MISSISSIPPI WATER
UTILIZING NASA EARTH OBSERVATIONS TO ASSIST THE AUDUBON MISSISSIPPI COASTAL BIRD STEWARDSHIP PROGRAM WITH HABITAT MONITORING AND RESTORATION PLANNING ACTIVITIES

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ABSTRACT

Coastal and migratory bird habitats in Mississippi are highly dynamic and constantly threatened by human activity. Today, these coastal and migratory species are typically found on managed public lands. However, as of 2014 the Pascagoula River Audubon Center (PRAC) and the National Fish and Wildlife Foundation (NFWF) reported shorebird populations in coastal Mississippi are continually in decline. In response, the Mississippi Audubon Coastal Bird Stewardship Program (CBSP) plans to focus on more than 20 sites in coastal Mississippi. This includes: planning and conducting standardized monitoring, implementing best-practice restoration projects, and a campaign to educate diverse audiences to increase understanding of the threats to and environmental/societal benefits of coastal and migratory birds. To support these efforts, this project used Landsat 8 OLI imagery from 2012 to 2014 to produce habitat classification maps that incorporated land use land cover, vegetation health, and water quality indices of areas in coastal Mississippi where these vital bird habitats are located. The project focused on at-risk coastal bird species such as the least tern. Products and methodologies aided end-users in focusing habitat restoration efforts based on individual species' propensity to a particular area.

Keywords: remote sensing, ecological forecasting, coastal birds, habitat mapping, Mississippi Coastal Bird Stewardship Program

INTRODUCTION

The loss and degradation of habitat is a significant threat to endangered species. Among the most vulnerable organisms to changes in habitat are birds. Many avian species have specific requirements and preferences when it comes to the environments in which they will live and thrive. This can be especially true of migratory bird species that travel very far distances and depend on returning to the same locations year after year to feed, rest, and reproduce. According to the 2014 State of the Birds Report, produced by the North American Bird Conservation Initiative, migratory and coastal birds are among the most at risk species groups, with some counts showing as much as a 50% decline over the last 40 years (Vogt, et al. 2014).

Coastal species can be very sensitive to changes in geography and the ecosystem. Some species will return to lay eggs at the same location that they hatched on years before. They attempt to nest, despite the fact that the habitat may have drastically changed due to factors such as hurricanes, subsidence, or development, resulting in much lower rates of offspring survival. This behavior may be driven by geographic cues instead of the presence of necessary criteria for viable reproduction, making the identification and protection of these shrinking habitats imperative for these species to be able to survive and thrive for generations.

Since bird populations are influenced directly by the conditions of their habitat, they can act as indicators of the overall health of an ecosystem (Vogt, et al. 2014). Migratory birds can be seen as a way to gauge the culmination of a myriad of factors, across a large geographic area. Downward trends in species populations serve as signals of declining habitat extent and quality.

Project Objectives

This project aimed to develop methodologies for classifying and mapping coastal and migratory bird habitats and to demonstrate the usefulness of mapping products for habitat management. Habitat suitability maps were produced for the following bird species: least tern (*Sterna antilliarum*), snowy plover (*Chararius nivosus*), American oystercatcher (*Haematopus palliates*), brown pelican (*Pelecanus occidentalis*), short-billed dowitcher (*Limnodromus griseus*), and red knot (*Calidris canutus*). The habitat suitability maps, as well as land cover classification maps, vegetation and water quality indices were provided to project partners including the Coastal Bird Stewardship Program (CBSP) to assist in decision-making regarding coastal and migratory bird habitat monitoring, protection, and restoration.

Study Area

The Mississippi Gulf Coast is a dynamic and diverse combination of ecosystems including barrier islands, beaches, marshes, swamps, and forests. The area is vital to the recreational and industrial development. It is home to a large variety of industries ranging from a vibrant tourism scene, to fisheries and oil and gas production. This area has seen frequent change over the past decade, most notably the devastation from a series of major hurricanes including Katrina and Rita, which ravaged this part of the coast. Although much of the area has rebounded, scars remain on both the natural and man-made landscape. The study area includes Hancock, Harrison, and Jackson counties and also includes the barrier islands off the Mississippi coast.

Figure 1. Map of study area, Mississippi Gulf Coast

Study Period

This project utilized data collected from 2012 to the present to capture a current snapshot of the coast. The Mississippi Gulf Coast is characterized by cycles of development and devastation. Currently, the area is still recovering from the destruction of the 2005 hurricanes and the more recent Deep Water Horizon oil spill. There have been no major storms to hit the coast in the past two years, though some recent urbanization has occurred on the landscape of concern.

National Applications Addressed

This project applies to the application areas of water and ecological forecasting. The methods and end products developed in this study will assist project partners in monitoring and planning migratory and coastal bird habitat restoration efforts. Because this project focused on coastal bird species, monitoring local rivers, lakes, marshes, estuaries, and the Gulf are important to the end-users.

