Utilizing NASA Earth Observations to Assist the Audubon Mississippi Coastal Bird Stewardship Program with Habitat Monitoring and Restoration Planning Activities

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Many migratory and coastal bird species found on the Mississippi Gulf Coast have specialized habitat requirements. The degradation of habitat for nesting and foraging from recent natural disasters and anthropogenic activity has contributed to nationally evident population decline of multiple migratory and coastal bird species. The Audubon Mississippi Coastal Bird Stewardship Program (CBSP) is working to improve coastal avifauna populations through habitat monitoring and educating the public on the importance of coastal and migratory birds. Landsat 8 Operational Land Imager (OLI) imagery from 2014 was used to produce a 15 meter land cover classification for Hancock, Harrison, and Jackson counties on the Mississippi coast. Nesting and foraging habitat suitability maps were created for several species of concern. Water quality indicator maps were also generated from Moderate Resolution Imaging Spectroradiometer (MODIS) data for the Mississippi coastline. These products allowed CBSP to gain a greater spatial understanding of how birds are using the habitat to enhance their decision making in relation to habitat and species conservation and restoration planning activities.

Background Information

In the last ten years, two major events have had a significant impact on the Mississippi Gulf Coast and the coastal and migratory avifauna that depend on this area for habitat. On August 29, 2005, Hurricane Katrina caused wide-scale devastation to the area. The storm ravaged coastal bird populations, as well as habitats critical to both native and migrating species. Almost five years later, The BP Deepwater Horizon oil spill inflicted its own damage to the area. These disasters have had an undeniable effect on the birds, both native and migratory, of Mississippi's coastal beaches. As the result of these two events, nesting success could be negatively impacted and fewer numbers of coastal birds supported in the habitat. Many bird species have strict requirements for suitable habitat and those species that migrate will often seek to return to their own hatching site. The degradation of habitat for nesting and foraging that has occurred in recent years has contributed to the national decline in numbers of migratory and coastal birds.

This project focused on several coastal and migratory bird species that are found on the Mississippi Gulf Coast during some part of the year, including the least tern, black skimmer, brown pelican, snowy plover, and American oystercatcher. Their required habitat is delicate and changes to it could quickly lead to harsh declines in population and an uncertain future for the species.

Water quality surrounding nesting and foraging habitat is also important in determining habitat suitability. Poor water quality affects the health of prey species such as invertebrates and fish and consequently, the health of the birds, as any contaminants found in prey that is eaten have the potential to be retained. Since bird populations are influenced directly by the conditions of their habitat, birds are often indicators of the overall health of an ecosystem (State of the Birds 2009).

Project Objectives

This project aimed to develop and demonstrate mapping products and methodologies for classifying and mapping coastal and migratory bird habitats along Southern Mississippi's coast and barrier islands. Bird species included the American oystercatcher, black skimmer, brown pelican, least tern, snowy plover, red knot, and short-billed dowitcher. This project provided the end-users with several mapping products including: classifications of suitable nesting and foraging habitats along the coast for several coastal and migratory shorebird species of concern, updated land cover classification, Moderate-Resolution Imaging Spectroradiometer (MODIS) derived water quality indices such as Colored Dissolved Organic Matter (CDOM) and Chlorophyll-a. These maps were utilized by project partners with the Coastal Bird Stewardship Program (CBSP) and enabled more informed decision making regarding coastal and migratory bird habitat monitoring, protection, and restoration.

Study Area and Period

The Mississippi Gulf Coast is a dynamic and diverse combination of ecosystems which include barrier islands, beaches, marshes, swamps, and forests. The area is also important for recreational and industrial development in the state. It is home to a large variety of industries ranging from a vibrant tourism scene to important fisheries to 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 severely impacted this part of the coast, as well as the Deepwater Horizon Oil Spill which released millions of gallons of oil into the Gulf of Mexico and whose full impact on the environment has yet to be seen. 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). This project utilized data collected from 2012 to present to capture a current snapshot of the coast. There have been no major storms to hit the coast since 2005, though more intense urbanization has occurred on the landscape of concern following the destruction of hurricanes Katrina and Rita.

National Applications Addressed

NASA Applied Science National Application Areas addressed by this project include water resources and ecological forecasting. The methods and end products developed assisted project partners in monitoring and planning migratory and coastal bird habitat restoration activities. Because this project focused on coastal bird species, the monitoring local rivers, lakes, marshes, estuaries, and the Gulf are important to the end-users. Specifically, this project focused on providing end users with maps of seasonal water quality indices such as CDOM and Chlorophyll-a to determine potential effects of water quality on bird species. The project also involved the mapping of suitable nesting and foraging habitats of coastal bird species through the use of NASA Earth observations.

