ERDC/EL TR-24-7

Environmental Laboratory

Dredging Operations Technical Support (DOTS) Program

Coastal Breeding Bird Phenology on the Dredged-Material Islands of the Baptiste Collette Bayou, US Army Corps of Engineers, New Orleans District, Louisiana

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Final Technical Report (TR)

Distribution Statement A. Approved for public release: distribution is unlimited.

Prepared for Dredging Operations Technical Support (DOTS) Program
US Army Engineer Research and Development Center (ERDC)
3909 Halls Ferry Road
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Under Funding Account Code U4391619, AMSCO Code 086000

Abstract

Coastal bird populations in North America have experienced significant population declines over the past four decades, and many species have become dependent upon human-made islands and other sediment-based habitats created through dredged material deposition. We monitored the breeding phenology of coastal bird populations utilizing dredged-material islands and open depositional areas in the Baptiste Collette Bayou in coastal Louisiana. Monitoring began in early May, prior to when most coastal species begin nesting, and continued through late August, when most breeding activity has ceased. Semimonthly surveys included area searches by foot and boat. Two deposition areas and one island supported large numbers of foraging, roosting, or breeding birds; surveys on these areas included using spotting scopes to identify species and count nests or young. Six islands and two open deposition areas were monitored. We also collected high-definition and lidar imagery using an uncrewed aerial system (UAS) in June, during peak nesting season. We recorded 77,474 cumulative detections of 68 species. Virtually all colonial nesting birds (terns and skimmers) nested on Gunn Island in 2021. We discuss these results in the context of dredged-material deposition by the US Army Corps of Engineers, New Orleans District, and offer recommendations for management of these areas.

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Preface

This technical report was funded by the Dredging Operations Technical Support (DOTS) Program under Funding Account Code U4391619, AMSCO Code 086000.

Portions of the fieldwork were funded by the US Army Corps of Engineers (USACE), New Orleans District, and the US Geological Survey, Wetlands and Aquatic Research Center, in Lafayette, Louisiana. This report was completed by the Ecological Resources Branch of the Ecosystem Evaluation and Engineering Division of the US Army Engineer Research and Development Center, Environmental Laboratory (ERDC-EL). At the time of publication, Mr. Joey Minter was branch chief, and Mr. Mark Farr was division chief. The deputy director of ERDC-EL was Dr. Brandon Lafferty, and the director was Dr. Edmond J. Russo, Jr.

COL Christian Patterson was commander of ERDC, and Dr. David W. Pittman was the director.

This report should be cited as follows:

> Guilfoyle, M. P., A. N. Anderson, S. S. Jackson, J. F. Jung, T. J. Zenzal, Jr., B. C. Suedel, and J. M. Corbino. 2024. *Coastal Breeding Bird Phenology on the Dredged-Material Islands of the Baptiste Collette Bayou, US Army Corps of Engineers, New Orleans District, Louisiana*. ERDC/EL TR-24-7. Vicksburg, MS: US Army Engineer Research and Development Center, Environmental Laboratory.

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1 Introduction

1.1 Background

The US Army Corps of Engineers (USACE) is responsible for maintaining our coastal infrastructure, including ports, harbors, and shoreline stabilization features, and for maintaining the Intracoastal Waterway System (ICWW; EPA/USACE 2007a, 2007b; Guilfoyle et al. 2019). Dredging operations are used regularly to maintain port and harbor depths sufficient to support international and national commerce. Natural coastal sedimentation processes are altered by maintenance dredging and shoreline armoring, both of which may reduce natural formation of coastal habitats, including beaches, sand spits, mudflats, marshes, and other wetland habitats (Guilfoyle et al. 2019). These changes can reduce or degrade important coastal habitat for local and regional floral and faunal species. In addition, dredged sediment material must be deposed locally or in offshore deposal locations (Guilfoyle et al. 2020; Guilfoyle et al. 2022).

The Baptiste Collette Bayou, in southern Louisiana, is a navigation channel in the USACE New Orleans District that must be regularly dredged to maintain sufficient depth for national and international commerce. This channel was created in 1968 by congressional authority to expand the waterway and provide access to the Inner Harbor Navigation Channel Lock through the Gulf Intracoastal Waterway. Jetties along the main channel were also authorized and constructed by 1979. The construction of multiple islands began in 1978 to establish local dredged material deposition areas and to provide nesting habitat for coastal birds. A constructed wetland west of the jetties was also completed around this period (USACE 2000).

Currently, there are six dredged-material islands and two open depositional areas in the Baptiste Collette Bayou (Figure 2-1). Gunn Island, which is the largest island and received dredge deposits in 2018, supported thousands of breeding birds when observed in 2020. However, neither the species composition nor breeding success of these birds were quantified on Gunn Island in 2020, and breeding coastal birds have not been monitored at any of these dredge-spoil islands or open areas in over a decade. Many coastal species depend on dredged-material islands for breeding (Soots and Landin 1978). Further, USACE requires better guidance on the size, shape, design, and management of dredged-material areas to benefit coastal birds across their annual life cycle. To understand avian use of dredge-spoil islands and open areas, we monitored coastal breeding phenology on these dredged-material islands and deposition areas in 2021. We also used an uncrewed aerial system (UAS) to collect aerial imagery and lidar to characterize the habitat availability and elevation features of these areas to provide guidance to the USACE New Orleans District on the design and function of dredged-material areas to create quality habitat for breeding coastal bird communities.