Project Partners

The Nature Conservancy (TNC) currently works in thirty-five countries and in all fifty states working to conserve land and water through science and partnerships (Nature Conservancy, 2014). The Pascagoula River Audubon Center (PRAC) has over a century-long legacy of conservation of wildlife and habitat in the Pascagoula River watershed in southeastern Mississippi. PRAC serves as a gateway for the community to experience this habitat through educational and recreational activities. It helps to monitor over 200 bird species that live in southern Mississippi (Pascagoula River Audubon Center, 2014). The Mississippi Audubon Coastal Bird Stewardship Program (CBSP) consists of workers and volunteers who work to ensure safety among the coast's migratory breeders. The program features knowledgeable bird experts that provide community awareness for migratory bird species and explain the importance in conserving their habitats (National Fish and Wildlife Foundation, 2013).

These partnering organizations will benefit from this project by obtaining up-to-date land use land cover maps. Migratory bird nesting and foraging habitat maps, Normalized Difference Vegetative Index (NDVI) maps, and water quality index maps will enable end users to determine where restoration and protection efforts may be most successful and necessary.

METHODOLOGY

Data Acquisition

Multi-Spectral Imagery - Landsat 8 OLI. Landsat 8 data sets were acquired using the USGS Earth Explorer platform. The study area was included in path 21, row 39. The most recent and most cloud free dates were selected for summer (June 14, 2014) and winter (January 12, 2014).

Bird Sightings. Bird Sightings were obtained from the eBird database, which is a near real-time online checklist program launched in 2002 by Cornell Lab of Ornithology and the National Audubon Society. The eBird project documents the presence or absence of species when birders log their observations after an outing. Local experts review unusual entries to ensure quality control.

Reference Imagery. National Agricultural Imaging Program (NAIP) Aerial photography was downloaded from the USDA Geospatial Data Gateway. County wide, were acquired for three coastal counties: Harrison, Hancock, and Jackson.

Water Quality - Aqua MODIS. Colored Dissolved Oxygen Matter Index (CDOM) and Chlorophyll-a pre-processed level 2 products were downloaded from NASA's Ocean Color Web. Monthly averages were acquired for January and June of 2014. Winter and summer seasonal averages for 2014 were also downloaded.

Data Processing

Land Cover Classification. Updated land cover maps were created using Landsat 8 data sets that were downloaded via USGS Earth Explorer. Landsat path 21, row 39 was selected because it covered the Mississippi Gulf Coast. The most recent summer and winter dates with the least amount of cloud cover were selected. By incorporating summer and winter data in the analysis, seasonal variations such as "leaf on" and "leaf off" tree canopy contributed to richer spectral data for land cover type determination. Bands 3, 4, and 5 for each respective season were layer stacked in ERDAS Imagine 8.7. In order to improve the spatial resolution, the stacked bands were combined with the 15-meter panchromatic band using the Resolution Merge tool in ERDAS Imagine to pan-sharpen the data from the standard 30-meter to 15-meter. Using the Unsupervised Classification tool, the spectral data was divided into 60 separate signature classes. These classes were then compared to the true color Landsat image and characterized, color coded, and labeled according to the specific land cover that each spectral signature represents.

During the signature class identification process several areas of class confusion were identified. This was due to the similarity in reflectance of different land cover types. To correct this problem, the Supervised Classification tool was used to select specific signatures as training classes to create new customized signatures (figure 2). This tool was used to create 15 new signatures for a total of 75 signature classes. These classes were then identified and consolidated for a total of 11 distinct class types. These types were then recoded to create a final land use land cover map for the study area (figure 3).

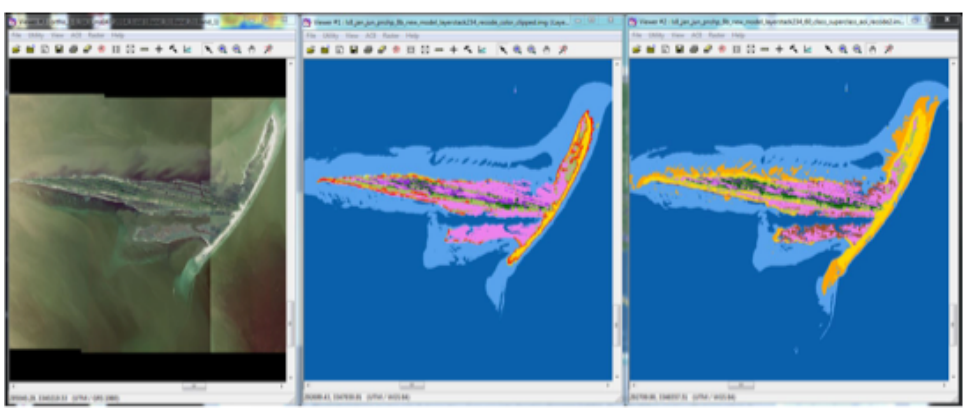

Figure 2. Example of corrections made to land cover classification of Cat Island, Mississippi. Reference image (left) is NAIP imagery from USDA. Original classification (center) and final classification with corrections (right) derived from 15-meter pan-sharpened Landsat 8 OLI images.