Project Partners

The Audubon Mississippi Coastal Bird Stewardship Program (CBSP), Pascagoula River Audubon Center (PRAC) and the Nature Conservancy (TNC), in coordination with the Mississippi Department of Environmental Quality (MSDEQ), Mississippi Department of Marine Resources (MSDMR), and National Fish and Wildlife Foundation (NFWF), monitor and plan restoration activities for coastal and migratory bird habitat. PRAC and TNC have limited exposure to the utility and experience of using remotely sensed data. Currently, CBSP, PRAC and TNC do not employ remote sensing and GIS in monitoring and planning activities. These groups mostly rely on costly and time-consuming *in situ* surveys and field campaigns along with occasional aerial surveys. Maps of bird habitats, land cover, and water quality indicator products to the partners, enabled partners to gain a more complete understanding of how bird species are using specific coastal habitats in order to enhance their decision making processes regarding habitat and species conservation, the planning of restoration activities, and the monitoring of coastal water quality within coastal bird habitats possibly impaired by the DWH oil spill.

Methodology

A. Data Acquisition

1. Landsat 8 OLI

Landsat 8 data 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).

2. NASA Ocean Color Web Water Quality Products
Pre-calculated Level 2 water quality products derived from Aqua MODIS were acquired using the Marine Geospatial Ecology Tool (MGET) from Duke University in ArcGIS 10.2. Chlorophyll-a, CDOM, and Sea Surface Temperature (SST) for the extent of the Gulf of Mexico for 2014.

3. Reference Data
NAIP Aerial photography was downloaded from the USDA Geospacial Data Gateway for the study area. This was used as reference data for the land cover error matrix discussed later in the results section.

4. 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 a birder logs their observations after an outing. Local experts review unusual entries to ensure quality control.

B. Data Processing and Analysis

1. Landsat 8 OLI

a. Land Cover Classification

Updated land cover maps were created using Landsat 8 data that were downloaded via USGS Earth Explorer. Landsat path 21, row 39 location 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. Bands 3, 4, and 5 for each respective season were layer stacked in Erdas Imagine 8.7. The stacked bands were then pan-sharpened using the 15 meter panchromatic band using the "Resolution Merge" tool in ERDAS Imagine 8.7. This created richer spectral data to obtain land cover information since this represented a "leaf on" and "leaf off" image to include in the analysis. Using the "unsupervised classification" tool, the data were sorted into twenty separate classes. The classes representing water were then identified and removed using the "mask" tool. The resulting data, representing the land area, were then reclassified into thirty-two separate classes using the same method.

The "unsupervised classification" resulted in a certain amount of error, due to the similar spectral signatures of several types of land cover. One of the most problematic errors was discovered during the class identification process last term, 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. To correct these areas of overlap between classes, the "supervised classification" tool in ERDAS Imagine 8.7 was used to select specific areas with class confusion, and use those signatures as training classes to create new customized signatures. This tool was used to create 15 new signatures for a total of 75 signature classes. These classes were then identified and regrouped according to the specific land cover type each spectral signature represents.

During the signature class identification process, 2 new classes, for tidally influenced areas were recognized. These new classes were designated as tidal flats sand and tidal flats mud, and were added to the other classes for a total of 11 land cover types. The ability to identify these areas was likely due to the combination of two dates, a summer and a 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 for foraging.

Once the final classes were determined, they were characterized, color coded, and labeled according to the specific land cover that each spectral signature represents. They were then combined and consolidated into land use types, ranging from developed land to individual forest type. The land cover classes were ranked individually for each species based on the level of importance for foraging and nesting. Land cover was ranked from one to three, with three being the most desirable nesting habitat for the bird. Since land cover is most important in determining site suitability, it was weighted by two in the final suitability model.

b. NDVI
NDVI was calculated using the same Landsat 8 OLI imagery used to create the classification to determine vegetation health in areas within and adjacent to ideal foraging and nesting sites. 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. NDVI was divided into three classes and ranked from one to three, depending on the bird's propensity for vegetation within nesting and foraging ranges. There were three separate NDVI products created: one from the summer image, one from the winter image, and an average of the two. The product used in the suitability model was based on the time of year the bird is present on the Mississippi Gulf Coast. For example, in determining least tern suitability, the summer NDVI image was used since this species arrives in the spring time and stays through the summer. The average NDVI image was used for species that can be found on the coast year-round.

2. NASA Ocean Color Web Water Quality Products

Once acquired, Ocean Color Web products were subset to the extent of the Gulf of Mexico in ArcGIS 10.2. A custom color ramp was created for each dataset in ERDAS Imagine 8.7 in order to optimize interpretability. Colorized final monthly products were also exported as jpegs and used to create time-series for partners (example shown in Figure 3).

3. Migratory Bird Habitat Maps
Since not all the birds prefer open beach, an assessment of coastal vegetation's condition and extent was necessary in determining prime nesting and foraging habitat for several coastal bird species. To identify and map specific nesting habitat zones, attention was placed on determining characteristics of each mapped land cover class that was correlated to the nesting habitat preferences of each bird species. After reclassifying the land cover and NDVI layers as specified in the data processing section, these attributes were added using Spatial Modeler in ERDAS Imagine 8.7 and a final habitat map was produced with pixel values ranging from one to nine, with nine representing the most desirable nesting and foraging habitat (Figures 4 - 10). Land cover was given a weight twice that of NDVI, due to the greater influence of cover type in the determination of prime nesting and foraging sites.