1.2 Objectives

The objectives of this study were to (1) determine which species of coastal birds use the open dredged material deposition areas and islands in the Baptiste Collette Bayou and to determine the abundance of each species, (2) document the phenology of the breeding season for nesting species on the islands or other dredged material deposition areas, (3) assess habitat availability and island characteristics using a UAS to collect high-definition imagery and lidar imagery, and (4) provide science-based recommendations to the USACE New Orleans District on the island features that are most important for supporting breeding, foraging, or roosting coastal birds. Tasks 1 and 2 were accomplished using semimonthly area search surveys on all islands and open areas. Task 3 was accomplished using high-definition imagery and lidar imagery. All information and data gathered were then summarized in task 4 to provide science-based recommendations to the USACE New Orleans District.

1.3 Approach

Surveys were conducted by foot on all open accessible areas and by boat (with the aid of binoculars and spotting scopes) for islands dominated by marsh and invasive vegetation (e.g., *Phragmites*). Boat surveys were conducted by slowly idling around the entire island and having observers record all species detected visually or aurally. The birds determined to be on or using the islands were emphasized. Flyovers, however, were recorded to document those species in the area that may not have been detected otherwise (e.g., Magnificent Frigatebird, *Fregata magnificens*). Surveys were conducted semimonthly, from 4 May to 19 August 2021. Almost all surveys were conducted from the early morning (0700) through late morning (1100), as weather and water conditions permitted. This protocol allowed each island or area to be surveyed approximately eight times during the season; however, due to weather and logistic issues, some islands were only surveyed seven times (or six times for Karen Island), and on one occasion, islands were surveyed in the afternoon due to inclement weather during morning hours.

Aerial and lidar imagery were collected using a UAS during June 2021. Imagery and lidar data were brought into ArcGIS. An iterative self-organizing data analysis (ISODATA) was performed to assess habitat types and availability on each island and open area. Lidar data were used to assess the elevational characteristics of each island and area.

Bird survey data were summarized using Statistical Analysis System (SAS) software (SAS Institute 2011). Birds were categorized into four groups: (1) focal species; (2) breeding species (those species either determined to be nesting or likely nesting on the islands), or those species likely breeding in the vicinity of the islands (e.g., herons and egrets), without known breeding activity on the island or areas; (3) nonbreeding species (those species known to largely breed outside of the area); and (4) total bird counts. A repeated measures analysis of variance (ANOVA) was used to determine which islands or areas supported the highest mean counts and species richness of bird groups.

1.4 Scope

This report targets USACE land managers or districts that manage or regulate coastal engineering projects, especially those that involve maintenance dredging and the deposition of dredged material in the nearshore coastal regions proximate to navigation channels or active ports and harbors. However, the results of this effort may be valuable to all biologists and land managers interested in habitat creation or restoration to benefit seasonal coastal avifauna. The results and methods described herein should be considered with monitoring on other USACE project lands or coastal engineering projects, on lands under other state or federal jurisdiction, or on private land with landowners who may have an interest in and objective to manage coastal lands for sustained seasonal use by populations of rare, sensitive, or regionally identified avian species of concern.

2 Study Area and Methods

2.1 Study Area

Six dredged-material islands and two open depositional areas were surveyed during the 2021 breeding season (Figure 2-1). Surveys were conducted semimonthly, starting in May, before breeding had begun for most coastal birds, and ending in late August, when most breeding activity had ceased for the year. The following summary about the islands created along the east of the jetties in the Baptiste Collette Bayou was taken from USACE (2000). Paul Island, on the east side of the jetties, was one of the first islands to be created in the Baptiste Collette Bay in 1978. Karen and Lynda Islands were created in 1980, and initial construction of Plover and Shea Islands began in 1982. Initially, most islands were no larger than five acres and were created as coastal bird nesting habitat. The first use of these islands as nesting habitat was documented in 1986. Between 1984 and 1987, additional dredged material was added to these islands to increase size and habitat availability for coastal waterbirds. Additional dredged material was added to Plover and Shea Islands between 1990 and 1993, and Willet Island was created in 1996. Additional dredged material was added to Shea and Willet Islands in 1998 and 1999.

Gunn Island and other dredged material deposition areas were added to the Baptiste Collette Bayou between 2000 and 2019 (USACE 2020). In 2012, a large marsh (Marsh Area G) was created just south of Paul Island (USACE 2020), and additional areas west of the jetties were formed. These areas, originally called E South, received additional material in 2019 and are now known as Open Area 1. Around this time, Plover Island was covered with dredged material that covered all the vegetation, recreating habitat for nesting waterbirds. Gunn Island was created in 2016 (USACE 2020). Between 2018 and 2020, Gunn Island received an additional 1,000,000+ cubic yards of dredged material, raising the elevation to 8+ ft[1] above mean sea Gulf level (MSG), eventually stabilizing to 6+ MSG due to compaction and dewatering. The total area of Gunn Island increased by 12 acres at this time to provide a total of about 40 acres of nesting habitat.