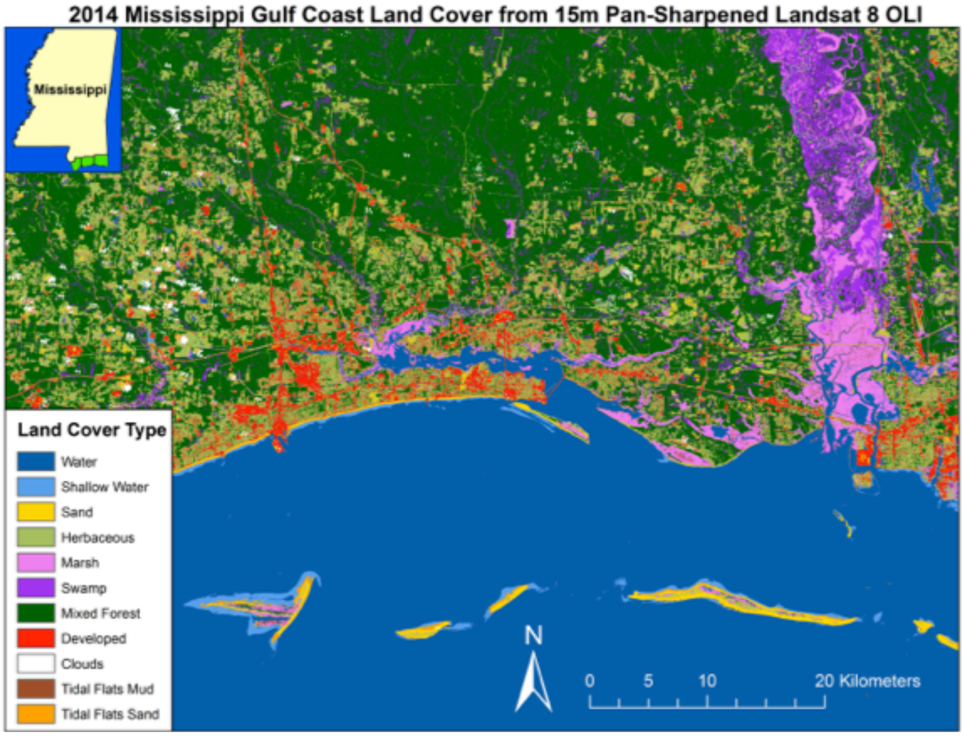

Figure 3. Land Use Land Cover Classification for Mississippi Gulf Coast derived from 15-meter pan-sharpened Landsat 8 OLI images.

NDVI. NDVI was calculated using Landsat 8 OLI imagery to determine vegetation health in the areas these coastal and migratory birds are known to reside. This was done in ArcMap 10.2 using a custom toolbox created in a previous DEVELOP term for calculating NDVI with Landsat 8 OLI spectral bands.

Water Quality. Water quality indices maps were created from Aqua MODIS data taken from NASA's Ocean Color Web to determine the overall health of the water and any fluctuations of CDOM and Chlorophyll-a concentrations over the course of the year 2014. These datasets were then subset in ArcMap 10.2 using the Marine Geospatial Ecology Tool (MGET) toolbox, and processed to create maps and time series (figure 4).

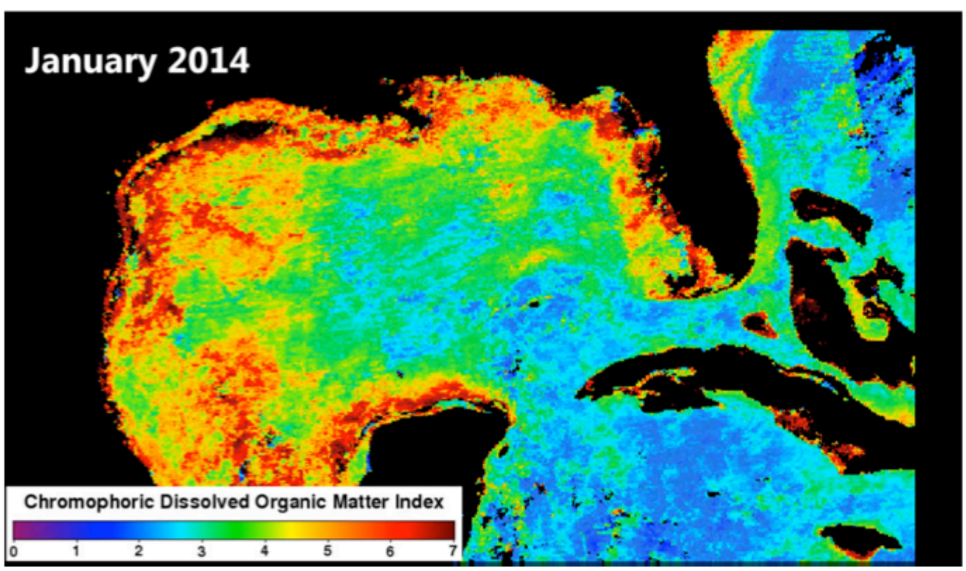

Figure 4. Gulf Of Mexico CDOM index from January 2014 derived for NASA Ocean Color Web.