4. Sightings from citizen scientists in the eBird database were used to look at the frequency at which each bird was observed and in which nesting suitability category these were most frequently found. This allowed for the identification of sites in which particular coastal bird species are more likely to inhabit. Though the eBird points were useful in getting a spatial understanding of bird sightings, sightings include birds exhibiting foraging, nesting, and all other bird behaviors. Further support from journal publications discussing preferred species nesting habitat specifics and more relatable data sources for nesting bird populations are needed in order to conduct more rigorous evaluation of the predicted suitability. Nesting habitat maps and

other products also need to be further evaluated by the end-users in order to determine the extent of refinement needed as well as to more closely tailor the products to the end-user's needs.

Results & Discussion

1. Land Cover Classification Accuracy Assessment
In order to test and validate the accuracy of the final classification map, the "Accuracy Assessment" tool in EDRAS Imaging 8.7 was utilized. This tool randomly selected 802 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 (Figure 11), which is a comprehensive analysis that plots the classified points against the observed points.

Though 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 combining 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, and 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 on 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 class such as sand. These larger classes are also easier to differentiate and therefore weight the over accuracy assessment by not being proportionally represented.

See Figure 2. Land Use Land Cover Classification for Mississippi Gulf Coast derived from 15 meter pan-sharpened Landsat 8 OLI images

2. Migratory Bird Habitat Maps
Nesting and foraging habitat suitability maps were created for each of the bird species in the study. By highlighting the best environments for nesting and foraging, based on the preferences of each species, a valuable tool was created for project partners to get an overview of the entire Mississippi coast and how it relates to the each of the bird species spatially.

Highlighted species for this proceedings paper include:

Least tern (*Sternula antillarum*). The nesting suitability map that was produced for the least tern clearly shows the limited area that is available for the birds to nest along the coast (Figures 4 - 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 marine invertebrates (Figures 6 - 7). The areas that are adjacent to the barrier islands and directly along the coastline are prime foraging habitats.

Snowy plover (*Charadrius nivosus*). The nesting Habitat suitability map for the snowy plover shows similar suitability to the least tern, having a strong preference for the sandy beach areas (Figure 8).

In contrast with the least tern, snowy plovers do not feed on fish in the water, but forage in flat, sandy areas for insects and invertebrates found in the sand. The foraging suitability map indicates a preference for slightly higher ground feeding areas than that of the least tern and no preference for areas that are continually inundated (Figures 9 - 10).

Errors & Uncertainty

No special parameters to deal with birds that nest based on geography instead of land cover type. Incorporating this factor could allow for a more accurate evaluation of prime nesting and foraging habitats in coastal Mississippi. 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. The model also does not account for biotic constrains such as predators or human visitation. The eBird data could be subject to bias based on where the bird watchers can easily access and most frequently visit. For example, the short billed dowitcher prefers to nest in secluded, more inland forested areas such as the upper Pascagoula River wetlands, which are not as easily accessible as the shoreline. EBird sightings also include sightings of birds exhibiting various behaviors, is not restricted to sightings only of birds exhibiting nesting behavior, and does not note bird behavior at the location and time of sighting. Because of this, finding other sources that enable more rigorous evaluation of nesting habitat, such as past journal publications and breeding bird population surveys, would be more useful.

Future Work

The methodology used for this project can be used as a basic framework that addition criteria could be added to increase the customization for each species. The incorporation of more in-depth information from partnering ornithologists can further assess and refine results. Products were turned over to end-users at the CBSP and will be amended as necessary in order to further validate and increase the reliability of these products based on partner evaluation. In addition to this, more literature review will be done in order to include data and habitat specifications as outlined in peer-reviewed journal articles in statistical validation of existing maps and to reevaluate the importance of various factors in determining ideal habitat characteristics.

Conclusions

The pan-sharpening tool provided an effective means for generating higher spatial resolution land cover classifications. The products derived from Landsat OLI provided up to date land cover and habitat maps for the Mississippi Gulf Coast, including several known areas that are important for migratory birds. These areas included the Mississippi barrier islands, marshlands, beaches, and estuaries. The project mapped and assessed habitat suitability for specific migratory bird species inhabiting Mississippi's coast.

Calculating vegetation indices for the study area proved to be useful in mapping out some of the birds' preferred environments by locating regions with healthier vegetation. By creating suitability maps, project partners can distinguish which environments are most suitable for certain nesting/breeding species. This information helped to facilitate the identification of threats to these habitats and focus restoration and protection efforts in these areas.

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- Mike Murphy - The Nature Conservancy (TNC) - Coastal Field Representative

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Figure 1. Study Area: Hancock, Harrison, and Jackson Counties in South Mississippi

