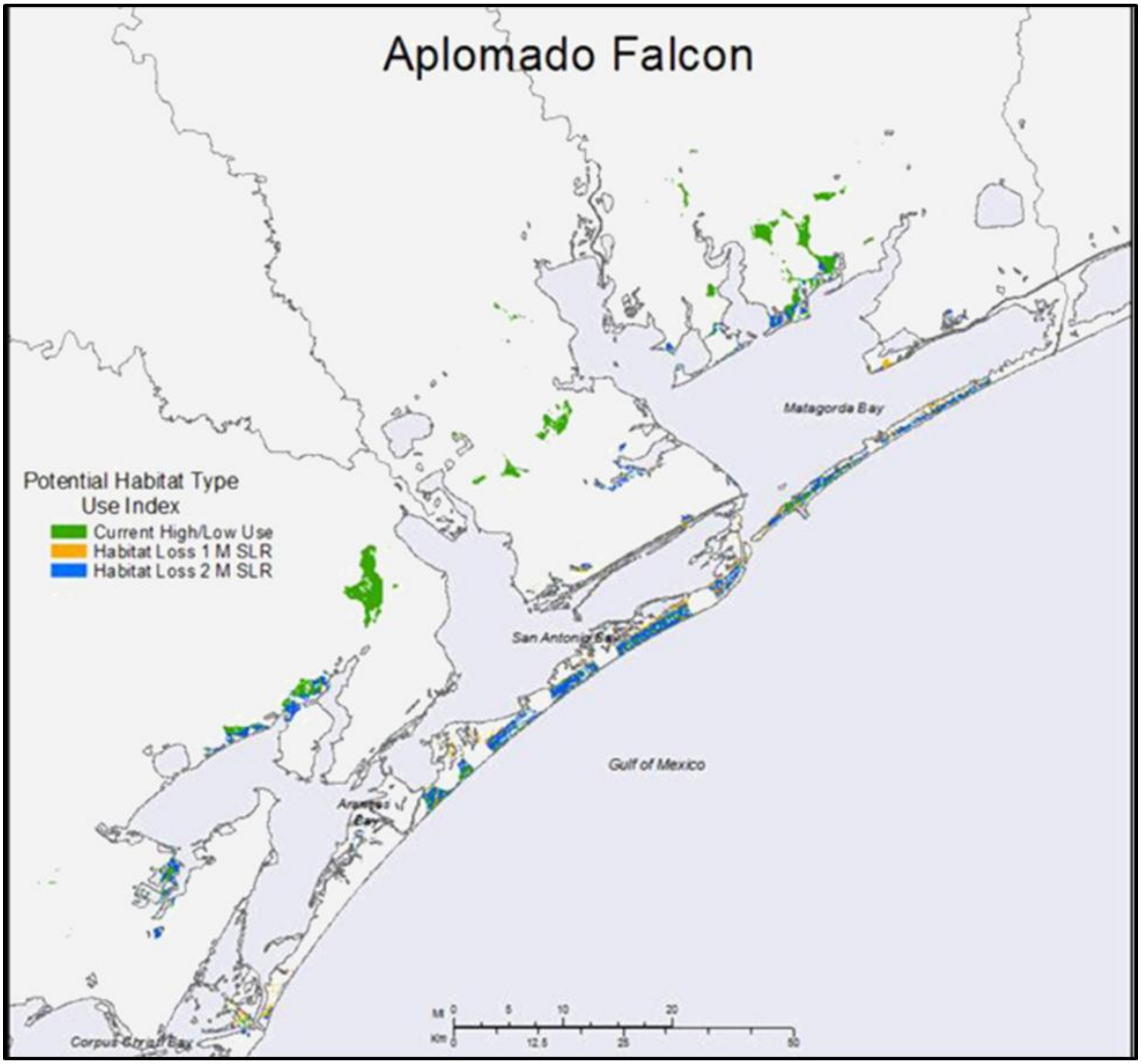


Figure 41. Potential impacts of sea-level rise on habitats selected by Aplomado Falcon in GCP pilot project area.

Table 21. Habitat Use availability, potential use index and predicted loss from 1- and 2-m sea level rise scenarios for Aplomado Falcon with woodland buffer applied.

Microhabitat	Mesohabitat	Macrohabitat	Index	Extent (acres)	0-1 m Loss (ac)	1-2 m Loss (ac)	Total Cumulative Loss (ac)
Gulf Coast: Coastal Prairie	Upland Grassland	Upland	3	12,601.8	3.2	196.1	199.3
Gulf Coast: Salty Prairie	Upland Grassland	Upland	3	17,654.7	2,312.3	7,951.6	10,263.9
Coastal and Sandsheet: Deep Sand Grassland	Upland Grassland	Upland	3	23,497.4	1,652.4	6,995.2	8,647.6
Gulf Coast: Salty Shrubland	Upland Shrub	Upland	2	472.9	15.3	206.2	221.5
Total				54,226.8	3,983.2	15,349.2	19,332.3

Northern Bobwhite

The Northern Bobwhite high use habitat types are primarily impacted along the barrier islands (Figure 42). High use habitats within the project area is relatively small with <1.0% predicted to be impacted at 1 m SLR, while only marginally more to be impacted at 2 m SLR (Table 22). If we assume that each acre of high use habitat can support one quail the impacts would be 376 and 1678 at 1 and 2 m SLR, respectively. Potential population level effects would be minimal considering an estimated North American population of more than 5 million individuals. However, in Texas the Northern Bobwhite is considered to be declining significantly every year, so even small losses in potential high use habitat acres could be significant in the long term.

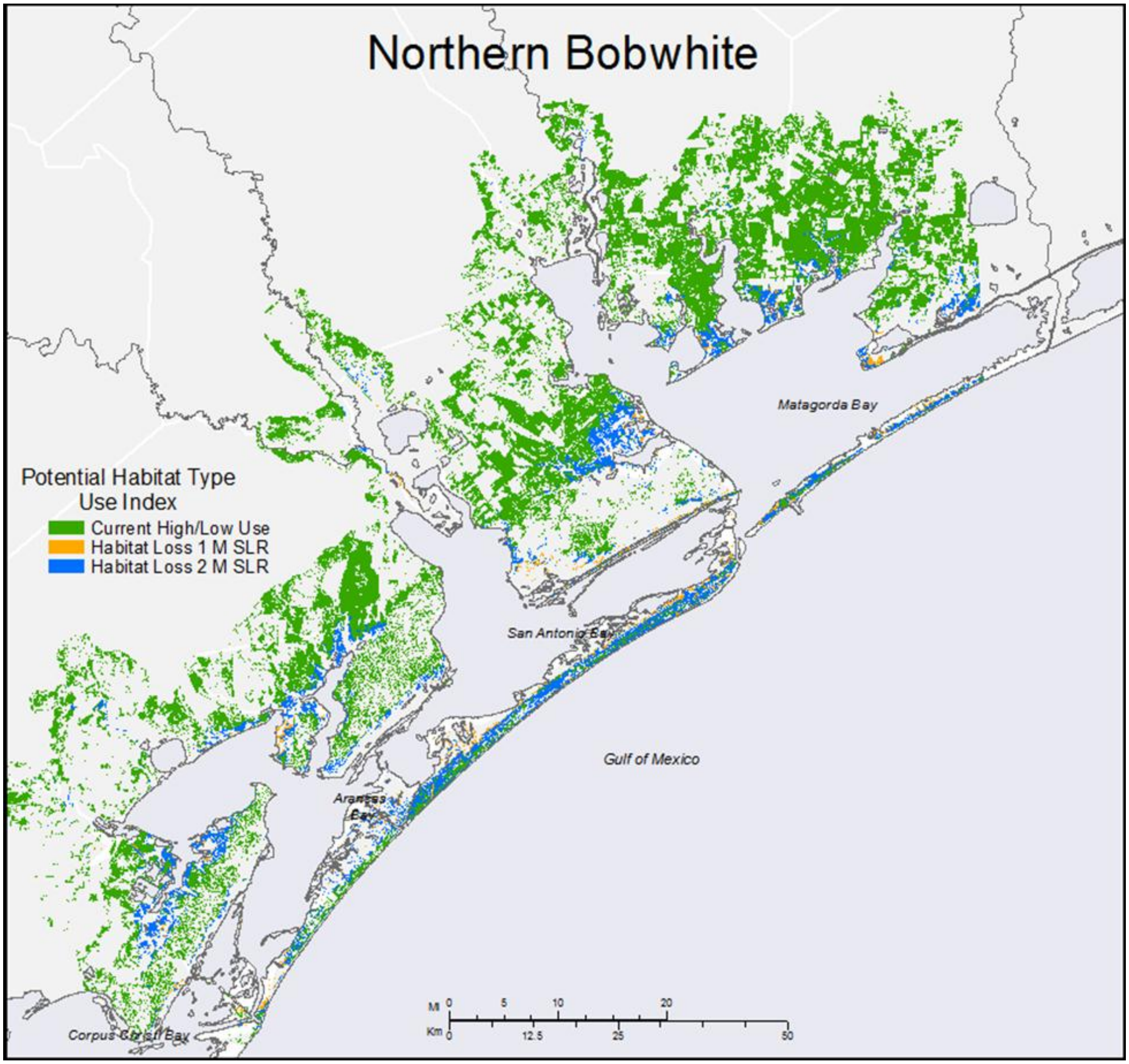


Figure 42. Potential Impacts of sea-level rise on habitats selected by Northern Bobwhite in GCP pilot project area**.**

Table 22. Habitat Use availability, potential use index and predicted loss from 1- and 2-m sea level rise scenarios for Northern Bobwhite.

Microhabitat	Mesohabitat	Macrohabitat	Index	Current (ac)	0-1 m Loss (ac)	1-2 m Loss (ac)	Total Cumulative Loss (ac)
Gulf Coast: Coastal Prairie	Upland Grassland	Upland	2	210,801.4	244.2	2,293.3	2,537.5
Gulf Coast: Salty Prairie	Upland Grassland	Upland	2	106,625.0	5,773.7	30,787.1	36,560.8
Coastal and Sandsheet: Deep Sand Grasslands	Upland Grassland	Upland	2	39,848.4	3,133.3	16,946.3	20,079.6
Texas Coast Dune and Coastal Grassland Active Dune	Upland Grassland	Upland	3	92.7	5.7	44.0	49.7
South Texas: Sandy Mesquite Savanna Grassland	Upland Grassland	Upland	3	38.6	0.0	0.0	0.0
Post Oak Savanna: Savanna Grassland	Upland Grassland	Upland	3	16	0.0	0.0	0.0
Coastal Bend: Floodplain Grassland	Palustrine Vegetated Marsh	Freshwater Wetland	2	7,974.8	292.6	1,317.3	1,609.9
Coastal Bend: Riparian Grassland	Palustrine Vegetated Marsh	Freshwater Wetland	2	3,615.7	12.6	83.0	95.6
Coastal Plain: Terrace Sandyland Grassland	Upland Grassland	Upland	2	947.5	0.0	6.0	6
Coastal Bend: Riparian Deciduous Shrubland	Palustrine Vegetated Shrub	Freshwater Wetland	2	479.9	256.8	320.4	577.2
Coastal Bend: Riparian Evergreen Shrubland	Palustrine Vegetated Shrub	Freshwater Wetland	2	230.2	117.6	170.9	288.5
Gulf Coast: Coastal Prairie	Upland Grassland	Upland	2	210,801.4	244.2	2,293.3	2,537.5
Gulf Coast: Salty Prairie	Upland Grassland	Upland	2	106,625.0	5,773.7	30,787.1	36,560.8
Coastal and Sandsheet: Deep Sand Grasslands	Upland Grassland	Upland	2	39,848.4	3,133.3	16,946.3	20,079.6

Microhabitat	Mesohabitat	Macrohabitat	Index	Current (ac)	0-1 m Loss (ac)	1-2 m Loss (ac)	Total Cumulative Loss (ac)
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	Upland Shrub	Upland	2	20,221.8	166.5	1,859.8	2,026.3
Coastal and Sandsheet: Deep Sand Shrubland	Upland Shrub	Upland	2	4,731.4	147.2	1,469.4	1,616.6
Coastal and Sandsheet: Deep Sand Live Oak / Mesquite Woodland	Upland Woodland	Upland	2	313.5	0.0	0.0	0.0
South Texas: Sandy Mesquite / Evergreen Woodland	Upland Woodland	Upland	2	147.6	0.0	0.0	0.0
Total				397,957.6	10,5212.1	55,924.2	66,446.3

Loggerhead Shrike

The Loggerhead Shrike high use habitat areas will be impacted primarily on the barrier Islands (Figure 43). However, only minimal loss (< 1%) of high use habitat types is predicted at 1 m SLR and an additional 7% loss of high use habitat types at 2 m SLR (Table 23). The potential effect is relatively small at 1 m SLR as the acreage loss of high use habitat types would support 46 resident size territories or 187 wintering bird size territories. At 2 m SLR acreage losses of high use habitat types represent an additional 460 or 1843 resident and wintering size territories, respectively. The project area is only a small section of this species range and the net effect at the population level may be small considering the species North American population is estimated at 2.9 million individuals. However, this species is of special concern as it is declining throughout its range.