Data Analysis

Creation of Migratory Bird Habitat Maps. To identify and map the suitability of nesting and foraging habitats, attention was placed on determining characteristics of each land cover type in terms of the preferences of each bird species. Each species was assigned values for each of the land cover types based on suitability. The least tern, for example, prefers to forage in shallow water and tidal flats so the highest value was given to those class types; lower values were given to less favorable foraging class types such as marsh. This resulted in a customized, coded map layer based on suitability ratings for nesting and foraging preferences for each species.

The NDVI map was used to assess the condition and extent of coastal vegetation. It was divided into three classes using natural breaks. It was then ranked from one to three, depending on each species' propensity for vegetation. After reclassifying the land cover and NDVI layers, these raster layers were combined using ERDAS 8.7 Spatial Modeler. A final habitat map was produced with pixel values ranging from one to nine, with nine representing the most desirable habitat.

eBird. The eBird data was used to add another perspective to the distribution of each species in the study area. The eBird database, run by the Cornell Lab of Ornithology, catalogs bird sightings into a searchable format, that can be accessed online to see where species have been observed. The eBird data was used in this project as a tool to compare the theoretical habitat suitability that was created for this project, based on the preferences of each of the bird species, to the actual observational data derived from eBird. Graduated points based on the number of birds sighted at each location, were created in ArcMap. This was then overlaid onto the suitability map for visual comparison of the eBird data and the habitat suitability map (figure 7). Histograms showing the eBird sighting frequency distribution of each species in each suitability category were produced (figure 8).

RESULTS & DISCUSSION

Land Use Land Cover

Due to the final suitability maps being heavily based on the land cover maps, special attention was paid to the detail and accuracy of the classification, particularly to the identification of classes along the shoreline such as the "sand", "tidal flats", and "shallow water" types due to the particular importance to this project. During the signature class identification process, two classes for tidally influenced areas were recognized. The ability to identify these areas was probably due to the combination of two dates, a summer and winter Landsat image for the original classification. One of the dates was likely taken during low tide and the other during high tide, which created distinguishable differences between the shallow water, the beach sand, and the tidal area that was exposed during one image and not in the other. The identification of these areas is especially important for this project because some of the bird species in this study rely heavily on these areas of foraging habitats. The birds will take advantage of times of low tide and feed on the organisms that become exposed by the receding water. One of the most problematic errors discovered during the class identification process was the overlap between the "sand" and "developed" classes. Some of the bird species in this study utilize the sand areas for foraging and nesting behaviors, but are adverse to areas of human development, so proper differentiation of these two classes is imperative to creating accurate land cover classification and suitability maps.

Suitability Maps

Least tern (Sterna antilliarum). The nesting suitability map that was produced for the least tern clearly depicts the limited area that is available for the birds to nest along the coast (Figure 5). The narrow strips of red, indicating "most suitable" habitats are isolated to the sandy beaches along the shoreline and the barrier islands. Given the amount of anthropogenic activity along the coast, especially in the high-traffic tourist areas, this map illustrates the need for protecting more of the small footprint of suitable locations for the least tern to nest.

The foraging map for the least tern highlights the shallow water and tidal flat areas as the most suitable locations. The least tern takes advantage of these shallow areas to hunt small fish and crustaceans (figure 6). The areas that are adjacent to the barrier islands and directly along the coastline are prime foraging habitats.

Snowy plover (Chararius nivosus). The nesting habitat suitability map for the snowy plover reveals similar suitability to the least tern, having a strong preference for the sandy beach areas (figure 9), but the foraging suitability map indicates a preference for slightly higher ground feeding areas than that of the tern (figure 10).

Nesting and habitat suitability maps were also created for the American oystercatcher (*Haematopus palliates*), the brown pelican (*Pelecanus occidentalis*), the short-billed dowitcher (*Limnodromus griseus*), and the red knot (*Calidris canutus*).