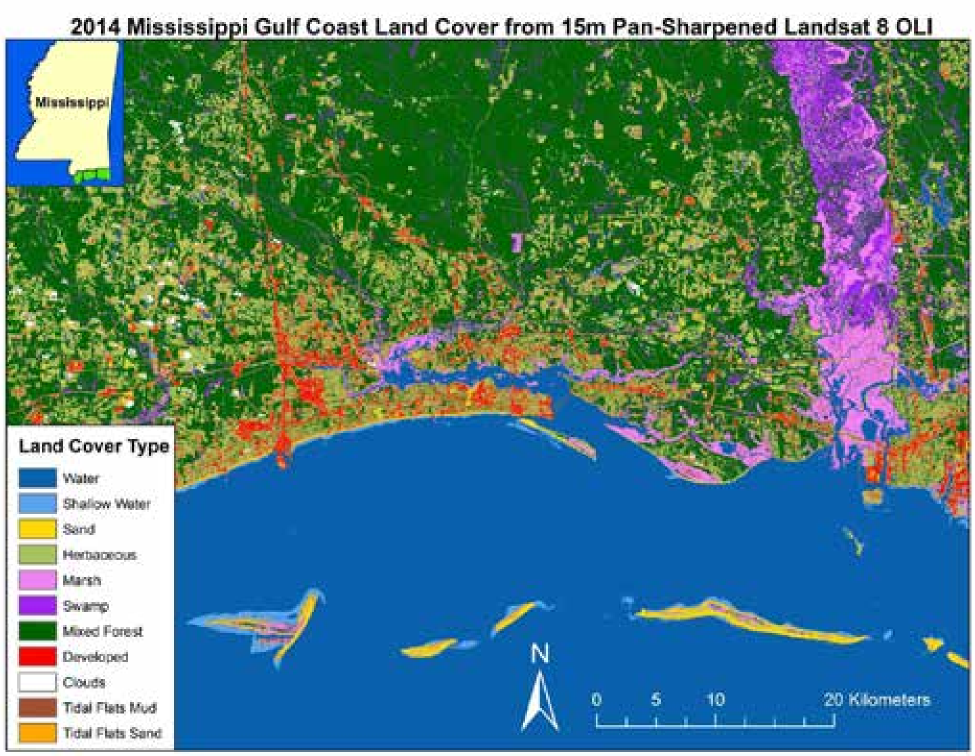

Figure 2. Land Use Land Cover Classification for Mississippi Gulf Coast derived from 15 meter pan-sharpened Landsat 8 OLI images