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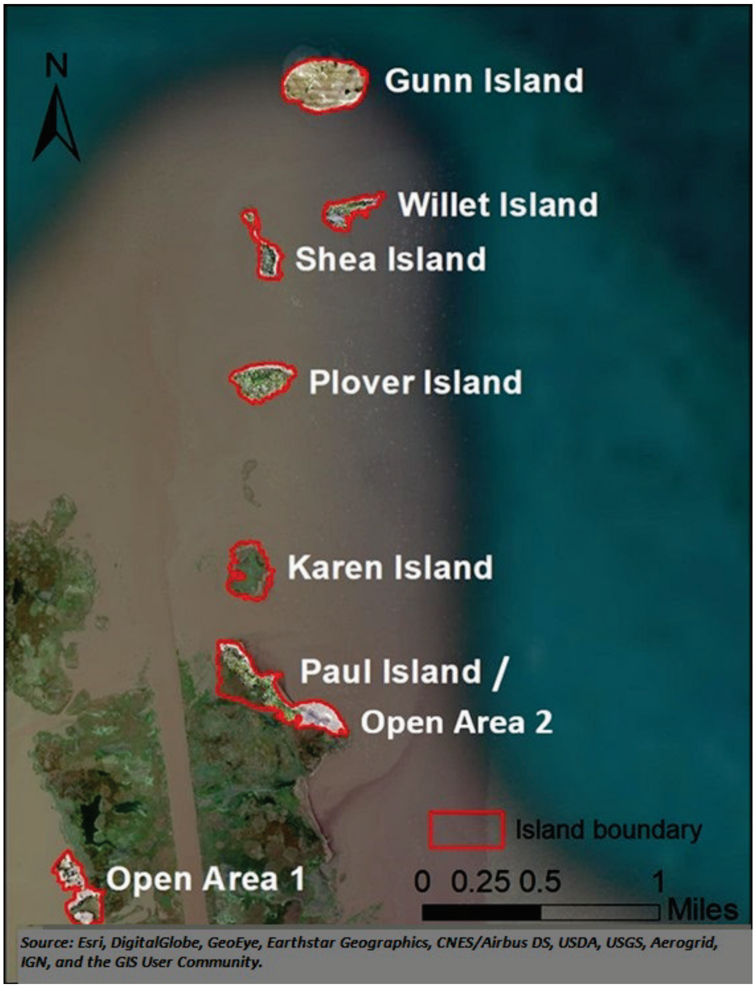
1 For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office, 2016), 248–252, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

In 2020, additional material was deposited that linked Marsh Area G and Paul Island; this has since been named Paul Island / Open Area 2 (Figure 2-1). In 2020, multiple tropical storms and hurricanes occurred in Louisiana during the breeding season and displaced many nesting birds, which resulted in multiple renesting attempts within a single season. An estimated 50,000 adult birds colonized Gunn Island due to weather-related colony failure at other historical nesting sites (McCormack 2020). In 2021, New Orleans District personnel determined that the coastal bird communities using these islands and dredged material depositional areas needed to be inventoried to update and verify historical records. The islands and depositional areas surveyed in 2021 (south to north, along the channel from the boat ramp in Venice, Louisiana) included Open Area 1, Paul Island / Open Area 2, Karen Island, Plover Island, Shea Island, Willet Island, and Gunn Island (Figure 2-1). Lynda Island, located between Karen and Plover Islands, was essentially submerged; therefore, no bird surveys were conducted on this island in 2021.

Figure 2-1. Aerial view of the islands and open depositional areas in the Baptiste Collette Bayou, Louisiana. (Map image is the intellectual property of Esri and is used herein under license. Copyright 2020 Esri and its licensors. All rights reserved.)



2.2 Breeding Season Community Monitoring

2.2.1 Area Search Surveys on Foot or Boat

Observers accessed the islands and dredged material deposition areas by boat (using an airboat or flat-bottomed boat) during semimonthly surveys, beginning on 4 May and ending on 19 August, for a total of 52 surveys. This effort resulted in at least eight surveys per island or area, except for Plover and Willet (7) and Karen (6), during the monitoring period. Survey efforts included a combination of boat surveys and foot-based surveys. Foot-based surveys constituted area searches, an acknowledged approach to surveying birds on DoD lands (Guilfoyle and Fischer 2007; Bart et al. 2012). At least two experienced observers conducted surveys to ensure a complete assessment of all species present with binoculars and spotting scopes, which were specifically used at open area sites (i.e., Gunn Island, Open Area 1, and Paul Island / Open Area 2). During initial island access, a boat driver circled the island, and surveyors recorded any birds detected visually or aurally, including flyovers. Almost all surveys were conducted during the early to midmorning period (0700 to 1100 CST); no surveys were conducted in heavy winds or rains. The only exception to morning surveys occurred in mid-July, when early morning storms necessitated afternoon surveys for two islands. Also, on occasion, some counts extended into the early afternoon to ensure complete survey coverage of the islands that day.

2.2.2 Spotting-Scope Surveys

When using spotting scopes, observers generally conducted perimeter counts from fixed survey stations around the island or open area. On Gunn Island, fixed survey stations separated by sufficient intervals around the colony permitted the maximum number of birds and nests to be counted. Unique landmarks or field markers were used to keep track of all birds and nests counted and to minimize double counting. Observers attempted to count all adults and nests by species when circumstances permitted. For both colonial and solitary nesting species, we counted the number of adults that displayed breeding behaviors like pair formation, defensive or territorial behavior, nest construction, nests with eggs, and adults with young. For colonial species, we also counted those adults loafing within or adjacent to a colony. Each observer conducted an independent count of adults and nests for each species present, and the highest count of each metric was recorded and then summed for all survey stations to yield a complete count for each island or open area. Generally, survey methods tend to underestimate population numbers (Bart et al. 2012); therefore, maximum counts were used as a best estimate of birds present on the islands at the time of the survey. Nests were counted when incubating adults, a visible nest with egg(s), or a nest with young were directly observed.