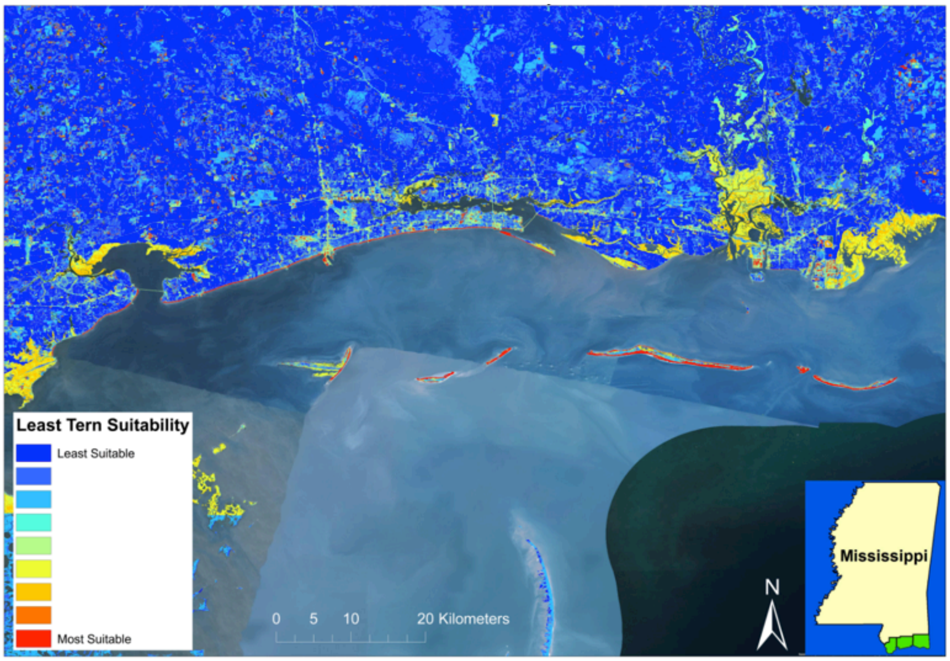

Figure 5. Least Tern Habitat Suitability - Bluer hues indicate areas less suitable for nesting, whereas redder hues indicate areas identified as more suitable for least tern nesting. Derived from Landsat 8 OLI and processed using ERDAS Imagine 8.7 and ArcMap 10.2.

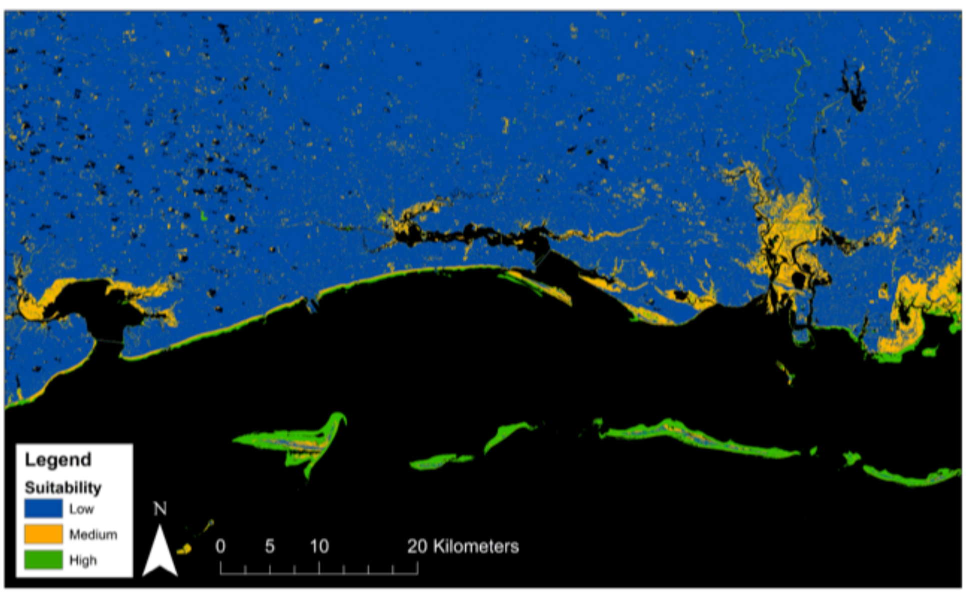

Figure 6. Least Tern Foraging Habitat Suitability – Blue areas are least suitable and green areas are most suitable for least tern foraging. Derived from Landsat 8 OLI and processed using ERDAS Imagine 8.7 and ArcMap 10.2.