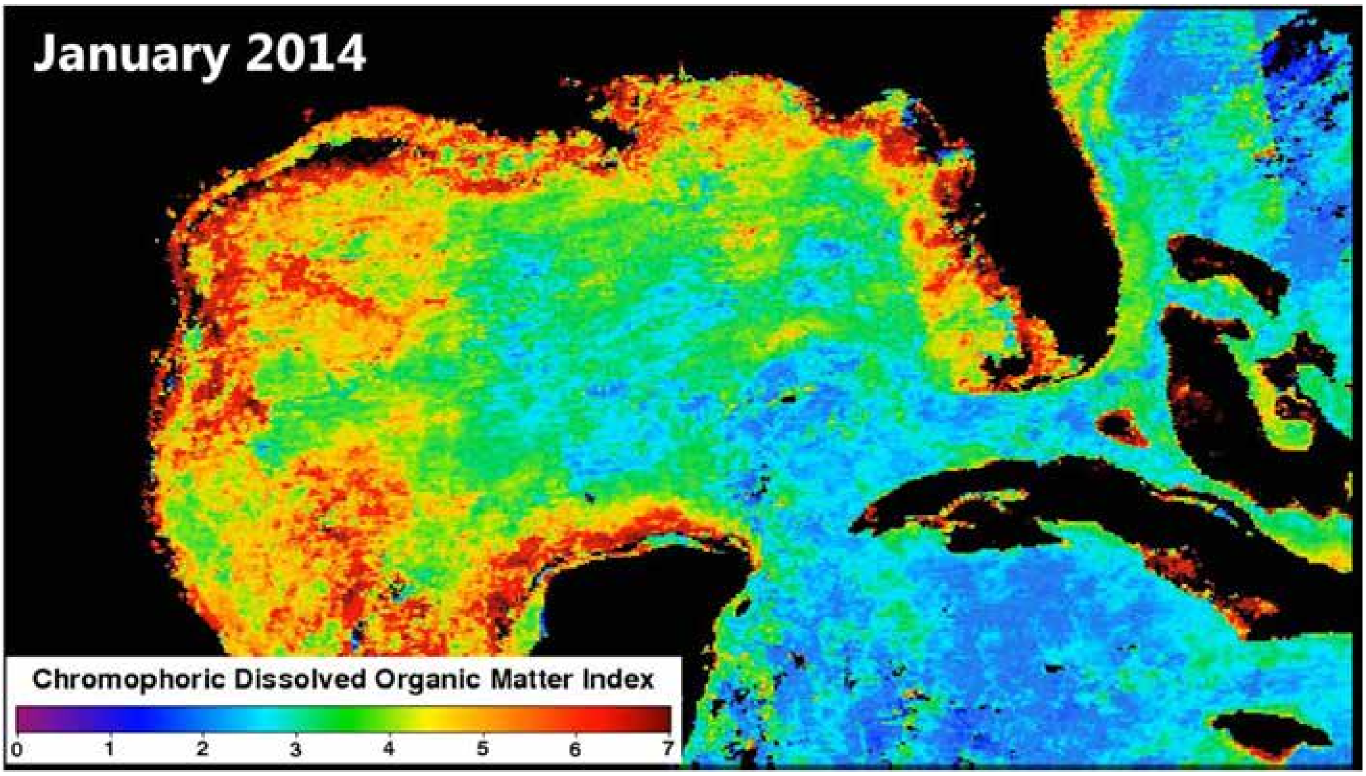

Figure 3. CDOM for the Gulf of Mexico – January 2014

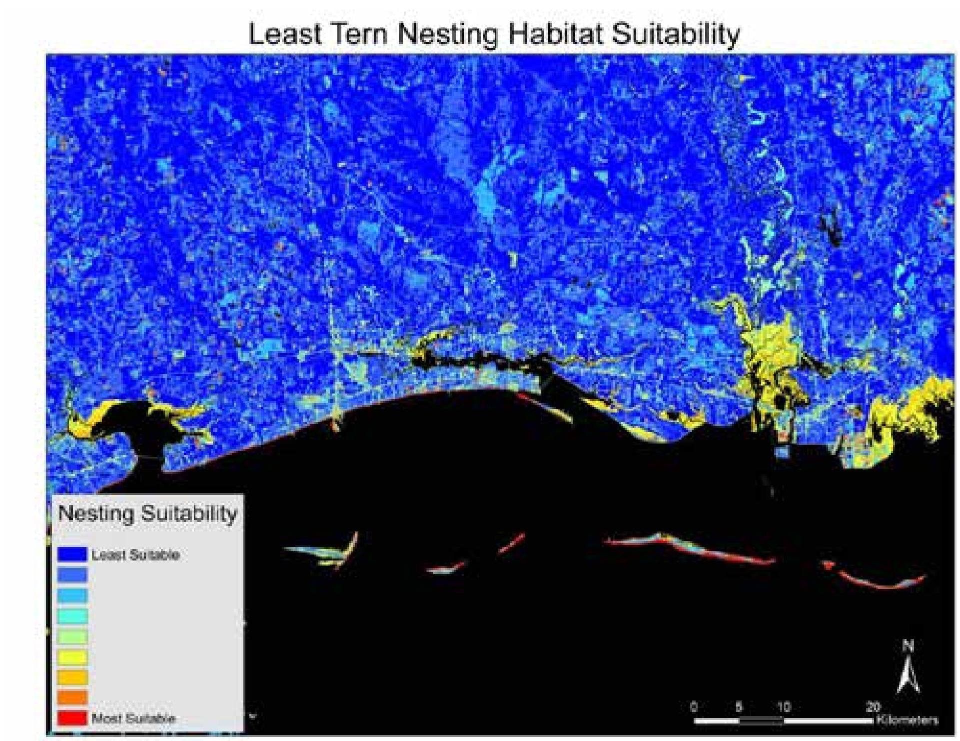

Figure 4. Least Tern Nesting Habitat Suitability – Bluer hues indicate areas less suitable for nesting, whereas redder hues indicate areas identified as more suitable for least tern nesting.

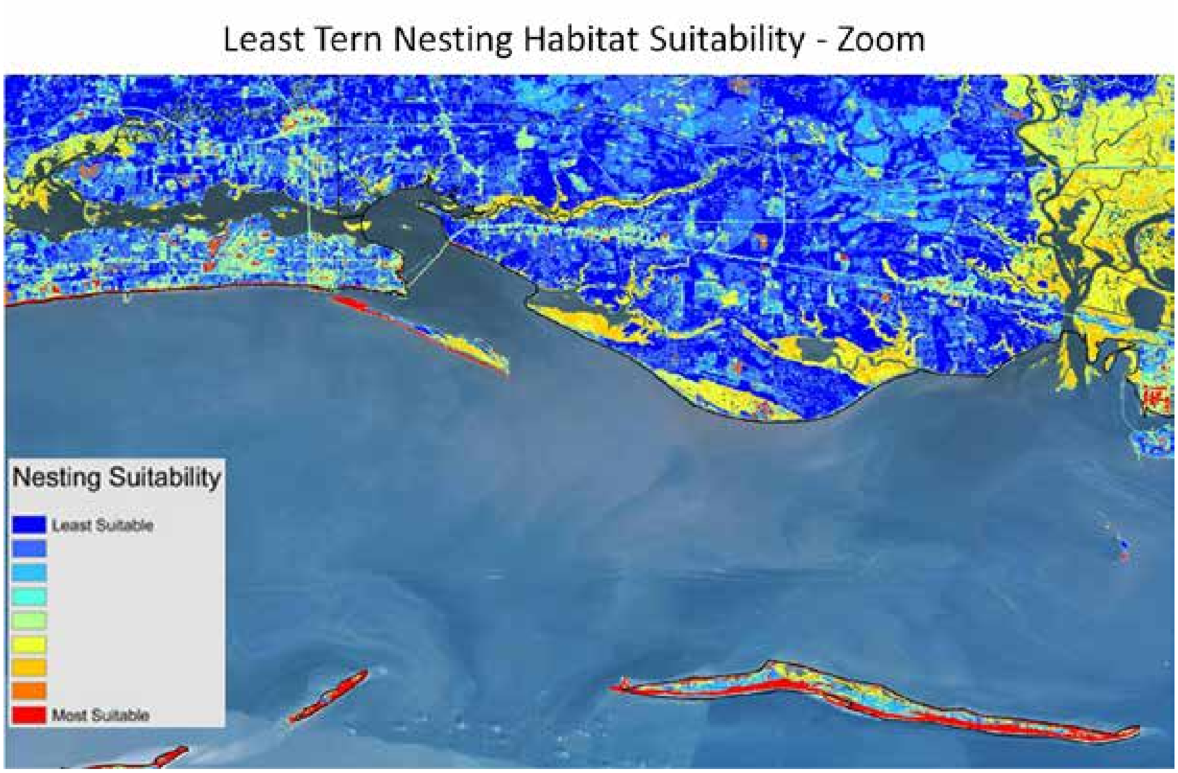

Figure 5. Least tern nesting habitat suitability – zoom of Deer Island/Horn Island area