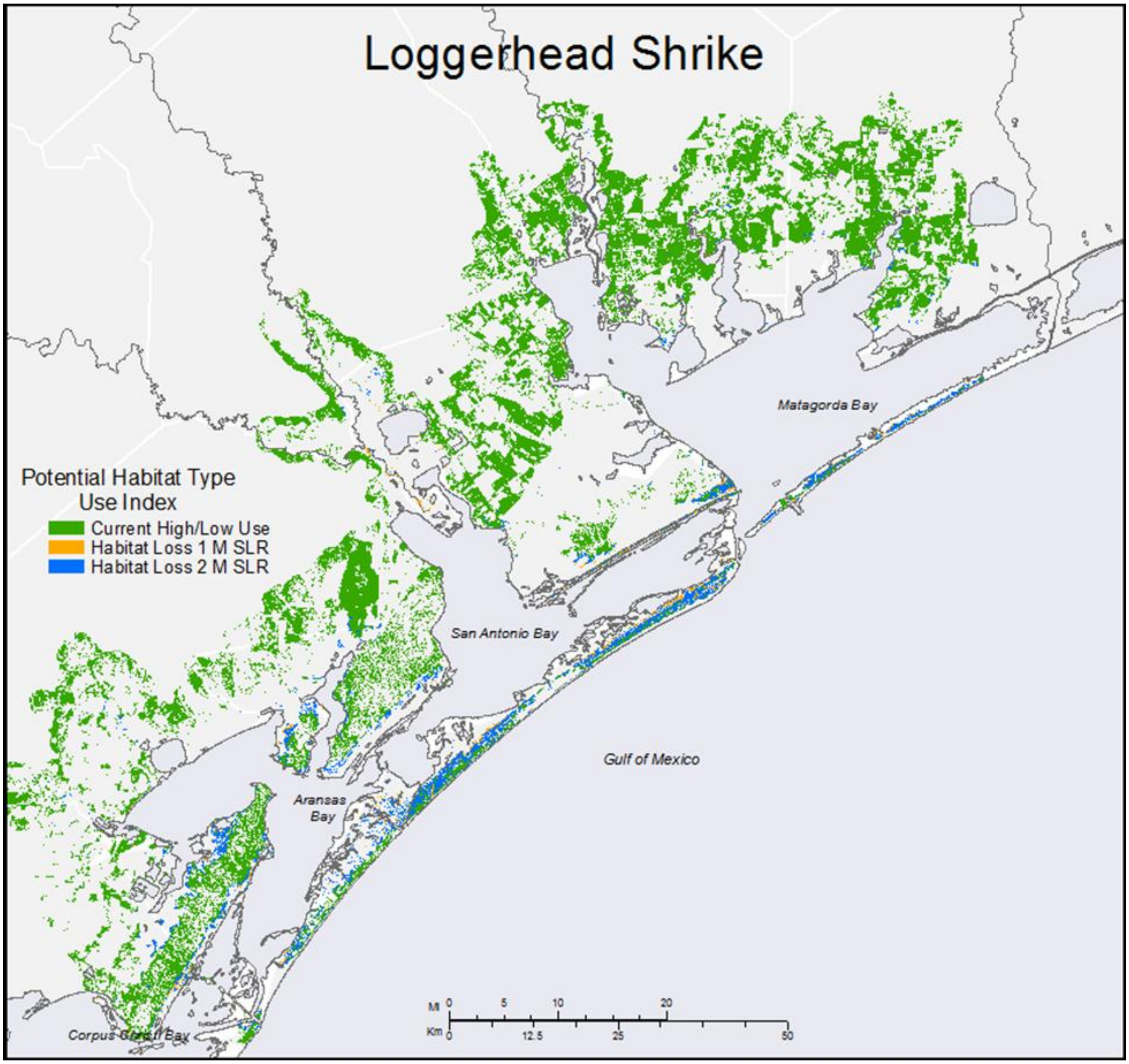


Figure 43. Potential impacts of sea-level rise on habitats selected by Loggerhead Shrike in GCP pilot project area.

Table 23. Habitat Use availability, potential use index and predicted loss from 1- and 2-m sea level rise scenarios for Loggerhead Shrike.

Microhabitat Type	Mesohabitat	Macrohabitat	Index	Current (ac)	0-1 m Loss (ac)	1-2 m Loss (ac)	Total Cumulative Loss (ac)
Coastal and Sandsheet: Deep Sand Live Oak Shrubland	Upland Shrub	Upland	3	20,221.8	166.5	1,859.8	2,026.3
Coastal and Sandsheet: Deep Sand Shrubland	Upland Shrub	Upland	3	4,731.4	147.2	1,469.4	1,616.6
Native Invasive: Huisache Woodland or Shrubland	Upland Shrub	Upland	3	6,963.6	0.7	74.8	75.5
Native Invasive: Mesquite Shrubland	Upland Shrub	Upland	3	19,327.2	61.5	285.1	346.6
Coastal Bend: Floodplain Deciduous Shrubland	Palustrine Veg Shrub	Freshwater Wetland	2	2,907.4	256.8	320.4	577.2
Coastal Bend: Floodplain Evergreen Shrubland	Palustrine Veg Shrub	Freshwater Wetland	2	1,070.3	117.6	170.9	288.5
Urban Low Intensity	Upland Developed	Upland	2	22,333.3	772.8	3,112.1	3,884.9
Coastal and Sandsheet: Deep Sand Grasslands	Upland Grassland	Upland	2	39,848.4	3,133.3	16,946.3	20,079.6
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	Upland Grassland	Upland	2	1,873.1	371.9	626.7	998.6
Gulf Coast: Coastal Prairie	Upland Grassland	Upland	2	210,801.4	244.2	2,293.3	2,537.5
Total				330,077.9	5,272.3	27,158.6	32,430.9

Le Conte's Sparrow

Potential habitat loss for Le Conte's Sparrow is predicted to occur to a large extent on the barrier islands (Figure 44). The most significant losses occur in the Upland Grassland Mesohabitat where losses are 8% at 1 m SLR with an additional 42 % loss at 2 m SLR (Table 24). Only small potential population effects are likely at 1 m SLR as the area to support 140 – 584 home ranges would be lost, but more significantly an additional area of high use habitat types sufficient to support 702 – 2928 could be lost at 2 m SLR within the project area. Since this species range is only marginally within the project area it is not clear that the potential estimated predicted losses would have significant population level effect overall particularly when the North American population is estimated at 3 million individuals.

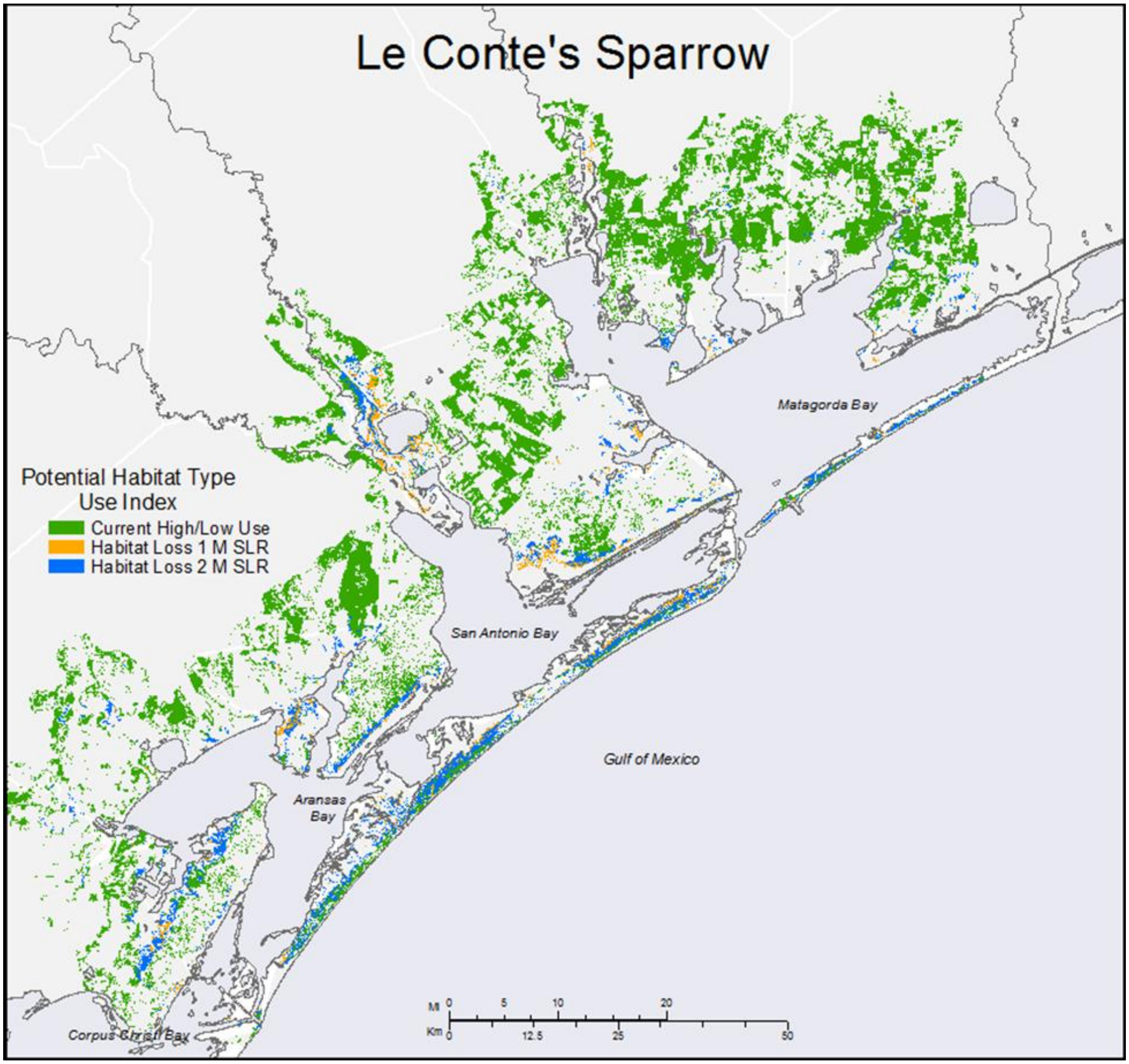


Figure 44. Potential impacts of sea-level rise on habitats selected by Le Conte's Sparrow in GCP pilot project area.

Table 24. Habitat Use availability, potential use index and predicted loss from 1- and 2-m sea level rise scenarios for Le Conte's Sparrow.

MicroHabitat	Mesohabitat	Macrohabitat	Index	Current (ac)	0-1 m Loss (ac)	1-2 m Loss (ac)	Total Cumulative Loss
Coastal and Sandsheet: Deep Sand Grasslands	Upland Grassland	Upland	3	39,848.4	3,133.3	16,946.3	20,079.6
Coastal and Sandsheet: Deep Sand Grasslands Swale Marsh	Upland Grassland	Upland	3	1,873.1	371.9	626.7	998.6
Palustrine Emergent Marsh Temp Flooded	Palustrine Vegetated Marsh	Freshwater Wetland	2	48,095.2	8,259.8	15,556.6	23,816.4
Palustrine Emergent Marsh Intermit Flooded	Palustrine Vegetated Marsh	Freshwater Wetland	2	5,920.1	1,304.8	1,957.5	3,262.3
Gulf Coast: Coastal Prairie	Upland Grassland	Upland	2	210,801.4	244.2	2,293.3	2,537.5
Total					13,313.9	37,380.4	50,694.3

<u>Seaside Sparrow</u>

The loss of habitat for the Seaside Sparrow unlike the other species will be throughout its range within the project area (Figure 45) as it is found primarily on the coastal edges. Loss of high use potential habitat is significant at 1 m SLR with as much as 68% loss, plus an additional minimal loss at 2 m SLR of <1% loss (Table 25). This species and others that are specialized on the intertidal zone are likely to be heavily impacted by any significant increases in SLR. If we assume a 2.5 ac (1 ha) territory for this species in the project area every 2.5 acre loss of habitat types would equal a potential territory loss for the species.