A handheld GPS was used to record latitude and longitude (in World Geodetic System 1984 [WGS84] decimal degrees) for each survey station, nest scrape, and nest with eggs or young for each visit during the monitoring period. To reduce colony disturbance, we estimated GPS locations for colonial nesting species by estimating the distance and direction to the species or nest from the surveyor's location. We recorded an exact GPS location for a scrape, nest with eggs, and young for most solitary species when located outside of a colony. We also delineated the extent of the waterbird nesting colony by recording multiple GPS points around the colony perimeter.

Additional data collected included survey start and end times, temperature, wind speed and direction, sky conditions, and high or low tide period. All data were entered and archived at the US Geological Survey, Wetlands and Aquatic Research Center, in Lafayette, Louisiana. These data were copied, and backups were stored at the US Army Engineer Research Center, Environmental Laboratory (ERDC-EL), in Vicksburg, Mississippi. All data collected are in the public domain and can be procured for public and scientific purposes by contacting the authors.

2.2.3 Statistical Analysis of Bird Data

Differences in mean counts were tested for individual species and species groups (i.e., focal species, breeding species, nonbreeding species, and total species) on all the islands and areas surveyed. During this effort, we identified several focal species based on known national and regional species of concern, particularly those coastal species identified as focal species and species of concern by the Gulf of Mexico Avian Monitoring Network.[2] We identified 16 focal species to document on the islands and areas monitored. (Table 3-1 contains species group and common and scientific names.) We also determined those species documented to breed on the islands during the current and past efforts (USACE 2000, 2020); in addition, we used field guides and the American Ornithological Society Birds of the World species accounts[3] to determine those species likely to be breeding in the vicinity of the islands and those species unlikely to be breeding in the vicinity of the islands. Final groups included 16 focal species, 41 breeding species, and 26 species of nonbreeders (Table 3-1)

We performed a repeated measures ANOVA to test for significant differences in mean metric values among islands and areas using the general linear model procedure (PROC GLM) described by SAS Institute (2011). A Tukey's multiple-range test (Sokal and Rohlf 1995) was used to identify islands and areas with significantly different mean values. We also performed simple descriptive statistics to gain cumulative means and

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2 https://gomamn.org

3 https://americanornithology.org/publications/birds-of-the-world/

standard errors for all counts and species richness metrics for all islands and areas.

2.2.4 Breeding and Nesting Behavior of Coastal Birds on Gunn Island

We documented the phenology of nesting birds on Gunn Island by conducting surveys when adults were present and noting various behaviors and activities, such as pair formation, territorial displays, nest construction, nests with eggs, and adults with young. We used cumulative moving average counts of adults in different stages of breeding behavior, including courtship, pair formation, nest scrapes or construction, nests with eggs, and adults with young, to document and visualize the reproductive phenology of nesting birds during the season. Because the initial survey in May occurred before breeding behaviors were initiated, data used in this effort started with the numbers of behaviors and activities recorded during the second survey. We then calculated a cumulative moving average for each set of behaviors documented during the nesting season. First, an average was calculated for surveys 2 and 3, followed by an average calculated for surveys 2 through 4, and so on, through to the last survey (survey 8) in August. This approach describes the nesting phenology but smooths out the data and removes sharp changes in the nesting behavior. From this information, one can visualize the appearance of adults, followed by an increasing number of pairs and nest scrapes. The number of adults decreased during the season as the averages of nests with eggs, nests with young, and adults with young increased. Finally, adults with young decreased as young fledged and left the island. We created graphs to document and describe this process for seven species of nesting birds on Gunn Island.

2.3 Uncrewed Aerial System (UAS) Field Methods

UAS lidar data and true color, three-band (i.e., red, green, and blue) imagery were collected for the Baptiste Collette Bayou islands in South Louisiana on 21–25 June 2021. Data derivatives from the data were used to assess bird habitat and elevation features for the dredged-material islands and depositional areas. The UAS was flown at an altitude of 70 m (6 m/s speed) for Gunn Island and 60 m (6 m/s speed) for all other islands, resulting in an approximate point density of 150 points/m^2. The UAS was flown at a slightly higher altitude over Gunn Island in an effort to avoid flushing coastal birds from their nesting locations without a significant decrease in point density or data resolution. The multirotor octocopter UAS platform used was a Harris Aerial HX8 (Figure 2-2). Table 2-1 provides the technical specifications of the Harris Aerial HX8. This system includes a Sony Alpha 7R II 42.4 megapixel digital camera and a Riegl miniVUX-2UAV laser scanner mounted to the underside of the platform. The spatial resolution (i.e., pixel size) of the imagery was 1.25 cm. The package also includes an onboard GPS and an inertial measurement unit (IMU) to record parameters such as altitude, flight speed, direction, and position of the sensor(s).

Figure 2-2. Harris Aerial HX8 uncrewed aerial system (UAS) platform. (Image reproduced from Harris Aerial, n.d. Public domain.)

Table 2-1. Technical specifications for the Harris Aerial HX8.

Uncrewed Aerial System Features	Technical Specifications
Payload (including gimbal and flight battery)	22,226 g (49 lb)
Maximum flight time (ideal)	33 min
Maximum airspeed	0 knots (hover)–50 knots (maximum)
Dimensions	50 mm (W), 15.5 mm (H), 81.5 mm (L)
Packed size	81.5 × 50 × 15.5 mm
Wind stability	<8 m/sec (17.9 mpg / 28.8 km/h)
Flight data log	128-bit
Servo connectors	8
Multirotor flight control	Yes
Redundant flight control	Yes

A total station GPS was set up at the site, in close proximity to the data collection areas. This was needed to correct GPS positions for the UAS payload and onboard sensors. Trimble R10 dual frequency GPS units were used by the survey team. One unit was placed in a stationary location for 2 hours, collecting raw GPS data at a rate of 1 Hz, and sent corrections to the second roving GPS unit when the surveys were being conducted. The raw data were downloaded and sent to the NOAA National Geodetic Survey Online Positioning User Service, where the raw positions were compared to several permanent-reference GPS stations. This provided coordinates for the control mark and subsequent coordinate system of the data to convert to the WGS84 Datum, Universal Transverse Mercator (UTM) Coordinate System (Zone 16N). Elevation coordinates were processed with ellipsoid elevation and converted to orthographic height using Geoid model Earth Gravitational Model (EGM2008; Pavlis et al. 2012).