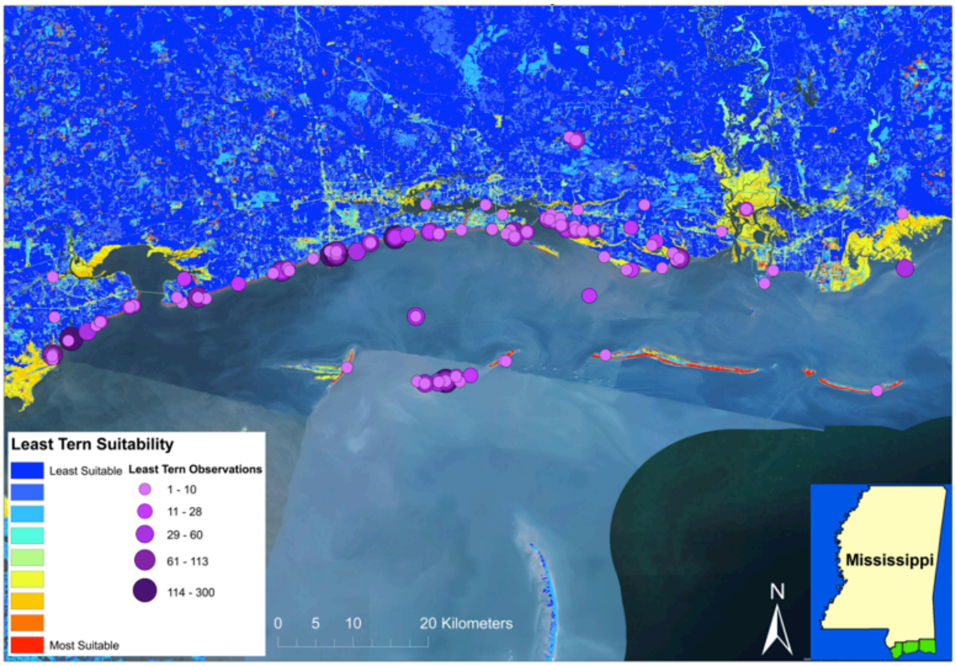

Figure 7. Least Tern Nesting Habitat Suitability with eBird least tern bird sightings overlain– Bluer hues indicate areas less suitable for nesting, whereas redder hues indicate areas identified as more suitable for least tern nesting. Bird observations are represented by the purple graduated symbols, with smaller symbols indicating a smaller number of individuals seen at a sighting and larger symbols indicating larger numbers of individuals observed at a sighting. Derived from Landsat 8 OLI and processed using ERDAS Imagine 8.7 and ArcMap 10.2.

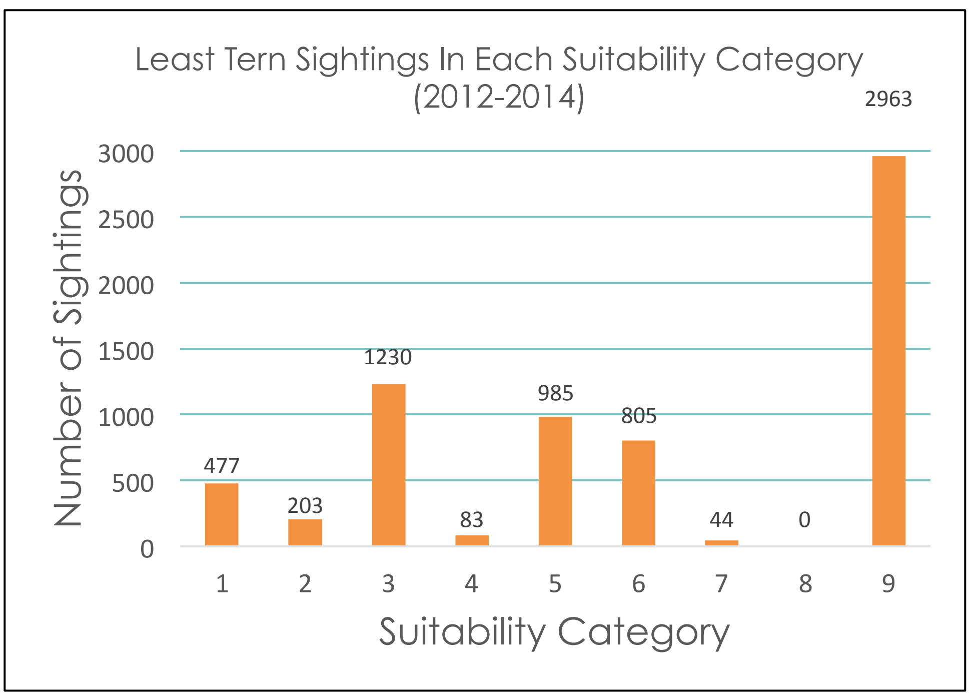

Figure 8. Histogram indicating the distribution of eBird sightings according to the level of nesting habitat suitability.