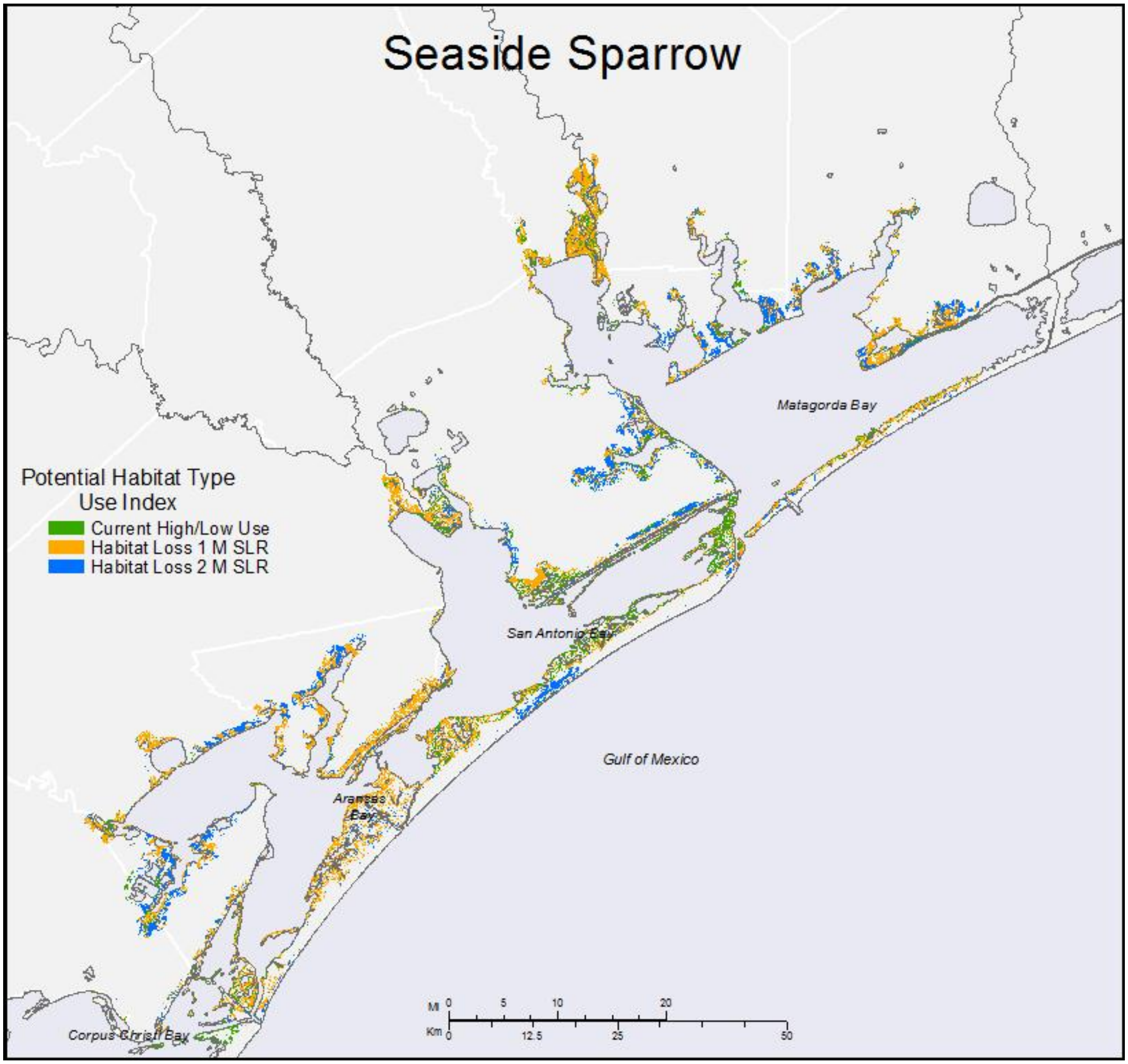


Figure 45. Potential impacts of sea-level rise on habitats selected by Seaside Sparrow in GCP pilot project area (note: only losses are depicted in estuarine marshes areas, refer to Whooping Crane sea-level rise section for additional habitat gain (if any) from estuarine marshes shifting inland over low-lying uplands).

Table 25. Habitat Use availability, potential use index and predicted loss only from 1- and 2-m sea level rise scenarios for Seaside Sparrow. Refer to Whooping Crane changes in habitat for sea-level rise scenarios for estuarine intertidal habitat.

MicroHabitat	Mesohabitat	Macrohabitat	Index	Current (ac)	1-m Loss (ac)	2-m Loss (ac)	Total Cumulative Loss (ac)
Estuarine Intertidal Emergent Marsh Regularly Flooded[a]	Estuarine Veg Marsh	Estuarine		38,141.1	27,266.3	477.8	27,744.1
Estuarine Intertidal Emergent Marsh Irregularly Flooded[a]	Estuarine Veg Marsh	Estuarine	3	23,658.7	18,570.6	2,456.4	21,027.0
Coastal: Salt and Brackish High Tidal Marsh	Estuarine Veg Marsh	Estuarine	3	8,990.5	2,755.4	3,675.1	6,430.5
Coastal: Salt and Brackish Low Tidal Marsh	Estuarine Veg Marsh	Estuarine	3	2,029.4	1,060.8	556.2	1,617.0
Mangroves[b]	Estuarine Veg Marsh	Estuarine	2	4,137.1	1,863.6	6.2	1,869.8
Estuarine Intertidal Scrub-Shrub (broad leaved evergreen) Regularly Flooded	Estuarine Veg Marsh	Estuarine	2	385.3	214.8	20.1	234.9
Estuarine Intertidal Scrub-Shrub (broad leaved evergreen) Irregularly Flooded	Estuarine Veg Marsh	Estuarine	2	319.4	92.7	99.3	192.0
Texas Coast Dune and Coastal Grassland Active Dune	Upland Grassland	Upland	1	79.4	5.7	43.4	49.1
Coastal: Borrichia Flats	Estuarine Veg Marsh	Estuarine	1	2,367.9	469.7	842.1	1,311.8
Estuarine Intertidal Emergent Marsh Irregularly Exposed	Estuarine Veg Marsh	Estuarine	1	1,657.0	850.4	1.2	851.6
Native Invasive: Common Reed	Palustrine Veg Marsh	Palustrine	1	2,773.7	89.9	1,072.0	1,161.9
Gulf Coast: Coastal Prairie	Upland Grassland	Upland	1	21,838.6	117.3	940.5	1,057.8
Gulf Coast: Salty Prairie	Upland Grassland	Upland	1	37,018.1	4,762.6	18,157.5	22,920.1
Total				143,396.2	58,119.6	28,347.8	86,467.4

[a] This method does not account for potential gains in estuarine habitat from sea level rise

[b] Incomplete coverage

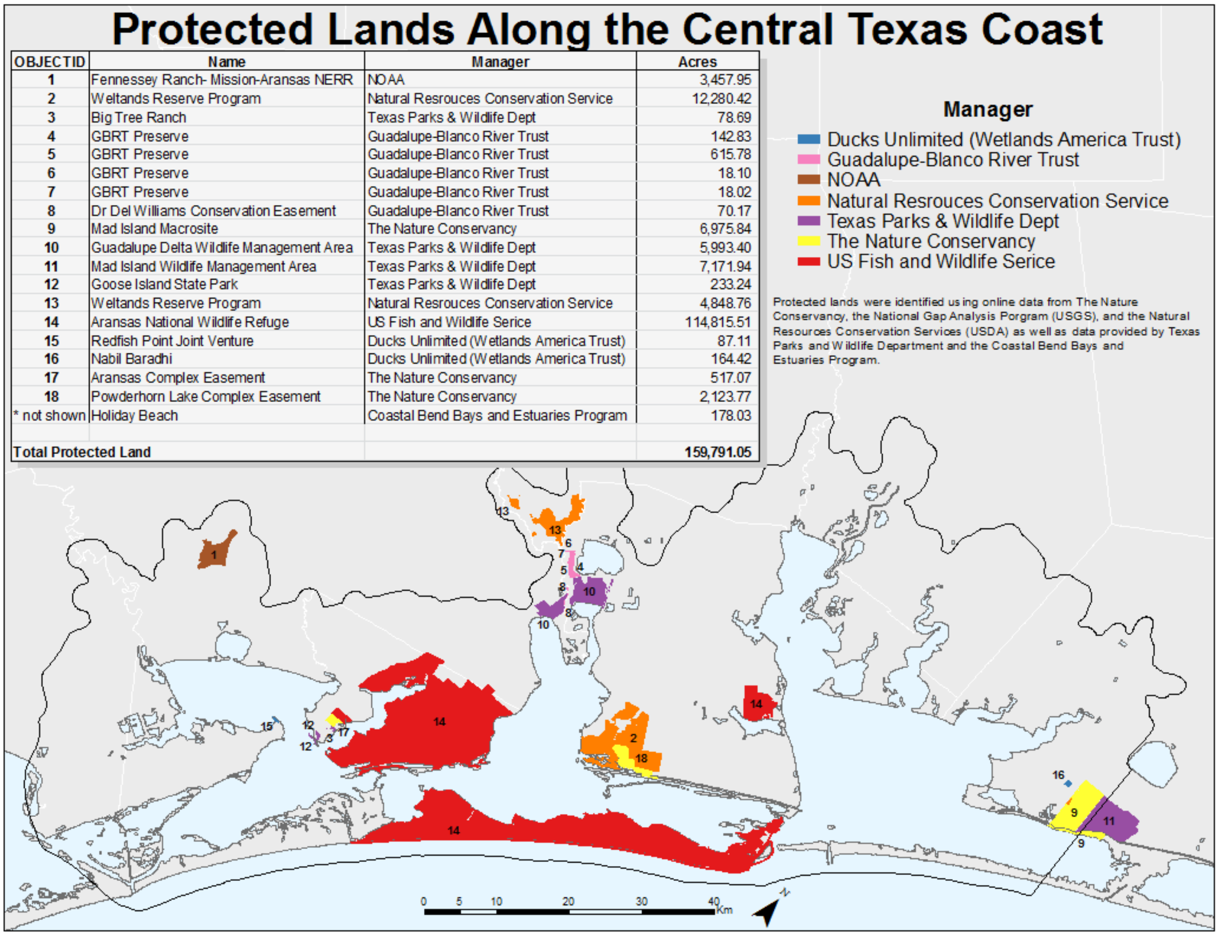
Protected Lands Conservation Mapping

A total of 18 tracts of land were identified as protected if they met the following criteria: acquisition or conservation easement with the intent to be conserved into perpetuity and managed for natural attributes (Table 26). We were not able to identify submerged land tracts which are managed by the Texas General Land Office in this study. The tracts available in web-based queries included 11 classified as acquisition and seven as conservation easements and managed by two federal agencies, one state, and four nongovernmental organizations. When the database acreage was compared to reported acres collected from independent web queries, differences ranged from 0.16 to 19.1%, which effectively encompassed between 9.15 to 9.29% of the total GCPLCC project area.

A large extent of protected lands is located within Aransas Matagorda Island National Wildlife Refuge Complex that encompasses Blackjack Peninsula and Matagorda Island as well as areas north of Powderhorn Lake and Lamar Peninsula (Figure 56). Additional conservation easements implemented by NRCS and TNC provide a large area of protection on Welder Flats area. In the northeastern portion of the pilot project area, TNC and TPWD (outside area) have secured a significant amount of land.

Table 26. Protected areas and areal extent within the GCPLCC pilot project area identified in web databases and compared to reported areal extent (sources listed in Appendix D).

Name	Manager	Database Acres	Reported Acres	Percent Difference
Fennessey Ranch- Mission-Aransas NERR	NOAA	3458	4,000	13.6%
Wetlands Reserve Program	NRCS	12,280	--	--
Wetlands Reserve Program	NRCS	4849	--	--
GBRT Preserve (4 preserves)	GBRT	795	--	--
Dr. Del Williams Conservation Easement	GBRT	70	--	--
Mad Island Macrosite	TNC	6976	7,063	1.2%
Guadalupe Delta Wildlife Management Area	TPWD	5993	7411	19.1%
Mad Island Wildlife Management Area	TPWD	7172	7,200	0.39%
Goose Island State Park	TPWD	233	242	3.7%
Big Tree Ranch	TPWD	79	80	1.6%
Aransas National Wildlife Refuge	USFWS	114,816	115,000	0.16%
Redfish Point Joint Venture	Ducks Unlimited	87	--	--
Nabil Baradhi Conservation Easement	Ducks Unlimited	164	--	--
Aransas Complex Easement	TNC	517	517	0.0
Powderhorn Lake Complex Easement	TNC	2124	2123	0.0
Area Total		159,613	161,883	



OBJECTID	Name	Manager	Acres
1	Fennessey Ranch- Mission-Aransas NERR	NOAA	3,457.95
2	Weltands Reserve Program	Natural Resrouces Conservation Service	12,280.42
3	Big Tree Ranch	Texas Parks & Wildlife Dept	78.69
4	GBRT Preserve	Guadalupe-Blanco River Trust	142.83
5	GBRT Preserve	Guadalupe-Blanco River Trust	615.78
6	GBRT Preserve	Guadalupe-Blanco River Trust	18.10
7	GBRT Preserve	Guadalupe-Blanco River Trust	18.02
8	Dr Del Williams Conservation Easement	Guadalupe-Blanco River Trust	70.17
9	Mad Island Macrosite	The Nature Conservancy	6,975.84
10	Guadalupe Delta Wildlife Management Area	Texas Parks & Wildlife Dept	5,993.40
11	Mad Island Wildlife Management Area	Texas Parks & Wildlife Dept	7,171.94
12	Goose Island State Park	Texas Parks & Wildlife Dept	233.24
13	Weltands Reserve Program	Natural Resrouces Conservation Service	4,848.76
14	Aransas National Wildlife Refuge	US Fish and Wildlife Serice	114,815.51
15	Redfish Point Joint Venture	Ducks Unlimited (Wetlands America Trust)	87.11
16	Nabil Baradhi	Ducks Unlimited (Wetlands America Trust)	164.42
17	Aransas Complex Easement	The Nature Conservancy	517.07
18	Powderhorn Lake Complex Easement	The Nature Conservancy	2,123.77
* not shown	Holiday Beach	Coastal Bend Bays and Estuaries Program	178.03
Total Protected Land			159,791.05

Figure 46. Protected areas within the GCPLCC pilot project area.