2.3.1 Image Classification and Processing

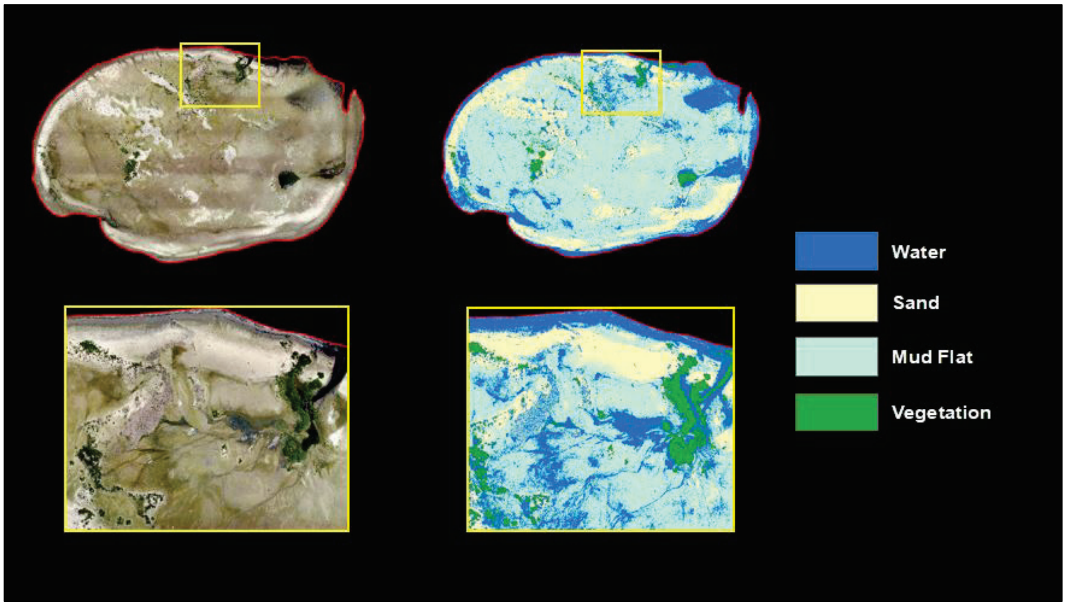
The image tiles were orthorectified and mosaicked using Pix4D drone mapping photogrammetry suite (Pix4D Mapper 2021). The process of stitching the individual images together to form one cohesive image, or mosaic (in GeoTiff format), allows a single output image to be generated for each island or area of interest. The extent of each island boundary was digitized from the true color image mosaics using Esri ArcGIS Pro version 2.4 (Esri 2019) and output in Esri shapefile format (polygons). The mosaic was then clipped to each island's polygon extent and used as the input image to perform image classifications to derive broad landcover or habitat types for each island.

Image classifications are best suited for use with multispectral imagery with at least four spectral bands (i.e., red, green, blue, and near-infrared) due to the increased spectral separability of wavelengths from higher spectral resolution imagery. However, for this study, and due to image availability, a hybrid unsupervised and supervised image classification was performed using the true color, three-band (i.e., red, green, and blue) image mosaics to derive broad landcover classes that were needed to assess bird habitat. Previous studies showed that image classifications can be derived using true-color histograms as a novel method for performing base image classifications (Singh 2009). Moreover, Fleming et al. (1975) outlined a hybrid approach for image classification that uses both supervised and unsupervised methods. The broad landcover classes used to quantify potential bird habitat for this study included water, sand, mudflat, and vegetation, and they were easily discernable using a color-based image classification method.

In an unsupervised image classification, the software (rather than the analyst) develops the signatures used to classify the image into distinct classes. In a supervised classification, the analyst is responsible for defining training samples (i.e., polygons) that represent the different cover types to extract from the image. The training samples are used to extract the digital values from the image to generate signatures (or statistical definitions) of each class. For this study, an unsupervised image classification was first performed on each image mosaic. The image classification workflow in ArcGIS 10.7 was used to perform the classifications. Because no ground truth information was available, we used an ISODATA clustering algorithm. ISODATA is a widely used clustering algorithm that makes a large number of passes through an image and uses a minimum spectral distance formula to form clusters. A maximum of 10 sample intervals were specified to have an output of four distinct classes (i.e., water, sand, mudflat, and vegetation). Nearshore, inland shallow water with a sand bottom, and open water areas were classified as water. Dry, white sand areas were classified as sand. Wet, sandy areas with no standing water were classified as mudflats. Finally, all vegetation types were classified as vegetation. The minimum class pixel size was set to 20, so in order to be a distinct vegetation class, it had to have at least 20 pixels or cells assigned to it. The clustering algorithm essentially helps the analyst determine the maximum number of spectral classes into which the image can be divided and assists in developing training areas and a signature file that can then be used as inputs for the supervised classification.