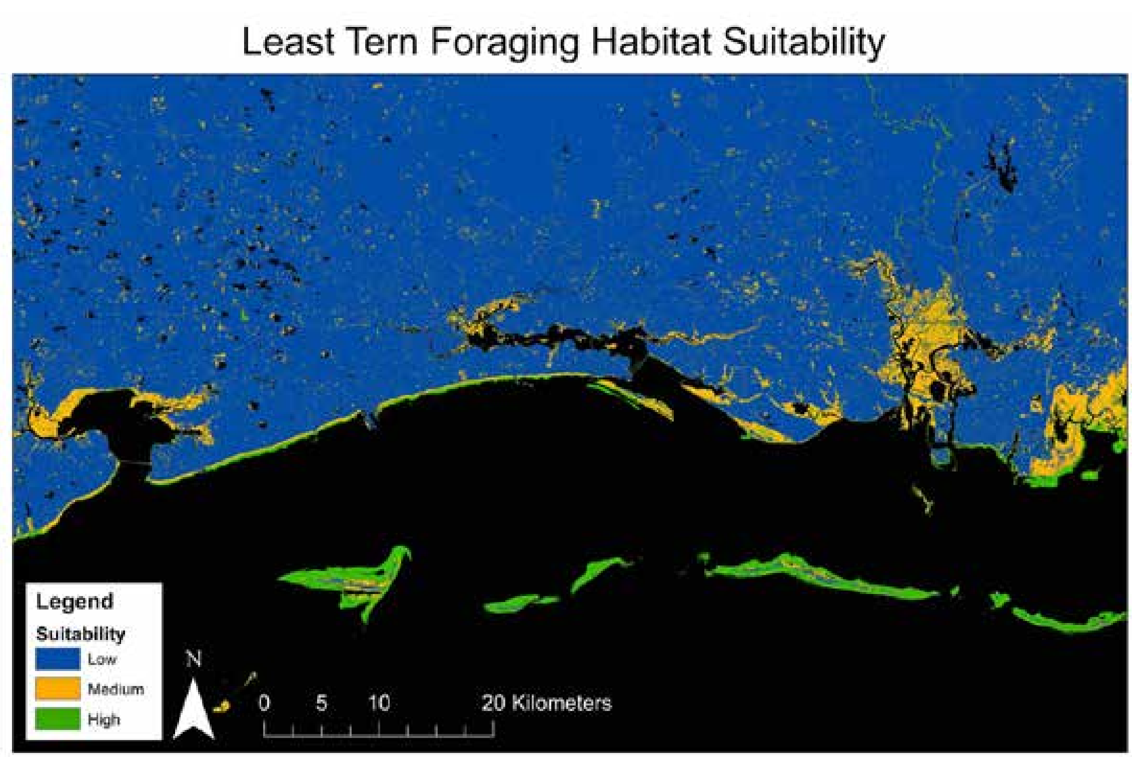

Figure 6. Least Tern Foraging Habitat Suitability -- Blue areas indicate low suitability for the least tern. Yellow areas indicate medium suitability. Green areas indicate high suitability. Shallow water and sandy areas are most suitable – the least tern eats small fish such as silversides and anchovies that swim along the shorelines. The least tern also takes advantage of dredge spoil areas for feeding. Also feeds in bays and estuarine environments.