The overlap in the distribution of protected lands and Whooping Crane Potential high use habitat is depicted on Figure 47. Highlighted areas where land cover data were misclassified and comprised an area >3,000 ac were not included in the analyses. Currently, only about 27% of potential high use Whooping Crane habitat within the project area is under some sort of protected status and the remainder is primarily within private lands. Protected areas that encompass habitat suitable for High Use by Whooping Cranes are largely within the Aransas NWR as well as Welder Flats. Barrier island habitat on San Jose Island currently provide wintering habitat and territory expansion continues along this landform. Other potential areas are concentrated along minor bay areas, river deltas, and barrier peninsulas in Matagorda Bay which have not yet experienced continuous use by Whooping Cranes to date.

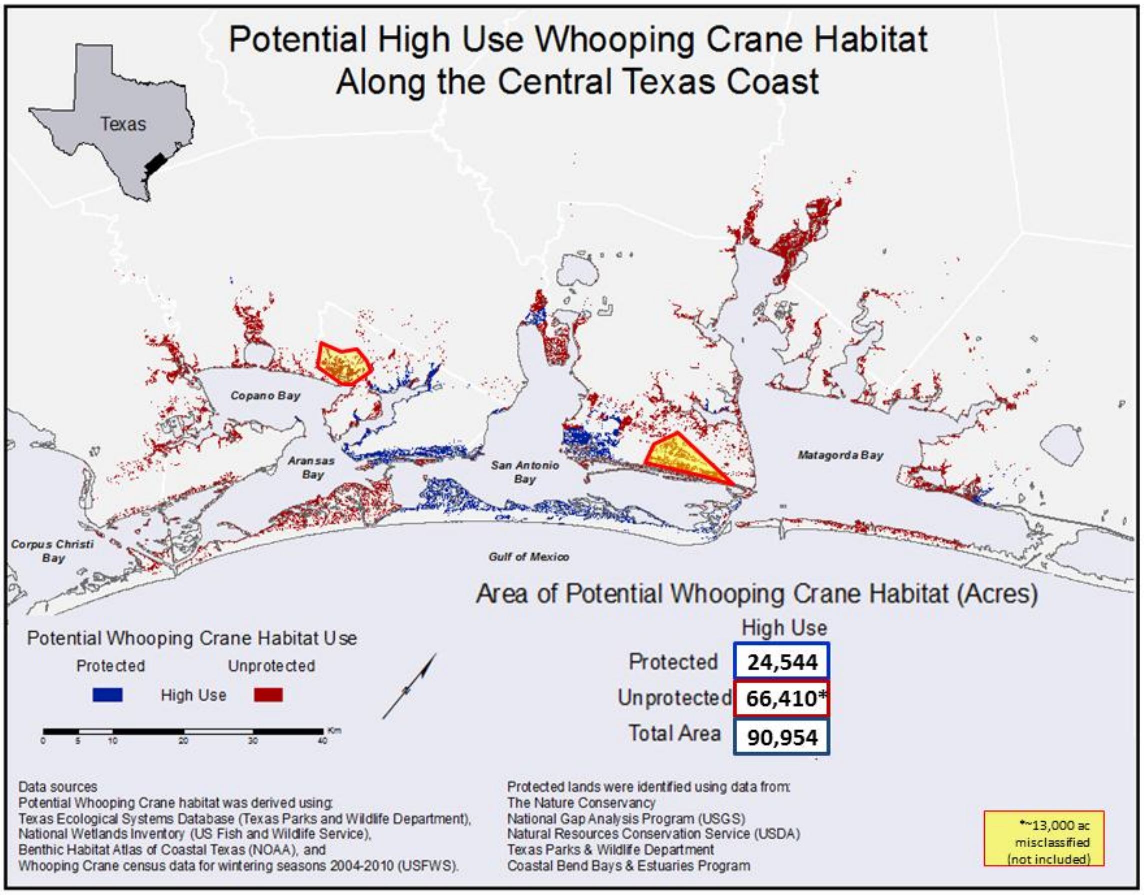


Figure 47. Distribution of potential Whooping Crane habitat use in protected and unprotected areas within the GCP pilot project area. See text for more explanation on highlighted areas.

For other selected species considered here, the proportion of potentially suitable high and low use habitat within protected areas in our project area was variable. The Aplomado Falcon had almost half of high and low use habitat types within protected areas (Figure 48). Some species had only 10-13% high and low use habitat type acres within protected area boundaries, such as Northern Bobwhite (Figure 49) Loggerhead Shrike (Figure 50) and Le Conte's Sparrow (Figure 51). The Seaside Sparrow has about one-quarter of high and low use potential habitat inside protected areas (Figure 52).

Habitat areas used by the Aplomado Falcon that are within permanently protected lands comprise 47% of the total area mapped for this species (Figure 48). Matagorda Island (within the Aransas NWR complex) comprises a linear extent of grasslands with minor shrublands along the interior, with few woodland patches that would potentially harbor predators (e.g., owls). Conservation efforts to protect larger portions of mainland depicted on the map as unprotected habitat for Aplomado Falcons should be incorporated with other species' conservation planning. Potential Aplomado Falcon habitat on Matagorda Peninsula also should be identified as a priority site for conservation, as it is geographically isolated from the mainland and relatively undeveloped.

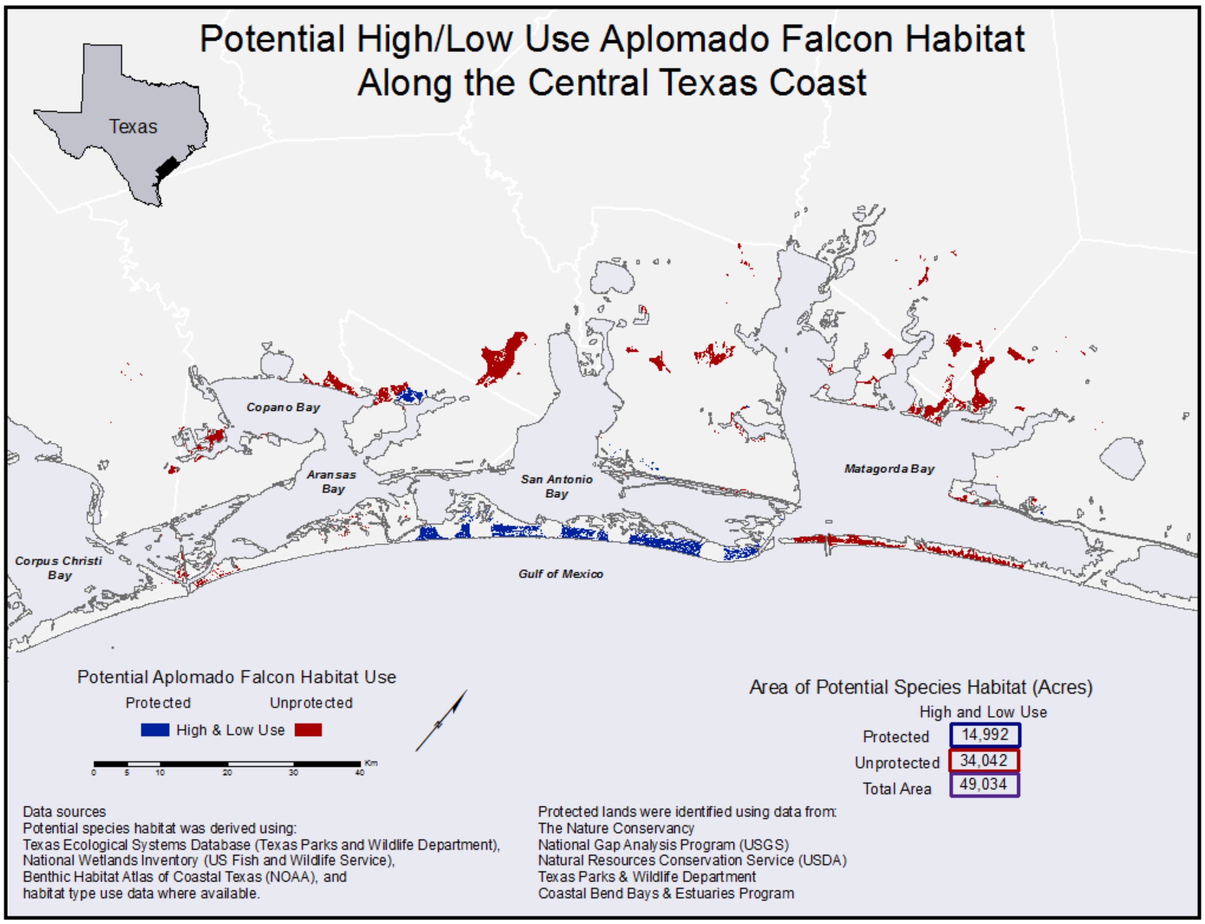


Figure 48. Distribution of potential Aplomado Falcon habitat use in protected and unprotected areas within the GCPLCC pilot project area.

Habitat areas used by the Northern Bobwhite that are within permanently protected lands comprise 13% of the total area mapped for this species (Figure 49). Most of the habitat types identified as high use are located on the barrier islands. Matagorda Island (within the Aransas NWR complex) comprises a contiguous linear extent of protected area; future protection of both San Jose Island and Matagorda Peninsula would provide more contiguous habitat within that high use designation.

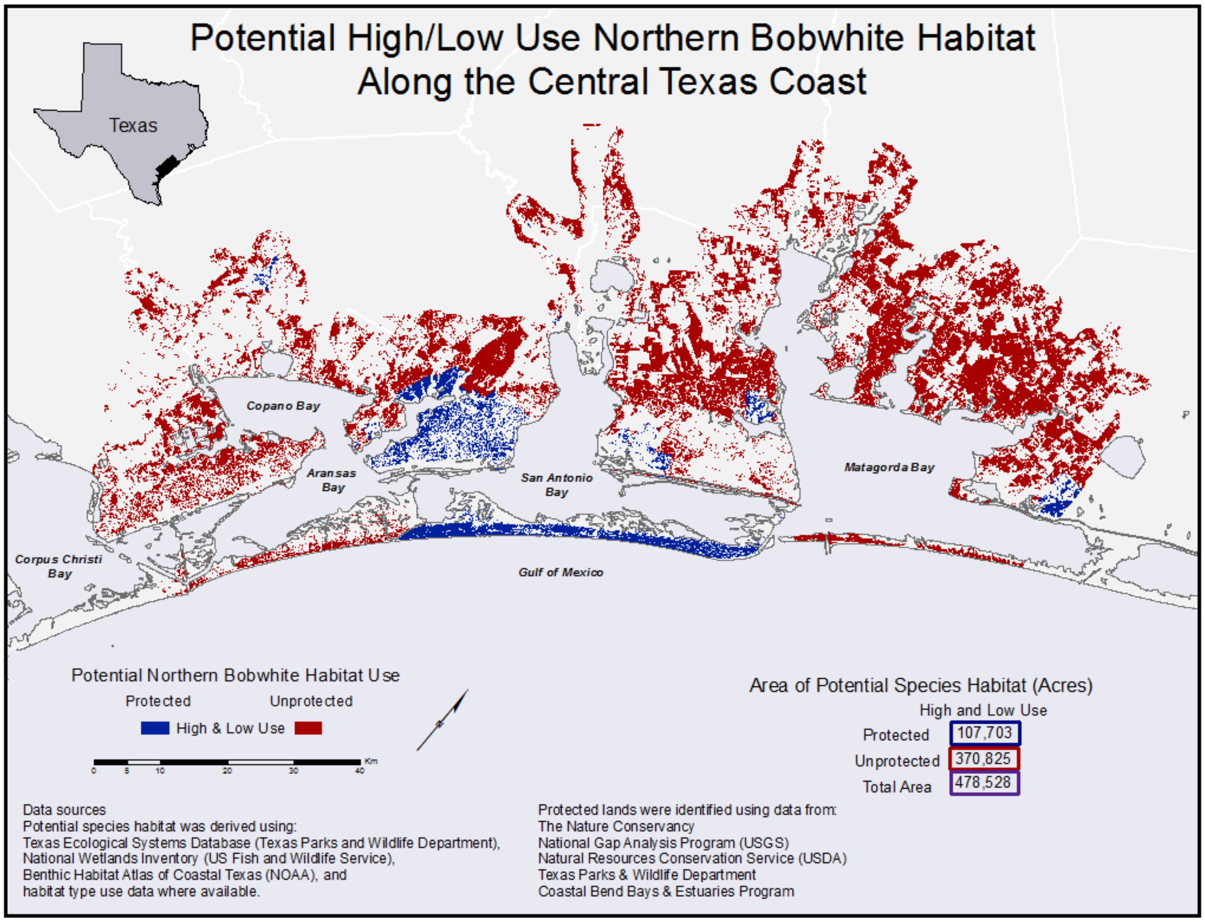


Figure 49. Distribution of potential Northern Bobwhite habitat use in protected and unprotected areas within the GCPLCC pilot project area.