The next step in the hybrid approach was a supervised classification using the maximum likelihood algorithm. The algorithm uses the parameters developed through the unsupervised classification and probability distribution estimates to determine the relative likelihood that a pixel belongs to a certain class. Training samples were generated from the interim classes developed from ISODATA and output to a signature file, which was then used to create a final image classification (Figure 2-3) for each island.

Figure 2-3. Hybrid image classification with broad land cover classes (water, sand, mudflat, and vegetation) shown on Gunn Island.



2.3.2 Lidar Postprocessing

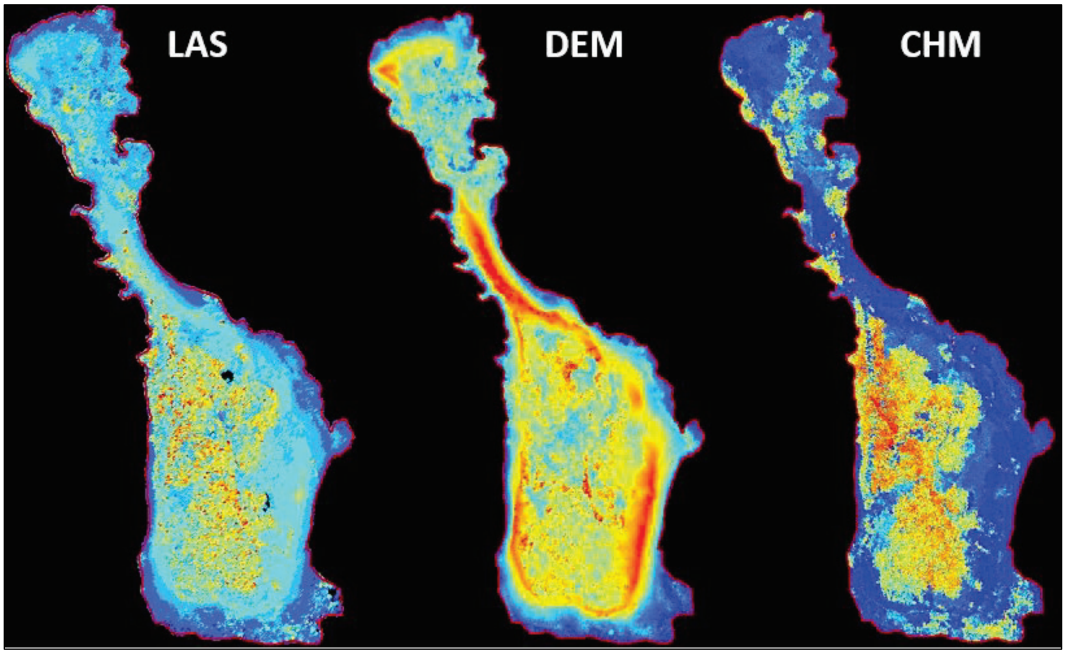
Initial postprocessing of the lidar data is required on the raw data files to produce an accurate LAS file to generate a functional elevation surface, or digital elevation model (DEM). After field collection of the raw lidar points, the point data IMU and GPS data were downloaded and organized for postprocessing. The first step used Applanix POSPac Mobile Mapping Suite UAS software (Trimble Geospatial 2018). This software enables direct georeferencing of UAS-derived datasets. Several steps are required to produce georeferenced data using the POSPac software. The software uses the (1) raw GPS data from the platform IMU (APX-15 GNSS, 336 channel dual frequency GPS), (2) the raw GPS data from the stationary terrestrial GPS unit, (3) the Online Positioning User System (OPUS) position computed from the stationary data file and the offset measurements of the airborne GPS antenna location in reference to the position of the IMU (including roll, pitch, and yaw measurements), and (4) information from the onboard gyro and accelerometer. The output file from this software contains the fully processed time and positional information in a georeferenced coordinate system and is used as the input file for generating the 3D point cloud or LAS file. Corrections in the form of calibrations and offsets for the lidar positioning relative to the IMU are first applied. The flight lines are displayed, and the flight mission lines of interest are selected for processing. This allows the processor to exclude areas that are not part of the mission and reduces unnecessary data creation. Finally, the output coordinate system and lidar vector lengths are set, and the ortho-corrected LAS files are generated. The final LAS files from these postprocessing steps are used to create the surface models and DEMs.

2.3.3 Lidar Data Analysis

ENVI Lidar version 5.5 (L3Harris Geospatial Solutions, Broomfield, Colorado) software was used to develop the steps and methodological framework for LAS file analysis and model generation. The LAS files were used to generate gridded models (Figure 2-4) of the island topography and in situ surface features. A 0.5 m DEM was generated from the last return points from the classified LAS files. A DEM provides a grid of elevation values of a bare ground surface terrain that removes vegetation and other structures (Suir et al. 2023). The miniVUX-2UAV lidar sensor uses waveform technology and echo digitization with multitarget resolution to penetrate vegetation (Riegl Laser Measurement Systems 2021) to generate an accurate, bare ground model even in densely vegetated areas. To produce the DEM, a triangulated irregular network (TIN) interpolation method with rural-area filtering was used. A TIN is a digital representation of a continuous surface that consists of triangular facets and is used primarily as a discrete global grid in primary elevation models. Similarly, a 0.5 m digital surface model (DSM) was created using the first return points from the classified LAS file. A DSM provides a grid of elevation values and includes vegetation and other structures (Suir et al. 2023).

The LAS files were processed using ENVI lidar that filters points specifically for outputting vegetation heights. A 0.5 m vegetation canopy height model (CHM) was created by subtracting the DEM from the DSM (Figure 2-4). This subtraction routine was performed using band math in ENVI. The CHM contains the vegetation canopy height for all areas within the lidar extent footprint and was clipped to each island extent. All of the 0.5 m raster models were output to a 32-bit floating point (GeoTiff format) with elevations or heights in meters.