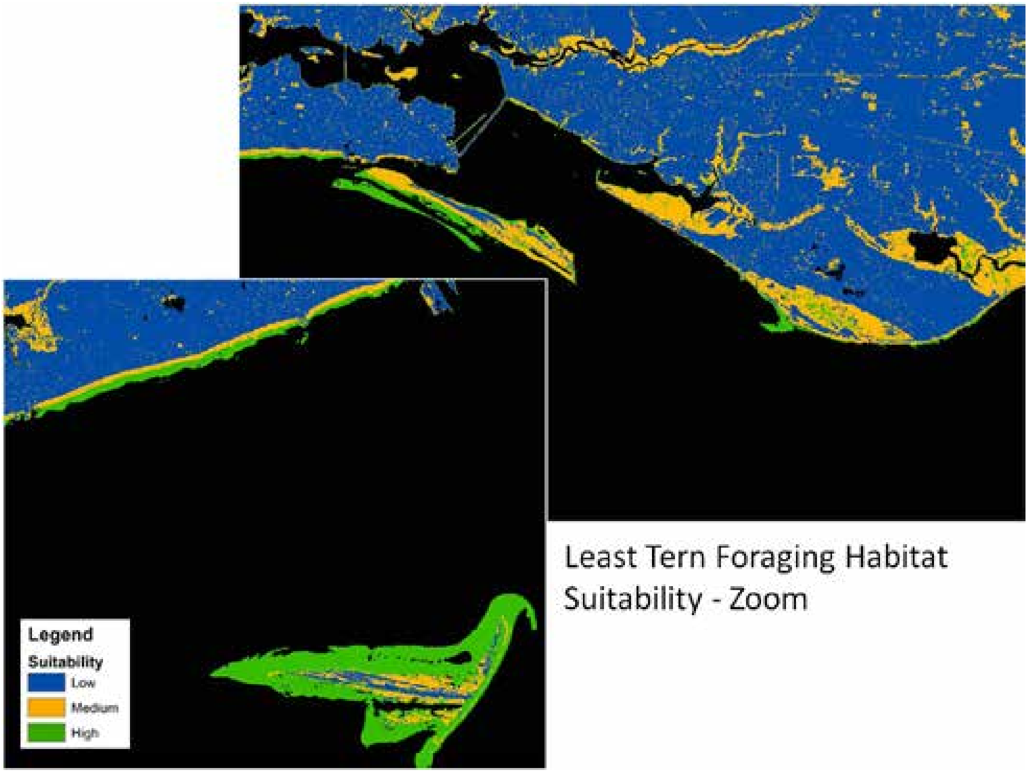

Figure 7. Least Tern Foraging Habitat Suitability Zoom -- Close-up of Cat Island (bottom) – green areas include shallow water, tidal flats, and sand closer to the water. Least tern is less likely to feed further up on the beach away from marine waters, but this is not unheard of. Deer island (top) and a shallow flat created from dredge spoils – ranked as highly suitable

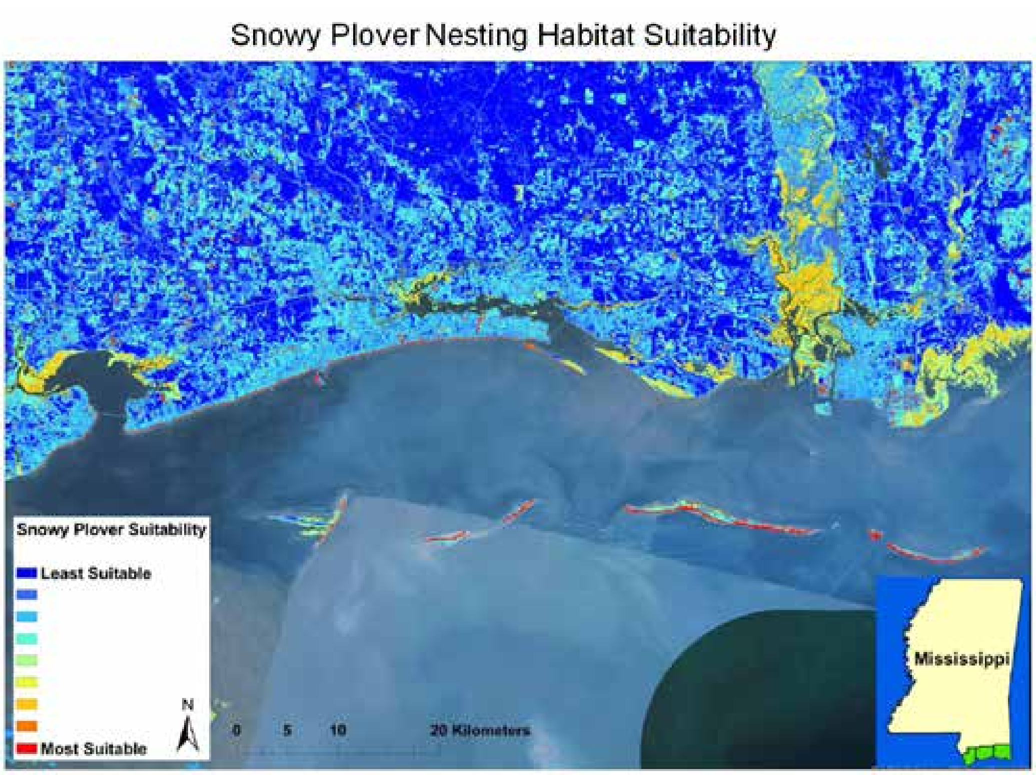

Figure 8. Snowy Plover Nesting Habitat Suitability – Bluer hues indicate areas less suitable for nesting, whereas redder hues indicate areas identified as more suitable for nesting.