Habitat areas used by the Loggerhead Shrike that are within permanently protected lands comprise 10% of the total area mapped for this species (Figure 50). Since the Aransas National Wildlife Refuge is the only large conservation site on the mainland, the remainder of the coastal interior habitat is within private lands. Efforts are underway to work with private landowners on management of coastal prairie that comprises a significant proportion of native shrublands designated as high use habitat for the Loggerhead Shrike.

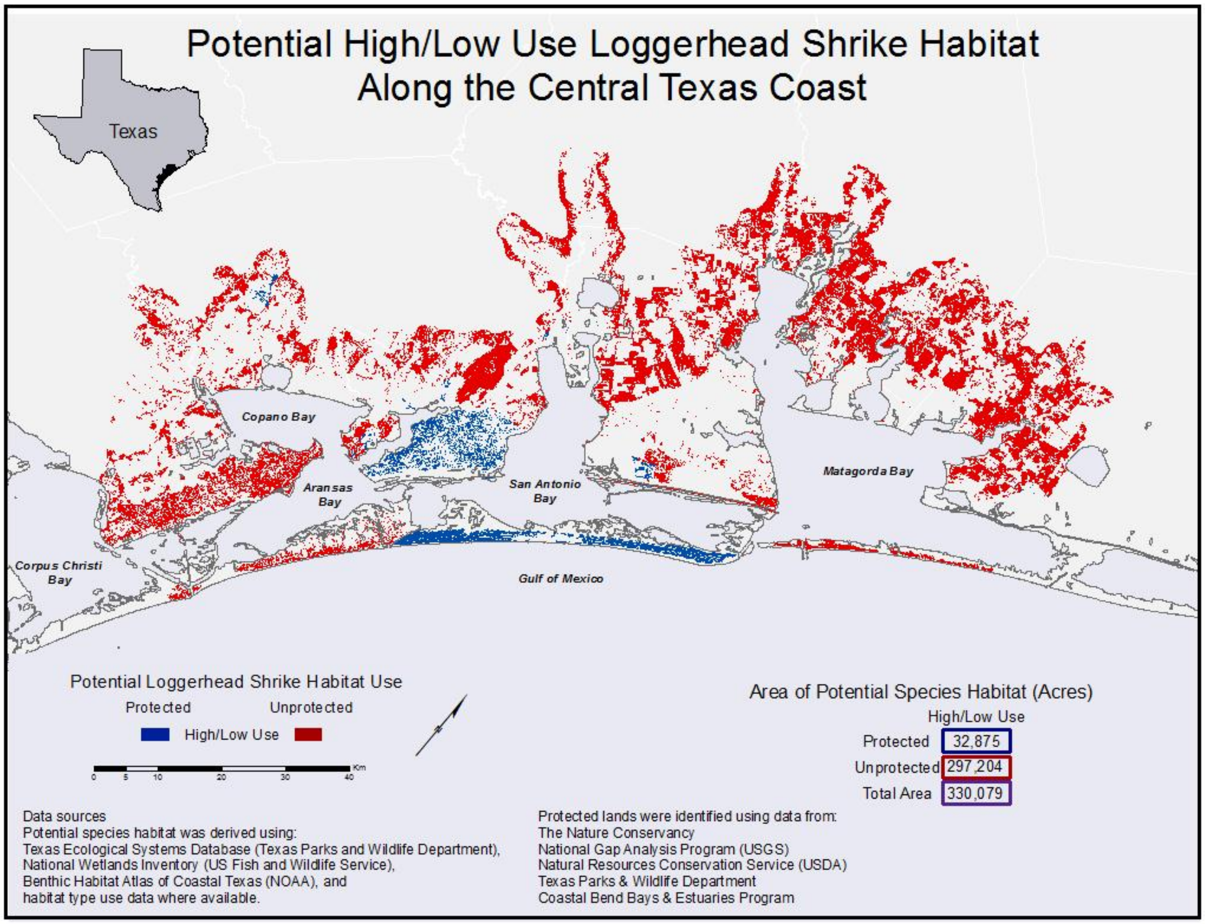


Figure 50. Distribution of potential Loggerhead Shrike habitat use in protected and unprotected areas within the GCPLCC pilot project area.

Habitat areas used by the Le Conte's Sparrow that are within permanently protected lands comprise 11% of the total area mapped for this species (Figure 51). Matagorda Island (within the Aransas NWR complex) comprises two main areas of conservation; future protection of both San Jose Island and Matagorda Peninsula would provide contiguous habitat with limited disturbance for the Le Conte's Sparrow. Several large areas have been identified on the mainland that would benefit from conservation efforts for Le Conte's Sparrow.

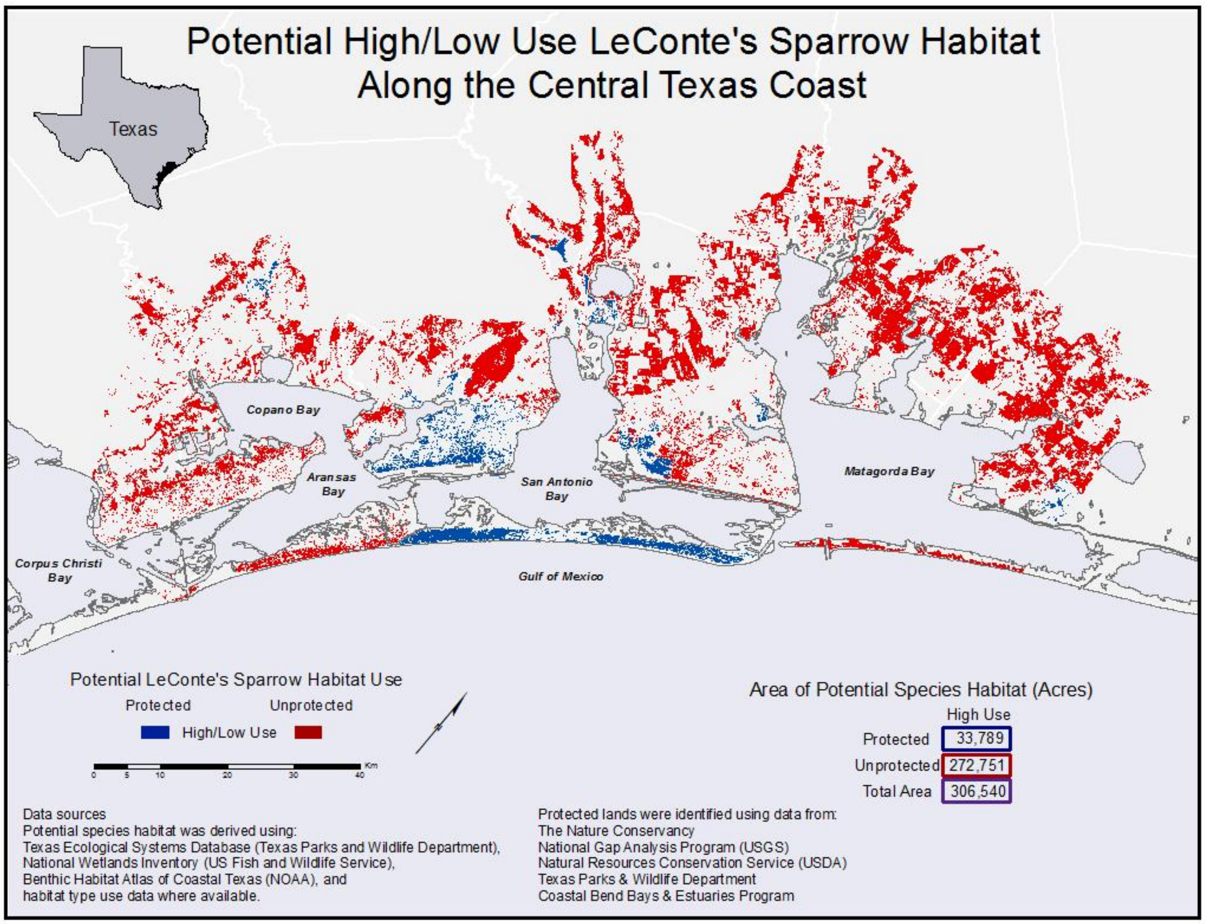


Figure 51. Distribution of potential Le Conte's Sparrow habitat use in protected and unprotected areas within the GCPLCC pilot project area.

The Seaside Sparrow has only 24% high and low use potential habitat inside protected areas, a large amount within the Aransas National Wildlife Refuge complex as well as contiguous tracts in the Welder Flats conservation easements and Mad Island Preserve in Matagorda Bay (Figure 52). Most undeveloped shorelines provide a continuous linear extent of habitat for the Seaside Sparrow where Estuarine coastal marsh is adjacent to Upland coastal and salty prairie. Development of protection strategies of these valuable natural shoreline features should be incorporated into any potential urban and industrial planning.

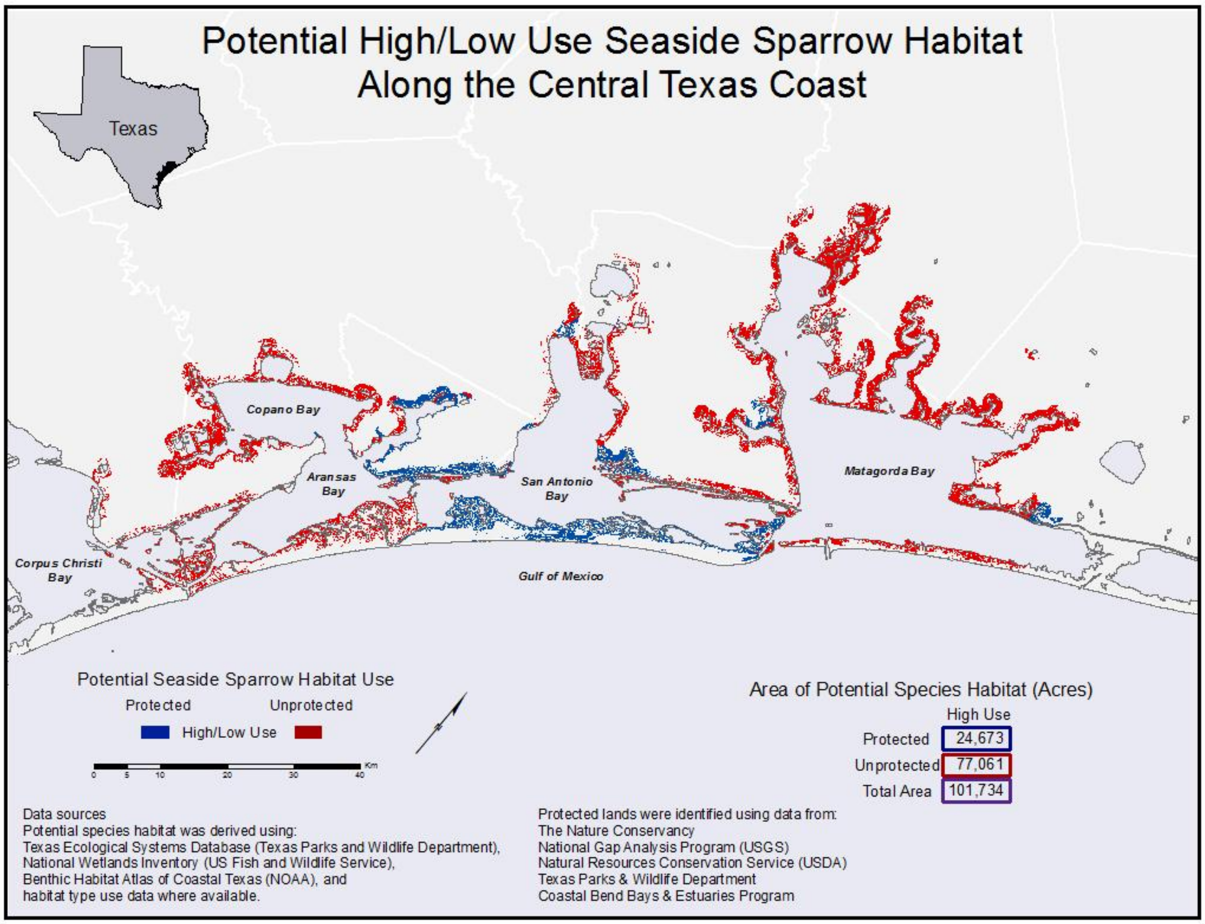


Figure 52. Distribution of potential Seaside Sparrow habitat use in protected and unprotected areas within the GCPLCC pilot project area.