Figure 2-4. LAS file, digital elevation model (DEM), and canopy height model (CHM) examples from Shea Island. Higher elevations/heights appear *red*, and lower elevations/heights appear *blue*.



Elevation statistics were calculated from the DEM and include elevation range (minimum and maximum), mean, and standard deviation. Surface topography and roughness values were derived from the DEM and calculated using the slope or change in elevation. The slope was calculated using Spatial Analyst (Esri) and is a measure of the degree of inclination, or steepness, of a surface area, and units are in degrees. Slope values range from 0 to 90, with lower values representing a flatter surface and higher values representing steeper terrain.

Surface roughness can be measured and inferred by calculating the standard deviation of a slope; this is referred to as the Terrain Ruggedness Index (TRI; Riley et al. 1999). TRI is calculated using the equation that follows:

$$\mathrm{TRI} = [\sum(Z_{\mathrm{ij}} - Z_{00})^2]^{1/2},$$

where Z_{ij} is the elevation of each neighborhood (i.e., window) cell, and Z_{00} is the value at the center of the window.

This index attempts to quantify how rough an area is by determining the relative change between a grid cell elevation measured against its neighboring cell elevation. The algorithm uses the square root of the sum of the square of the difference between a cell and its surrounding cells. Therefore, TRI is a relative measure of surface roughness and depends on the spatial resolution of the DEM. The output cell values range from 0 to approximately 1, with increasing values indicating a rougher surface and correlated to increasing slope.

3 Results

3.1 Bird Monitoring

3.1.1 Mean Abundance and Species Richness on Islands and Areas

Excluding Gunn Island, surveys totaled 1,591 min of counts, with an average duration of 36.2 min (range 12–86 min). Gunn Island supported thousands of nesting birds, which required the use of spotting scopes to count adults, nests, and young; thus, more time was required to survey breeding birds. A total of eight surveys were conducted on Gunn Island, with an average time of 167.8 min per survey (range 54–231 min). Forty-one breeding species and 27 nonbreeding species, including all of our 16 focal species, were identified during the season across all islands (Table 3-1 and Appendix A).

During these surveys, we recorded 77,474 cumulative detections of 68 species on the six islands and two depositional areas in the Baptiste Collette Bayou (Table 3-1 and Appendix A). Gunn Island had more detections of focal species (mean = 1,779 ± 313.05; $P < 0.0001$), breeding (mean = 8,453 ± 1,567.09; $P < 0.0001$), and total individuals (mean = 8,463.13 ± 1,567.09; $P < 0.0001$), but lower breeding species richness (mean = 9.13 ± 1.46, excluding flyovers; Table 3-2), while Open Area 1 had the highest mean counts of nonbreeding species (mean = 241.88 ± 90.95; $P < 0.0001$) and highest total species richness (mean = 22.5 ± 1.58; $P < 0.001$; Table 3-2). Paul Island / Open Area 2 had the second highest nonbreeding species count (mean = 48.88 ± 15.04; $P < 0.001$) and total species richness (mean = 17.38 ± 0.96; $P < 0.0001$; Table 3-2). Cumulative mean values of detections and species richness differed among the islands and areas and were statistically significant over the course of the field season for all islands (Table 3-2). Despite high counts for breeding species and focal species on Gunn Island, this island had some of the lowest overall species' richness for all species groups.

3.1.2 Breeding Behavior Phenology of Coastal Birds

We also examined the phenology of breeding behaviors exhibited by nesting birds for the seven common nesting species on Gunn Island (Figures 3-3 to 3-9). The Royal Tern was the most common breeding seabird on Gunn Island, followed by the Black Skimmer, Sandwich Tern, Gull-billed Tern, Caspian Tern, and Laughing Gull (scientific names included in Table 3-1). The Forster's Tern attempted to nest in the wrack line near the island's edge, but most of the nests were washed out in mid-June during a tropical storm, and the birds largely vacated the island and never returned (Figure 3-5). Many Black Skimmer nests were also lost in the tropical storm, but the birds quickly renested and were able to successfully produce young by the end of August. Most birds had completed breeding by the end of August. A typical pattern was observed for most species as the season progressed: first, relatively high numbers of adults; followed by territorial behaviors, courtship, and nest-building behaviors; then followed by nests or scrapes, nests with eggs, or young; and ending with adults and young by late July and August (Figures 3-3 to 3-9).

Courtship behavior by Least Terns was detected on Paul Island / Area 2 (located in the open sand habitat of depositional Area 2), and 51 nests with eggs were detected during the monitoring period (Table 3-3). However, these birds vacated the area due to the tropical storm in mid-June and, possibly, the presence of mammalian predators. After the Least Tern vacated the island, Forester's Terns were observed, but they never nested. In general, because Paul Island / Open Area 2 was attached to a larger segment of land, it was likely not a good nesting site because mammalian predators were present (canine tracks were often observed on the open area). Also, soil disturbance and visual confirmation of the presence of non-native feral pigs (*Sus scrofa*) lowered the suitability of this area for nesting birds. Most of the other islands were dominated by invasive *Phragmites*, with few open sandy areas, and therefore were largely devoid of breeding coastal birds. Several islands with a combination of native marsh and *Phragmites* supported marsh birds, including the Least Bittern (Figure 3-1) and Clapper Rail, that were likely breeding. Small sandy open areas on Paul Island / Open Area 2 and on Karen, Plover, Shea, and Willet Islands supported nesting Common Nighthawks and a few Black-necked Stilts (Figure 3-2). On Gunn Island, we observed two pairs of nesting American Oystercatchers and two pairs of nesting Black-necked Stilts (Table 3-3).