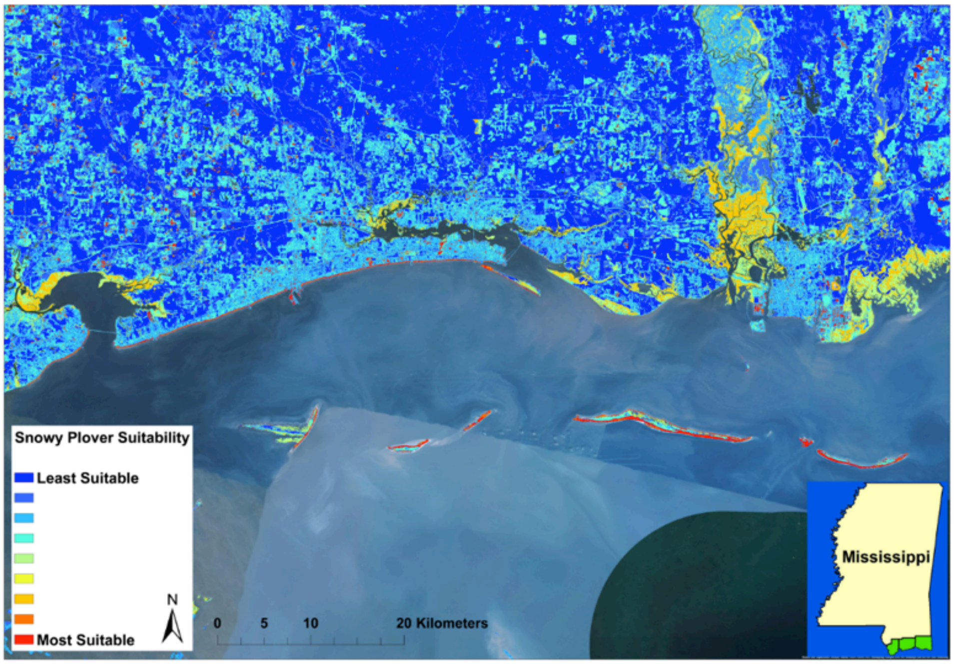

Figure 9. Snowy Plover Nesting Habitat Suitability – Bluer hues indicate areas less suitable for nesting, whereas redder hues indicate areas identified as more suitable for nesting. Derived from Landsat 8 OLI and processed using ERDAS Imagine 8.7 and ArcMap 10.2.

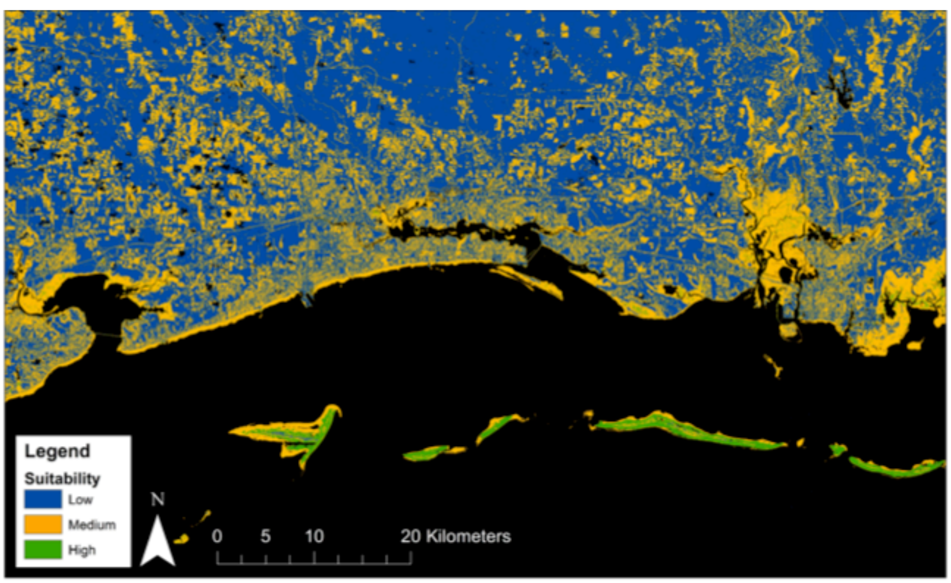

Figure 10. Snowy Plover Foraging Habitat Suitability – Blue areas are least suitable and green areas are most suitable for snowy plover foraging. Derived from Landsat 8 OLI and processed using ERDAS Imagine 8.7 and ArcMap 10.2.

Errors and Uncertainty

Accuracy Assessment. In order to test and validate the accuracy of the final Land Cover Classification map, the Accuracy Assessment tool in EDRAS Imagine 8.7 was utilized. This tool randomly selected over 800 points, with a minimum of 70 points per class. The points were then overlaid on top of the high resolution NAIP imagery. Each of the points was then coded according to the land cover type that was observed in the reference image. These codes were then crosschecked against the type of land cover designated during the classification process. The result is an Error Matrix (table 1), which is a comprehensive analysis that plots the classified points against the observed points.

Through the use of the Error Matrix, not only can the amount of error in each class be quantified and compared, but the correct class for each misclassification can be identified. The largest amount of error was in the "sand" class. Out of 72 total points, only 30 were classified as "sand" and also observed as "sand" in the reference image. During the reference process, the source of this discrepancy was apparent. The Land Cover Classification was created by the combination of summer and winter Landsat images. The NAIP image was taken during the summer. Many of the points that were created for the "sand" class corresponded to agricultural fields in the reference image, were likely cleared or covered with dead vegetation in the winter, and were covered again with green herbaceous vegetation at the time the NAIP imagery was taken. This theory is supported in the matrix because 28 of the 72 total "sand" class points were observed as herbaceous. The next largest source of misclassification was in the "tidal flats mud" class. This was also likely due to temporal differences between the data used for classification and the reference imagery. Out of 71 total points, only 42 were correctly observed as "tidal flats mud", but 20 were observed as "shallow water". This was due the water being lower during the time of one of the Landsat images than the water level at the time of the NAIP image. Mud flats in these areas were inundated with water and therefore not visible.