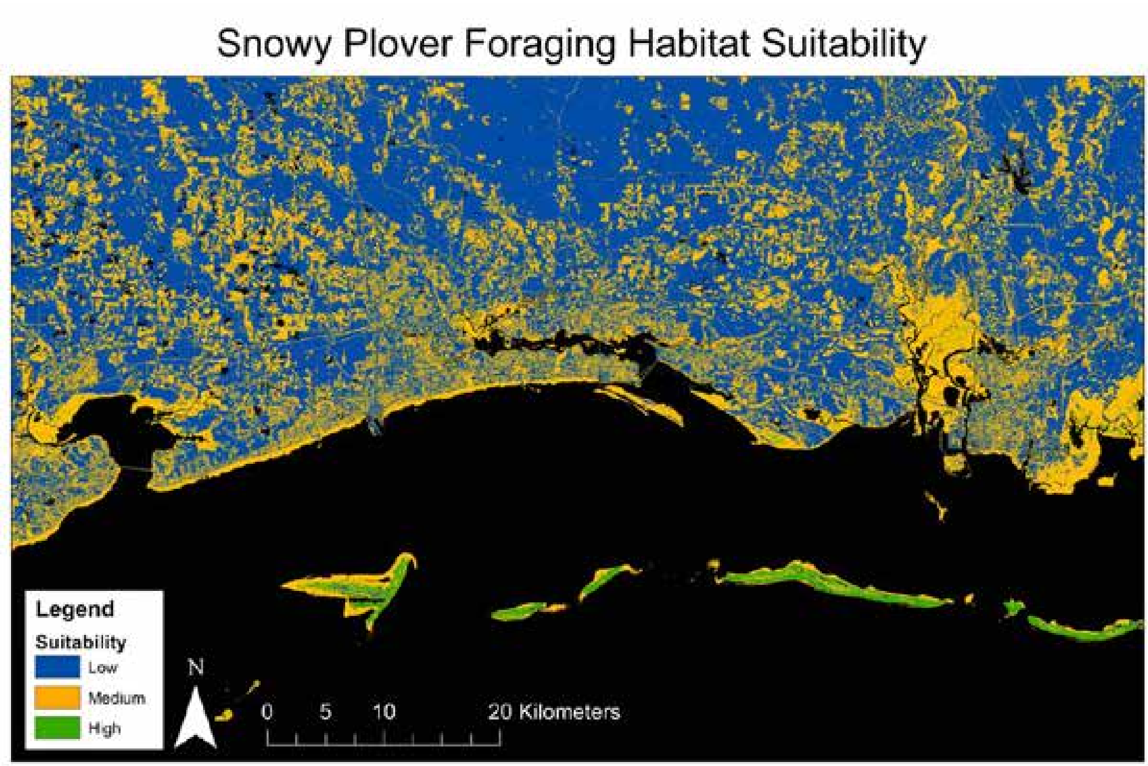

Figure 9. Snowy Plover Foraging Habitat Suitability -- Blue areas indicate low foraging suitability. Yellow areas indicate medium suitability. Green areas indicate high suitability. Sandy beaches close to the water and shallow mud flats are most suitable for plover foraging. The snowy plover will not forage in water.

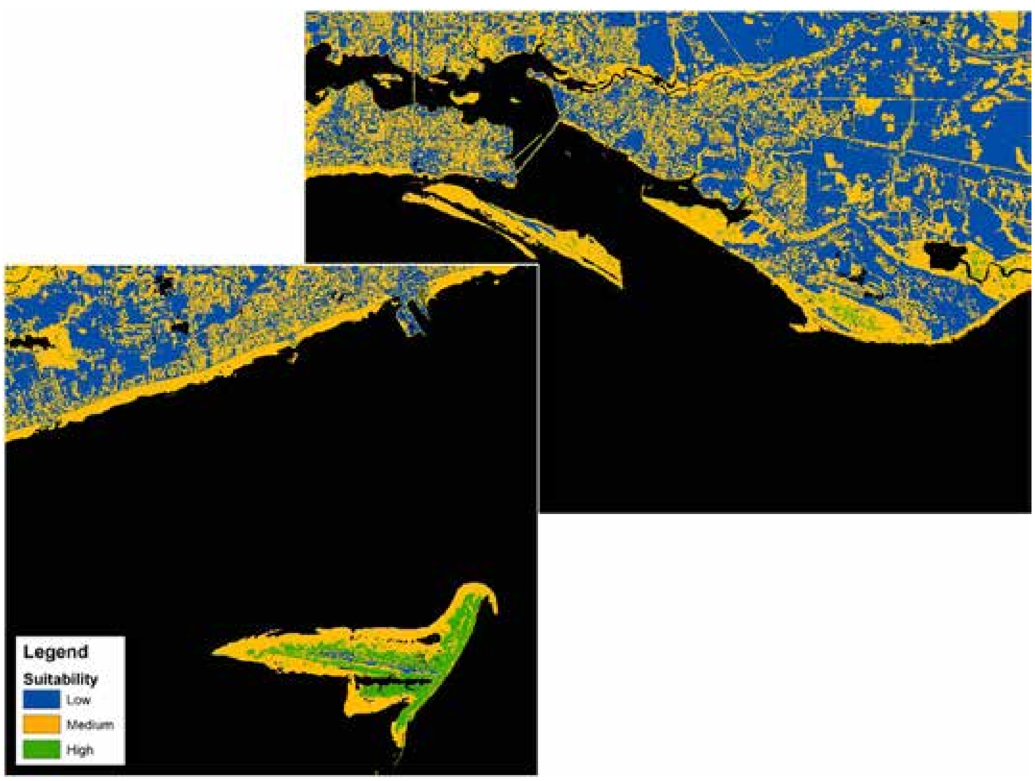

Figure 10. Snowy Plover Foraging Habitat Suitability -- Zoom of Cat Island (bottom) and Deer Island (top). Medium suitability in shallow water areas reflects SP preference for foraging in higher areas not in water. Also, prefer barrier islands to mainland beaches due to human presence