DISCUSSION AND RECOMMENDATIONS

Objective 1 Composite Habitat Types Dataset

The initial focus of this Gulf Coast Prairies Landscape Conservation Cooperative project involves evaluation of the implementation of the conservation design approach in our ecoregion. Conservation planning at this level requires a large amount of spatial information that can be collated and queried to address specific questions. Ideally, this information detail is also maintained down to the landowner parcel level of interest. Certainly, the best approach would involve developing a database specifically intended to satisfy these needs. However, the cost of such a project throughout one ecoregion (and potentially all ecoregions) would be prohibitive. In one alternative approach, we evaluate and incorporate the most appropriate spatial data that are available for a pilot project area that would represent several conservation planning needs: multiple coastal basins and estuarine bay systems in GCP ecoregion, avian species of concern that represent regional habitat diversity, and endangered species that depend entirely on this area for a significant portion of their annual cycle.

The development of the CHTD provides many benefits for a conservation planning approach. First, the CHTD combines land cover classifications from a variety of sources at a relatively high resolution, taking advantage of each source database's particular focus on benthic, estuarine/wetland, or upland environments. These databases are publicly available and generated by professional geospatial experts. We selected the Texas Ecological Systems Database (TESD), National Wetland Inventory (NWI), and Benthic Habitat Analysis (BHA) to construct the CHTD. Second, no other landcover dataset covering the study area includes classifications encompassing such a large environmental range. Spatially, the dataset provides full coverage of best available land cover data across the entire study area, with as comprehensive detail as currently documented for this area. As a result of the hierarchical construction of this comprehensive dataset, users can be confident that the data at any particular location within the dataset is the best available.

Most macro-, meso- and microhabitat types contain classifications from two or more source databases. Although geographic coverage of each database was not strictly tied to upland, wetland/aquatic, and estuarine environments, natural variation within and among the study area makes delineation of a strict dividing line between environments difficult. Therefore, within a particular mesohabitat type, some geographical areas may be classified to a more or less detailed level than other areas at the microhabitat type (e.g. Coastal: Tidal Flat from the TESD compared to Estuarine Intertidal Unconsolidated Shore, Regularly Flooded from the NWI). Each database was developed by independent entities with specific foci and funding levels; therefore, reduction of some class levels were necessary to maintain a manageable number of habitat types while retaining the detail within the CHTD GIS database files.

The synthesis of these separate databases as defined by our assembly rules does not reduce the level of error in any one database. In each database used, we identified areas where further groundtruthing and reclassification are necessary as well as continuing the mapping extent to cover more of the pilot project area. The TESD data provided the most comprehensive coverage of the upland areas and includes the most descriptive detail in their classification for this area. The mapping project encompasses the entire state of Texas and involved years of groundtruthing throughout each phase of the project. The spatial detail is intended for change analyses at a broad scale, not at specific parcels of interest. We do envision collaborating with Texas Parks & Wildlife to refine certain classes of the TESD portion of the CHTD with a primary focus on the grassland microhabitat types. While this effort should be conducted regionwide, particular emphasis on the barrier islands is recommended to increase accuracy for avian species utilizing primarily these areas. Managing high quality grasslands for species' needs requires a platform that can be updated with management strategies by management unit to target conservation areas for grassland birds. However, the value of this database would be greatly enhanced for all species of concern in the GCP.

The NWI hierarchical classification has been used as a national standard for wetland mapping for decades (Cowardin et al. 1979). Remapping coastal areas every 10-20 years provides essential status and trends information, and this pilot project area has been updated fairly regularly. The level of spatial detail is extremely valuable across a broad area and much information is contained within the classification acronyms. However, we found a misclassification at the hydrologic modifier level for Estuarine Intertidal Emergent Marsh that limited our ability to refine to the microhabitat type for coastal birds. The area within the Aransas National Wildlife Refuge and the contextual area included in the Sea Level Affecting Marshes Model (SLAMM) incorrectly mapped irregularly flooded emergent marsh as regularly flooded. As a result of the minor tidal range and flat coastal topography in the region, most of the estuarine emergent marsh is irregularly flooded and plant composition, as well as prey species availability, is very different for coastal birds. In addition, the model outcomes are affected by the timing of permanent inundation by sea-level rise and overestimate the amount of coastal marsh loss at an earlier date. Further groundtruthing is needed to refine the NWI prior to use in conservation planning at this microhabitat type level and in future SLAMM use.

The BHA provides valuable spatial data for mangrove, oyster reef, and seagrass areal extent which is lacking in other databases. Coverage throughout the pilot project area is not complete, however, and is limited in other areas in the GCP. In our project, oyster reefs were not mapped in Espiritu Santo Bay or Matagorda Bay system. Mangroves and seagrasses were not mapped in Matagorda Bay system as well, which limited our conservation planning in these areas for species that use or are limited by the distribution and extent of these habitat types. We support the continuation of this mapping program to provide baseline information as well as trend analyses, particularly for mangroves as this estuarine shrub species continues to establish in our region and replace emergent marsh and unvegetated flats.

Efforts to identify all protected areas within the GCPLCC area were met with limited success, although the availability of data for conservation easements on private lands has improved. The range of acreage provided by spatial data located on the web did not match the information reported on program websites (Table 26). This discrepancy could be due to a number of reasons, including: spatial data may not reflect accurate survey data (i.e. polygons could have been hand-digitized in a GIS to show approximate boundaries instead of having been collected in-situ or derived from official surveys), incongruent projected coordinate systems between GIS users, lack of metadata to indicate which coordinate system should be used, and/or multiple databases collated into a single dataset resulting in overlapping or repeating polygons representing the same parcel of land. However, the spatial extent can be reported by location and size classes to provide better information for future conservation based on adjacency to protected areas (such as next to Aransas National Wildlife Refuge or protecting habitat in areas where existing protection is limited (such as upper Matagorda Bay system).

We recommend that more accurate maps that identify protected areas are essential to identify additional areas and potential partners as well as measure success of conservation programs. The National Gap Analysis Program Protected Areas Data Portal (PAD-US) managed by the USGS seeks to create a spatially explicit database of protected areas across the U.S. for such purposes as conservation and land management planning, as well as providing terrestrial protected area map and statistics for publications such as NOAA's State of the Coast Series and Gulf of Mexico at a Glance. The program goal is to provide the best quality and most extensive database of protected lands for the United States. We recommend that steps are taken in Texas to compile and assess quality and accuracy of protected lands data and provide regular annual geodatabase updates to the PAD-US database.

Objective 2 Current Conservation Needs for Whooping Crane

The current conservation map for Whooping Crane shows the distribution of potential habitat types used by the species based on its habitat use patterns. The survey data shows the species to have high fidelity to the wintering grounds (Stehn and Prieto, 2010) and individuals are known to show high fidelity to specific wintering territories (Stehn and Prieto 2010). This results in a geographically extremely small wintering range. While some individuals will occasionally be found outside the traditional winter range the vast majority of Whooping Cranes can be found within the traditional range during the winter months. The large amount of information available on Whooping Crane habitat use patterns collected over many years and dates throughout the winter period allowed us to quantify not only habitat use but also habitat selection. Therefore the current conservation map is a very good representation and combination of the current areas used by Whooping Cranes and areas with high potential to be Whooping Crane habitat in the future. From the perspective of our analysis for this project, the only difference between used areas and potential use areas is the actual presence of Whooping Crane territories in the former and no territorial pairs yet in the latter. The conditions of the landscape based on habitat type characteristics are considered to be the same based on our land cover dataset.

It is important to keep in mind that the incidental use habitat types represent less than 10% of total observations. Several things should be highlighted; first the vast majority of the incidental habitat types never get used by Whooping Cranes, rather there were a few observations in that habitat type and therefore the potential habitat map shows all patches of those particular habitat types. Secondly, even though incidental use is less than one 10% of observations it does not mean that it may not be an important habitat type. For example, one reason Whooping Cranes are observed in incidental habitat types is when they visit freshwater ponds to drink water. Drinking freshwater when there are high salinity conditions in the salt marsh territories, makes freshwater ponds critical for Whooping Cranes. It must be noted that the ponds where Whooping Cranes drink water are not identified in our land cover classes separately than the surrounding habitat type. Rather the habitat type where the pond is found is what is recorded as the habitat type. So a limitation of our datasets and point overlay analysis is that Whooping Cranes are recorded in a habitat type, but in reality they are visiting only a small patch (i.e. pond) within the landscape that is not separately classified in our land cover maps. Additionally, another reason Whooping Cranes are observed in some incidental habitat types is when they visit upland areas after prescribed fires. Whooping Cranes visit recently burned areas to take advantage of easily obtainable food resources (Chavez-Ramirez et al. 1994). This is a conditional situation where the cranes visit a particular habitat type but only after a recent burn. So in this case that particular habitat type is used but only intermittently and only after a temporary modification of the area has occurred there. It should be considered that many areas classified as potential incidental use have never been burned and therefore the potential for an area to be used by Whooping Crane in the future would only be realized if prescribed fire was applied.

The habitat use depicted on the current conservation map for Whooping Crane clearly shows this species to be highly dependent on the intertidal estuarine environment as its winter habitat. The potential habitat use map highlights those areas with conditions similar to those currently utilized by Whooping Cranes, estuarine vegetated marshes adjacent to open water of the bays. As the Whooping Crane population continues to increase it is very likely that those areas of potential high use depicted in the map will be occupied by future territorial wintering pairs. As young have shown high fidelity to their first winter territory (Stehn and Johnson 1987), the potential areas most likely to be used the earliest will be those in close proximity to the current wintering range (Stehn and Prieto, 2010).

For future conservation planning within the study area, focusing on protection of areas of high use potential under the current conditions and associated uplands would be desirable thing to do. Prioritization of specific areas for conservation as Whooping Crane winter habitat should be based on the distance from existing Whooping Crane range and occupied territories. Those areas in close proximity to existing Whooping Crane range should receive higher priority as they are more likely to be utilized in the near future. Secondarily, areas that are not in close proximity but are within the migratory corridor should also be prioritized. In the longer term, such as that in the sea level rise scenarios presented here, there should be an effort to ensure that where possible there is a minimum of obstructions or coastal barriers that may limit the movement and establishment of coastal marsh environments as water levels increase. This may only be possible on conservation designated lands as most coastal armoring and shore protection structures are intended to protect human structures and habitation.

Currently, only about a quarter of potential high use Whooping Crane habitat has some sort of protection. The remainder is primarily private lands. While private lands and Whooping Cranes do not have to be incompatible, particularly rural areas such as ranches and farms, there may be other actual or potential threats. Coastal edges are prime targets for urban development so that is a primary threat in the future, the loss of potential Whooping Crane habitat to urban and suburban development. In addition, all private lands have a primary use unrelated to protecting Whooping Cranes and or crane habitat which in some cases are activities not compatible with cranes. For example, private lands are used for recreation, hunting and fishing activities which may cause direct disturbance to Whooping Cranes and could increase the chances of direct or accidental shootings. Whooping Cranes have derived some benefits from cattle ranching and hunting operations as well. Whooping Cranes regularly use cattle watering areas particular dirt tanks and they visit game feeders on a regular basis. However, visits to game feeders poses a potential threat to Whooping Cranes as those are also the areas frequented by hunters and where other game animals are hunted. Also, frequenting areas to eat or drink water in areas with thick shrubs and/or woodlands can increase the potential for predation of Whooping Cranes by bobcats.

Objective 3 Selected Avian Species

For all avian species, except Whooping Crane, considered in this project there must be some caution when considering current conservation maps. Whooping Crane is the only species whose entire winter range is included within the project area. While we feel confident that the current conservation maps are a good representation of potential habitat use for most species for which we present habitat use index information, many species have only limited distribution within or use of the project area. For example, for some species (Bobwhite, Loggerhead Shrike and others) our project area is only a small fraction of their entire range and may therefore not be a complete representation of its overall habitat use patterns.

In the case of some species only considered in our Appendix, such as the Piping Plover and Oystercatcher, the maps do not adequately show the distribution of their habitat patches due to the small size and the scale of the maps (Appendix B). Two inset maps that show smaller sections of the project area with greater resolution for these species are presented that show that the distribution of their habitat types are indeed represented in the map but are difficult to identify at the scale of the entire project area. Actual GIS maps and software may be required to adequately view some of these maps to the finest resolution possible.