The overall classification accuracy was 78.55% including the low accuracy due to the error as discussed with the "sand" and "tidal flats mud" classes. This percentage is probably low due to the proportionality of the classes. There is a much larger portion of the overall area covered by water or forest than is covered by some of the smaller classes such as sand. These larger classes are also easier to differentiate and therefore weight the overall accuracy assessment by not being proportionally represented.

eBird. The eBird data could be subject to bias based on where the bird watchers can easily access and most frequently visit. Sightings from eBird also included birds exhibiting various behaviors, therefore in the comparison to a nesting habitat suitability map, the eBird data only expresses that the birds were observed in that location and does not indicate that the birds were nesting. Because of this, other sources that enable more rigorous evaluation of habitats, such as journal publications and bird population surveys that account for behavior would be more applicable to validate suitability maps based only on nesting or foraging.

Future Work

The methodology used for this project could be used as a basic framework in which additional criteria could be added to increase the customization for each species. Additional parameters to deal with birds that nest based on geography instead of land cover type. An example of this type of specialization is the brown pelican, which does not typically nest on shoreline beaches, but prefers more secluded beaches of barrier islands. Extra weight could be added to the barrier islands for the pelican nesting map. The model also does not account for biotic constraints such as predators or human activity. By incorporating these types of factors, habitats in coastal Mississippi can be more accurately evaluated.

The additional errors in the land cover classification discovered during the accuracy assessment process could be corrected using the same Supervised Classification tool in ERDAS Imagine.

The foraging and nesting habitat maps could be combined to create a more comprehensive overall suitability map for each species.

The methodology and base maps created for this project can be used to map the suitability of additional bird species of concern.

The incorporation of more in-depth information from partnering ornithologists can further assess and refine results. Products were turned over to end-users and will be amended as necessary in order to further validate and increase the reliability of these products based on partner evaluation.

CONCLUSIONS

The methodologies utilized in this project provide an efficient way to create resources that contribute to a more comprehensive understanding of migratory bird habitats along the Mississippi Gulf Coast. Landsat 8 OLI provided the basis for creating up to date land cover maps including several known areas that are important for migratory birds such as the barrier islands, marshlands, beaches, tidal flats, and estuaries. By pan-sharpening the data, land cover classifications with much finer resolution were produced.

The inclusion of water quality indices such as CDOM provided another layer of assessment of the health of the environment and therefore the viability of the habitat for birds.

Nesting and foraging habitat suitability maps were created for each of the bird species in the study. By highlighting the best environments based on the preferences of each species, a valuable tool was created for project partners to get an overview of the entire Mississippi Gulf Coast and how it relates to the each of the bird species spatially. With this information, they can distinguish which environments are most suitable for the nesting and foraging activities of specific species and focus restoration and protection efforts in these areas.

	Water	Shallow Water	Sand	Herbaceous	Marsh	Swamp	Mixed Forest	Developed	Tidal Flat Mud	Tidal Flat Sand	Row Totals
Water	90	9	0	0	1	0	0	0	0	0	100
Shallow Water	1	68	0	0	0	0	0	0	0	2	71
Sand	1	1	30	28	2	1	0	6	0	3	72
Herbaceous	0	1	0	78	0	0	8	3	0	0	90
Marsh	0	5	0	9	54	4	2	0	4	0	78
Swamp	0	0	0	2	5	50	17	0	0	0	74
Mixed Forest	0	0	0	6	1	1	93	0	0	0	101
Developed	0	0	1	2	0	0	0	72	0	0	75
Tidal Flats Mud	0	20	0	0	2	1	0	4	42	2	71
Tidal Flats San	0	8	2	0	0	0	0	6	1	53	70
Column Total	92	112	33	125	65	57	120	91	47	60	802

ACCURACY TOTALS

	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Water	92	100	90	97.83%	90.00%
Shallow Water	112	71	68	60.71%	95.77%
Sand	33	72	30	90.91%	41.67%
Herbaceous	125	90	78	62.40%	86.67%
Marsh	65	78	54	83.08%	69.23%
Swamp	57	74	50	87.72%	67.57%
Mixed Forest	120	101	93	77.50%	92.08%
Developed	91	75	72	79.12%	96.00%
Tidal Flats Mud	47	71	42	89.36%	59.15%
Tidal Flats San	60	70	53	88.33%	75.71%
Overall Classification Accuracy = 78.55%					

Table 1. Error Matrix analysis created using the accuracy assessment tool in ERDAS Imagine 8.7, compared the classified data to reference imagery.

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