An additional caution regarding the American Oystercatcher map must be noted; that its primary oyster reef habitat has only been mapped and available for our CHTD for the central portion of our project area. Therefore, the estimated extent (acreages) of available habitat types, is conservative because they represent only the habitat present and available in only a partial section of our project area. The lack of high use habitat type representation (purple) in the northern and southern portions of our project areas does not signify an absence of oystercatcher habitat but rather a lack of information on the location and extent of oyster reefs in those locations. Future mapping of oyster reefs would be important as they are not only critical for oystercatcher breeding and foraging areas, they are also important breeding areas for other coastal species, such as tern, skimmers, gulls, and even some wading birds. Accurate mapping of oyster reefs should be considered an urgent priority as oyster reefs are changing rapidly and are considered among the world’s most endangered marine habitats with an estimated 85% decline worldwide (Beck et al. 2011).

The distribution and habitat type use maps generated in this report represent the overlap in habitat type land cover information, avian species range, and actual or potential habitat type use. Therefore, from an ecological standpoint the maps only represent the distribution and abundance (actual or potential depending on the species) within our study area. Consideration was made as to whether we could determine or define actual carrying capacity for different species. Estimates of carrying capacity would require us to know or estimate differential abundance or density of required resources for each different habitat type in our CHTD. This type of information is not available. With the information and data sets we had available a carrying capacity estimate, from an ecological standpoint, was only possible for species for which spatially explicit information was available. That is for species that have size of area used defined to some extent or actually measured, for example those that are territorial and for which we know the size of the territory or home range. Excluding Whooping Crane, within our suite of species this type of information was only available for Le Conte’s Sparrow. However, we also used information on territorial size from other areas for Loggerhead Shrike, Seaside Sparrow and Northern Bobwhite to present an estimate of potential number of territories, in the case of shrikes and sparrows, and potential individuals in the case of the quail.

Percentage of potential habitat within protected area ranged from about one half of total potential habitat type area available for Seaside Sparrow and Whooping Cranes. Only a third of the Aplomado Falcon range is within protected areas and approximately 12% for Northern Bobwhite, Loggerhead Shrike, and Le Conte’s Sparrow. All species benefited from the habitat diversity protected within the Aransas National Wildlife Refuge complex that encompasses

Matagorda Island and Blackjack Peninsula. Collectively, all species would be afforded better protection from conservation strategies on the mainland within remaining coastal prairie and native shrubland habitats. Coastal development will be especially detrimental to Seaside Sparrow as it inhabits coastal marsh and adjacent prairie uplands along a narrow fringe of bay shorelines.

Special Conditions Maps

For several species we applied buffers to eliminate areas classified as potential habitat within the CHTD because of conditions that preclude use by a species, making those areas unsuitable or unavailable. For example, for Whooping Cranes estuarine open water is only considered available if it is less than 0.6 m in depth. Therefore all areas of open water deeper than 0.6 m were removed from the estimates of potential habitat. In the case of the terns (Appendix B) we only included open water up to 2 km from the coastline as they prefer to forage in open water but at more shallow depths closer to the coastlines.

The most dramatic change in potential habitat type acreages estimated in the project area compared to available based on a buffer conditions was for the Aplomado Falcon. When potential habitat type areas are buffered so they are only suitable if found greater than 1 mile from a forest or wooded area, Aplomado Falcon potential high and low use habitat types decrease to approximately 10% of the total originally estimated. So while it appears that there is considerable acreage of potential high and low use habitat types for Aplomado Falcon in the project area, if indeed the proximity to wooded areas makes it unsuitable, then the actual potential habitat is only a fraction of the aerial extent of appropriate habitat types within the project area.

The example with the Aplomado Falcon is instructive in that it shows a dramatic reduction in the extent of suitable available habitat types present in the landscape to what is actually usable by a species (availability) based on a biological/ecological requirement or constraint of the species. For the vast majority of species we do not have ecological information similar to the Aplomado Falcon's that could be applied to convert potential extent of habitat types to potentially available habitat area. Even when we have some knowledge of specific habitat condition requirements for a species (i.e. short grass) we do not have the specific details within the classification systems in CHTD for each individual habitat type patch. So we were unable to differentiate usable and unusable areas based on some condition of the habitat, such as density of grass, or percent of exposed ground.

Patch Size Maps

For Le Conte's Sparrow, the GCJV plan has proposed a management patch size of 500 ac. While the minimum patch size for Le Conte's Sparrow has not been quantified within our project area, there are analyses that suggest area sensitivity in the species (Johnson and Igl 2001). When only patches greater than 500 ac are considered as appropriate habitat types, as suggested, there is a reduction of more than 60,000 ac from the total acreages for habitat types of high and low use. This has implications for estimates of potential carrying capacity or potential effects of predicted changes in habitat types for Le Conte's Sparrow. The 60,000 ac difference could represent potential habitat for a minimum of 2,300 birds (95% probability of home range 25.4 ac) or as many as 10,000 (50% probability of home range 6 ac, Baldwin et al. 2010). The map (Figure 26) provides the geographic location of those patches of suitable habitat types and greater than 500 ac. For our analysis, a patch could be composed of separate smaller patches of appropriate habitat if they were 50 m or less from each other.

The GCJV proposes a management patch size for Seaside Sparrow of >10,000 ac, however, there were no patches of that size identified within our project area of suitable habitat types. The 10,000 ac may be a goal for restoration and management purposes but seems larger than what is likely required biologically for occupancy by Seaside Sparrows. Breeding territories that have been estimated in other areas are relatively small (< 1 ha), although nests can at times be close to each other and appear to form loose clusters of breeding individuals (Marshal and Reinert 1990).

We attempted to compare our results with some of those reported in the United States Shorebird Conservation Plan (USSCP) and the Gulf Coast Joint Venture (GCJV) where applicable. However, in was not possible to make direct comparison for a variety of reason including different land cover classification schemes and temporal differences in how estimates were derived. Some of our selected shorebird species are considered high priority species in the United States Shorebird Conservation Plan (USSCP). The USSCP considers the availability of shorebird habitat on the Texas mid-coast categorized at the macrohabitat level as two broad habitat types recognized as; maritime and non-maritime. Within the maritime macrohabitat the following mesohabitat types are recognized; beach, washover channel, tidal flats, made land, and reef flanks. Species use was documented from aerial surveys for presence in geographical areas but not by directly quantified habitat type use. The use of specific habitat types was derived from literature sources. Differential use of specific habitat types by particular species is not attempted. It is recognized that the habitat type categories are likely to be used by shorebirds and therefore are potential habitat even though they have not been specifically quantified. The USSCP (table 5) estimates the amount of acres available of different mesohabitat types on the Texas Gulf Coast.

The USSCP states that the Goals and Objectives listed in the plan are based on several assumptions (stated and implied). The basic assumption related to shorebird conservation in the Gulf Coastal Prairie planning region is that habitats in this region are potentially limiting to the shorebird species that utilize them. This assumption, however, is untested, and its validity likely varies among species. Quantitative habitat objectives that are biologically meaningful are difficult to set without some knowledge of limiting factors. Hence, one of the highest priorities for research should be to determine limiting factors for the highest priority species.

The USSCP states that with 29% of the highest priority species using wet meadow/prairie habitats, quantification of the amounts of these habitats in the region is important. Furthermore, the value of agricultural habitats, such as fallow rice and associated management (i.e. grazing), to this guild deserves attention. While our CHTD can identify agriculture lands within the project area the type of management in each habitat patch is unknown.

The Gulf Coast Joint Venture has developed fall habitat objectives for priority shorebirds species along the Gulf Coast (Vermillion 2012). The GCJV plan uses energetic estimates (potential prey density) on a per area basis and the energetic requirements of species to develop an estimate of managed acres necessary to support the population estimated to migrate through the area. The reason GCJV focuses on managed wetlands is that shallow water/mudflat habitat is assumed limited during the period of southbound shorebird migration in the Gulf coastal plain (Reinecke et al. 1988, Twedt 1999, Elliott and McKnight 2000). Consequently, this plan has a limited temporal and spatial scale considered. The time frame it is dealing with is considered the fall migration period for shorebirds along the Gulf Coast from 15 July to 5 November. In addition, the acreages considered and reported are only for managed wetlands and grasslands which include impoundments managed for waterfowl on state or federal lands, rice fields, aquaculture ponds, prairies and pastures. The spatial configuration and area of natural habitat types is not considered. For example, it states that "the extent and availability of suitable grassland habitat available to southbound priority shorebird species which preferentially use that habitat is unknown. Extent of habitat use may also vary markedly from year to year".

The GCJV uses the following macrohabitat type categories: 1) beach-inlet, 2) intertidal, and 3), managed and all inland wetlands, agriculture, and grasslands. Published data on habitat preferences and expert opinion were used to partition shorebird habitat use in the BCR among the habitat type classes. Acreage estimates of habitat needs however are only reported in regards to managed lands as described above. No information is presented in regards to habitat use and/or required of natural habitat types. It is possible that the information presented in this report could be complementary to the GCJV managed lands data as we are reporting acreages for different natural habitat types, although our study area is only a limited section of the area of the entire GCJV.

Objective 4 Future Conservation Needs for Whooping Cranes and Selected Avian Species

All scenarios show general decreases in acreages of Whooping Crane potential habitat in the high and low use categories by 2075 and 2100 with one exception. Under the 2 m sea level rise scenario a positive increase in high use potential habitat type occurs between 2075 and 2100, but still less than initial conditions. Low use habitat types also decreases significantly overall in all scenarios, although there is also a rebound from 2075 to 2100 in the IPCC scenario A1B maximum. Some estimates may be conservative, because of alterations in and along the coastal areas many structures have been built that will hold back the water. This will have the effect of not allowing the marsh to shift upland with increasing sea levels creating less desirable conditions for Whooping Cranes, such as open and deeper water.

Conservation of habitat adjacent to current and potential habitat for Whooping Cranes provides two primary ecologic and economic benefits. First, these areas are currently used by other species of concern including grassland species and nesting waterfowl in freshwater marshes. Second, the natural resiliency of the vegetation structure and shallow wetlands provide a storm buffer for higher elevations and protect upland habitat, agricultural and developed areas.

The downlisting goal of 1,000 Whooping Cranes, resulting in an estimated area necessary to sustain that number of cranes of 125,000 ac, within the only core wintering area for this last wild population will not be met within the pilot project area. Planning and implementation efforts to protect additional habitat should focus to the northeast up the Texas coast and inland within grasslands, freshwater wetlands and agricultural rice fields. In addition, maintaining the ecological integrity of these coastal estuarine systems is imperative to ensure adequate prey populations are maintained for this and other coastal species. The primary factor to a sound ecological environment involves understanding and managing freshwater inflows for both ecologic and economic benefit. By limiting development in flood-prone areas natural shifts in habitat types will continue as sea-levels rise, effectively providing a natural buffer for upland areas, and effectively maintaining habitat for the recovery of the federally endangered Whooping Crane.

The upland terrestrial group will likely be affected by losses of significant areas at the 0-1 and 1-2 m contours. The most significant loss of habitat occurs in the grassland mesohabitats, so grassland birds are likely to be the most negatively affected by predicted potential changes in the uplands (i.e. Loggerhead Shrike, Le Conte's Sparrow, Northern Bobwhite). However, both shrublands and woodlands are predicted to be lost although at lesser rates than grasslands. So species that use shrubland and woodlands are also likely to be negatively impacted. Within the uplands the wetland habitat types are also predicted to be lost with as much as 35% loss at 2 m contour. The group of upland freshwater species (Northern Pintail, Mottled Duck, Little Blue Heron, Appendix B) is likely to be negatively impacted as well. All species that depend or use freshwater to a significant extent will be affected by these predicted losses in the future, particularly species that use vegetated wetlands for nesting or resting. Intertidal species are likely to be affected by predicted losses of Estuarine macrohabitats. These species include rails and Whooping Crane.

A limitation of this type of analysis is that it is only a reflection of loss of habitat types because of increases in the water level of the seas. So we observe net losses of habitat types but no possibility of habitats, particularly estuarine and marine habitat types, to actually appear or shift farther inland in response to the increases in sea level. This needs to be addressed as it is likely that marine and estuarine environments may move upslope along with sea levels. So it is possible that some marine and estuarine habitat types will shift and result in less of a decrease as suggested by this contour analysis, and in some cases have the potential to increase overall over time, as results with SLAMM analysis. However, as explained elsewhere, SLAMM has the limitation of not adequately addressing the changes in upland habitats. The finer resolution DEM would be better suited to develop finer resolution assessments of changes in habitat types based on topography and water levels.

Objective 5 Future Recommendations for Conservation Design

The Whooping Crane and Aplomado Falcon were the only species we evaluated which had geographic information (location points) on habitat use collected in the study area and which could be linked unto the land cover maps. This approach allowed us to conduct an evaluation of the species habitat type use patterns in relation to habitat type classes already defined in the land cover classification schemes. The summary of all the Whooping Crane observation points determines the habitat use pattern. Extrapolating the habitat types actually used by Whooping Cranes beyond the actual range of use creates the habitat suitability map. Basically all habitat categories known to be used by Whooping Cranes and classified as high, low or incidental use are considered to be of potential use by Whooping Cranes even though they have not been observed there to date. In essence a habitat suitability map reflects the areas of habitat types used by Whooping Cranes inside and outside their normal range within the study area of this project. While information on Whooping Crane habitat use has been collected for several decades, only the observations for the winters from 2004-2012 were used as they are the closest in temporal correspondence with the dates the images used for land cover classification were collected.

Avian Habitat Type and Land Cover Classification

One of the biggest potential problems in trying to evaluate changes in habitat types as defined in land cover classification schemes and potential effect on bird species is a lack of congruency between land cover classes and a bird species habitat definitions or descriptions. Land cover classes are defined based on actual or potential vegetation association, soil type, or a combination of these factors. Most bird habitat definitions use broad habitat type classes (i.e marsh, grassland) with additional requirements listed (i.e. dense tufts of grass for nesting; exposed mudflats for foraging). In most cases there is no equivalent for species habitat definitions in habitat type land cover classes. Ideally, as an analysis of the type conducted in this study, where land cover classification is already available one would overlay a species distribution and dispersion patterns as points on the land cover maps and define the habitat use in a quantitative way, as was done with Whooping Cranes for this project.

Information on Aplomado Falcon nest locations was also used. None of the other species considered in this study had geographically explicit data sets available to quantify their use of different habitat types as defined in the land cover classifications used to develop the CHTD. It should be recognized that during the International Census for Piping Plovers conducted every five years locational data are collected. However, these data are not comprehensively digitized within a survey among years. We recommend funding be allocated to develop this GIS dataset for use in conservation planning.

The Whooping Crane data base represents monitoring of the species over many years. Whooping Cranes have the advantage of being very conspicuous in the landscape where they are present and therefore easy to locate and record on maps. In addition, until very recently weekly or biweekly aerial surveys were undertaken during the winter months to locate and record Whooping Cranes throughout their winter range. For most species, this kind of data is not available or is not feasible to gather in a timely or cost effective manner. However, there are other alternatives to evaluating the species use of different habitat types in selected landscapes of interest. In most cases it is not possible to equate the land cover classification classes to specific bird habitat types. To take full advantage of land classification maps (i.e. Ecological Systems Classification and Mapping System of Texas, National Wetlands Inventory) being developed throughout the US and specifically the GCPLCC region, for conservation purposes it will be necessary to sample bird distribution, abundance and dispersion patterns in relation to existing classification schemes. By connecting actual abundance or density data to specific habitat types will greatly increase the value of the land cover classification maps and increase the benefits for conservation planning activities of the different species of interest. A better understanding of the potential changes in habitat types in the area and landscape dispersion due to sea level rise can help plan future conservation and management actions. In addition, by sampling in a stratified (strata defined as land cover classes) manner the effects of loss or gains in acres of specific habitat types or land cover classes can be more directly equated to bird species numbers.

Accuracy of Land Cover Classifications

Errors in classification of land cover classes overestimates the cover type that is labelled in error and underestimates habitat types that are actually in the field but misclassified. This has an impact for current conservation maps and planning activities for future potential impacts. It also over or underestimates the losses or gains that may occur to a particular cover type based on predictions of sea level rise. Oyster reefs and other benthic habitat types are not adequately mapped or have been mapped only in a limited area. In addition, data which reflect the depth of oyster reefs in relation to high/low tides would be helpful to ascertain seasonal availability for avian species. This is an important element as these reefs are used by many species for loafing and resting, nesting, and/or foraging. Also, this type of marine habitat is one of the most endangered with estimated declines of 85% worldwide (Beck et al. 2011). NOAA bathymetry data used in this project were generally limited to where motorcraft could access the areas. More data collection and analyses should be funded in areas that are prone to habitat shifts during sea level rise in back bays and sloughs. GIS analysts that originally developed each dataset were encouraged that so much interest has been generated on the utility of these datasets for conservation. Guidelines should be provided to field researchers with associated protocol and data sheets for further groundtruthing of each dataset used in the CHTD.

Land Cover vs Avian Habitat

Habitat use quantitative data for different species is necessary to determine actual habitat type selection. Habitat descriptions for avian species and land cover classification maps are not equivalent categories. One may be able to find equivalent definitions at the macrohabitat level, but it is well known that mesohabitat types and microhabitat conditions can influence bird distribution, dispersion patterns, density and behavior. If land cover maps are to be used for conservation planning purposes that entail specific bird species habitat effects, then habitat type selection must be quantified to understand real potential impacts of losses to particular habitat types. The most efficient way to accomplish this would be to consider this apriori rather than a posteriori. That is sampling for bird distribution and abundance should be conducted by stratifying surveys based on land cover habitat types already mapped and available. A more direct association between avian habitat type use and land cover classes could be accomplished by sampling bird distribution and abundance in a stratified fashion on top of land cover classes already in existence, assuming they have been verified in the field.

Avian Distribution and Dispersion Patterns

Actual home range or territory size for bird species within the area of interest, are needed. We also need to evaluate the influence of land cover or habitat type on territory and home range size. Territorial behavior and territory size is greatly dependent on resources available in an area, therefore, it is likely that territory size for a species will differ among different habitat types as they are expected to provide resources at different levels. Therefore, to fully utilize land cover maps to determine changes in species numbers or distribution, the distribution and dispersion patterns of bird species must be conducted using the land cover classes as sampling strata.

Minimum patch size requirements for species within the area of interest are needed. This is important as landscapes become more and more fragmented and if a species requires a minimum patch size that means that suitable habitat type patches smaller than the required size are not available to be used by the species. If this is not taken into account when estimating habitat area available for individual species it will be overestimated within different study areas.

The maximum distance between two or more patches of suitable habitat that a species can utilize needs to be determined for each species. The landscape is increasingly fragmented and it is possible that two or more patches not adjacent but in close proximity to each other could add up to the appropriate patch size. However, to conduct GIS analysis of available acreages and potential effects of changes we must know that maximum distance between patches for each individual species under consideration. This is important as if the species has a minimum patch size requirement the available size and configuration of habitat patches will have a significant influence on the proportion of habitat actually suitable for use of that entire acreages present. An example of this is for Le Conte’s Sparrow in our project area. Total acreages of high and low use habitat types available for use by Le Conte’s Sparrow decreased by 20 % after applying a minimum patch size requirement of >500 ac for presence.

Selected Species

We identified a need for further groundtruthing to differentiate between Gulf Coast: Coastal Prairie and Gulf Coast: Salty Prairies that would affect the areal extent among high, low and incidental Use of several species. However, since use of these two habitat types for the Aplomado Falcon was ranked similarly (high use), this issue did not affect the results for this species. Accuracy of the TESD database between woodland and shrub cover classes was more problematic, particularly on San Jose Island. We used woodland features to create a buffer mask that effectively eliminated potential use habitat 1 mile from any woodland land cover type. Reviewers identified the mapped differences between San Jose Island and other adjacent landforms in the barrier chain as questionable. We recommend that a strategy to assess vegetation structure (i.e., woodland vs. shrubland) be conducted on the barrier island chain to improve the accuracy of identification of potential habitat use for this endangered species. These results would be helpful in identifying and prioritizing areas for reintroduction and protection for Aplomado Falcons and other grassland dependent species.

The diversity of habitat types that can support Northern Bobwhites results in a broad coverage across the project area. However, the potential high use is directly related to management strategies that modify those land cover types. The active management on large tracts (both private and public) for this species provides a special opportunity to expand the CHTD into management units by management activity. In addition, census techniques currently used to estimate Northern Bobwhite densities on specific tracts can be used to spatially track and measure habitat improvements for this species.

The land cover classes that comprise the habitat types identified for the Loggerhead Shrike encompasses a wide diversity of grassland and shrublands. Few discrepancies were identified within the shrubland vegetation classification, with the exception of shrub classes being misidentified as woodland classes on San Jose Island. This area should be ground-truthed to ensure potential habitat for Loggerhead Shrikes has been correctly classified. Another issue identified between Gulf Coast: Coastal Prairie and Gulf Coast: Salty Prairie where the latter may have been mapped as the former would effectively reduce the amount of potential habitat for Loggerhead Shrikes. Developing a groundtruthing strategy to reclassify these to correct cover types would benefit many species evaluated including these species.

The land cover classes that were identified as comprising potential high and low use habitat types for Le Conte’s Sparrow were favorably reviewed as accurate in the project area. Therefore, little groundtruthing is necessary before continuing to develop conservation strategies.

The combination of Upland and Estuarine habitat types that comprise The Seaside Sparrow conservation map provide a unique opportunity to further evaluate adjacency of landscape features in an area vulnerable to urban and industrial development in a coastal setting. We recommend that this species be selected to further refine the CHTD particularly where sea level rise is a real concern. In addition, the use of mangroves/scrub shrub where present introduces another adaptive response to climate change in a coastal environment. In addition to groundtruthing these habitat types, it is essential that census techniques be incorporated to evaluate influences of marsh to mangrove shifts may have on a resident coastal species.

Colonially-nesting waterbirds in Gulf coastal areas comprise a special group of avian species who nest together in isolated bay islands and spits. Because of the decline of many of these species in the Gulf Coast Prairies ecoregion in Texas, we were charged with determining if the conservation design approach could be implemented for this avian guild. A suite of species were selected by the stakeholders during the first workshop and incorporated in the spatial assessment. After data mining for available spatial digital data at the resolution necessary to implement the technical elements of strategic habitat conservation framework, we determined the data were not available at this time.

Several spatial characteristics can be defined for a rookery area, and the diversity of habitat types within a rookery depends on both size and elevation gradients. The successful rearing of young each year also depends on isolation from predators; therefore, distance from other landforms that harbor mammalian predators is a key criterion. Along the Texas coast, rookery islands are often created and continually reshaped by the deposition of bay shell fragments on underlying sandy spits or oyster reefs. They are relatively small in size, floodprone from storm tides, and comprise a diversity of salt-adapted vegetation in microzonal gradients. Therefore, the scale of resolution required to assess changes in habitat types on a rookery island is much finer than that provided by land use/land cover datasets developed at a regional scale. In addition, most elevation models do not depict microelevation (<1 ft) vertical measurements that commonly drive presence/absence of vegetation or vegetation height. Since colonial nesting waterbirds are commonly associated with these parameters, the paucity of data limits the use of a spatially-driven strategic habitat conservation framework.

To fully integrate colonially-nesting waterbird rookeries into a landscape conservation plan, both elevation and land cover data will be required at the sub-meter (optimally sub decimeter) resolution both in a vertical and horizontal plane. The expense of this type of data would require a spatial reconnaissance of the project area to determine efficient flight paths to capture information on each island in a cost-effective design. Flight times corresponding to very low tidal levels would provide additional information on bare areas to differentiate between soil types (mud, sand, shell) that can dictate species' specific uses. Through coordination with resource conservation biologists, collecting additional spatial data during active rookery periods could also provide a non-invasive technique to undertake colonial waterbird surveys in conjunction with identifying their spatial locations within the rookery island habitat types and develop density estimates. Upscaling such data into landscape-level habitat models would provide the linkage to evaluating potential availability of foraging habitat peripheral to the rookery locations. This information would be valuable in developing population-spatial objectives so important in strategic habitat conservation at the ecoregional scale. Additionally, through a better understanding of the spatial elements of rookery island dynamics, the development of restoration and rookery creation objectives and site prioritization could be improved.

Application of this Conservation Design Approach in other areas of GCPLCC

The Strategic Habitat Conservation framework anticipates and factors in the need to identify knowledge gaps and incorporate that information in feedback loops. For the Gulf Coast Prairies ecoregion, we recommend to the GCPLCC including focal species from the coastal environments that are most sensitive to immediate climate change impacts, such as sea level rise. In addition, all priority species that are within the GCPLCC and are affected by habitat changes should have a population objective that quantifies habitat types needed for key life history needs, as well as areal extent requirements to maintain and achieve population objectives. Testable hypotheses should be developed that evaluate these population-habitat relationships to use in model refinement. This information is critical for the use of species-habitat decision support tools, such as the Composite Habitat Type Dataset developed in this pilot project in the Conservation Design element of SHC. We relied heavily on the abundance of expert knowledge specific to the GCPLCC and species of conservation concern; this scenario is likely similar in other LCCs. Using the SHC framework and incorporating that information into Conservation Design approach will provide the quantitative data in a landscape context that is necessary to affect conservation objectives.

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