Open Area 1 was a lower elevational area, and water was pumped through the dredge pipes during the deposition. This action created numerous tidally influenced channels, pools, and depressions. While this area did not support nesting coastal birds, tidally influenced sand flats are known to provide excellent foraging and roosting areas for coastal waterbirds

(Iglecia and Winn 2021). Indeed, Open Area 1 supported the highest counts of nonbreeding birds and the highest species richness of all the islands or areas (Table 3-2).

Figure 3-1. The Least Bittern (*Ixobrychus exilis*) was documented on islands, including Paul (excluding Area 2), Karen, Plover, Shea, and Willet Islands, that were dominated by *Phragmites.* (Photo by Jacob Jung, US Army Engineer Research and Development Center, Environmental Laboratory [ERDC-EL].)

Figure 3-2. The Common Nighthawk (*Chordeiles minor*, *top*) and Black-necked Stilt (*Himantopus mexicanus*, *bottom*) were regularly observed and exhibited nesting behaviors at five locations during the 2021 breeding season. (Photo by Jacob Jung, ERDC-EL.)

Table 3-1. Common and scientific names and total and mean counts (±standard error [StdErr]) for all species detected during semimonthly breeding-season monitoring on the six dredged-material islands and two open depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	43	0.83 ± 0.32
Fulvous Whistling Duck[2]	*Dendrocygna bicolor*	1	0.02 ± 0.02
Mottled Duck[1,2]	*Anas fulvigula*	828	15.92 ± 5.82
Blue-winged Teal[3]	*Spatula discors*	51	0.98 ± 0.87
Mourning Dove [2]	*Zenaida macroura*	1	0.02 ± 0.02
Common Nighthawk[2]	*Chordeiles minor*	49	0.94 ± 0.20
Clapper Rail[1,2]	*Rallus crepitans*	30	0.58 ± 0.12
Common Gallinule[2]	*Gallinula galeata*	22	0.42 ± 0.11
American Avocet[3]	*Himantopus mexicanus*	2	0.04 ± 0.04
Black-necked Stilt[2]	*Recurvirostra americana*	332	6.39±2.63
American Oystercatcher[1,2]	*Haematopus palliatus*	11	0.21 ± 0.08
Black-bellied Plover[3]	*Pluvialis squatarola*	57	0.98 ± 0.87
Killdeer[2]	*Charadrius vociferus*	1	0.02 ± 0.02
Wilson's Plover[1,2]	*Charadrius wilsonia*	10	0.19 ± 0.19
Semipalmated Plover[3]	*Charadrius semipalmatus*	120	2.31 ± 1.21
Whimbrel[1,2]	*Numenius phaeopus*	1	0.02 ± 0.02
Marbled Godwit[1,3]	*Limosa fedoa*	238	4.58 ± 2.17
Ruddy Turnstone[1,3]	*Arenaria interpres*	12	0.23 ± 0.10
Red Knot[1,3]	*Calidris canutus*	2	0.04 ± 0.04
Sanderling[3]	*Calidris alba*	155	2.98 ± 1.56
Semipalmated Sandpiper[1,2]	*Calidris pusilla*	417	8.02 ± 4.64
Western Sandpiper[1,3]	*Calidris mauri*	461	8.87 ± 4.83
Least Sandpiper[3]	*Calidris minutilla*	412	7.93 ± 3.85
White-rumped Sandpiper[3]	*Calidris fuscicollis*	16	0.31 ± 0.29
Dunlin[1,3]	*Calidris alpina*	55	1.06 ± 0.75
Short-billed Dowitcher[1,3]	*Limnodromus griseus*	306	5.89 ± 5.92
Spotted Sandpiper[3]	*Actitis macularius*	16	0.31 ± 0.11
Willet[1,2]	*Tringa semipalmata*	427	6.39 ± 2.63
Greater Yellowlegs[3]	*Tringa melanoleuca*	21	0.40 ± 0.10
Lesser Yellowlegs[3]	*Tringa flavipes*	56	1.08 ± 0.72
Laughing Gull[2]	*Leucophaeus atricilla*	4,211	80.98 ± 31.82
Ring-billed Gull[3]	*Larus delawarensis*	1	0.02 ± 0.02
Herring Gull[3]	*Larus argentatus*	2	0.04 ± 0.04
Least Tern[1,2]	*Sternula antillarum*	72	1.39 ± 0.85
Black Tern[3]	*Chlidonias niger*	137	2.64 ± 1.31

Table 3-1 (cont.). Common and scientific names and total and mean counts (±standard error [StdErr]) for all species detected during semimonthly breeding-season monitoring on the six dredged-material islands and two open depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Forster's Tern[2]	*Sterna forsteri*	593	11.40 ± 5.93
Gull-billed Tern[2]	*Gelochelidon nilotica*	6,086	117.04 ± 42.97
Sandwich Tern[2]	*Thalasseus sandvicensis*	9,799	188.44 ± 73.58
Royal Tern[2]	*Thalasseus maximus*	31,984	1626.43 ± 225.55
Caspian Tern[2]	*Hydroprogne caspia*	4,047	77.83 ± 24.83
Black Skimmer[1,2]	*Rynchops niger*	14,331	275.60 ± 100.58
Magnificent Frigatebird[3]	*Fregata magnificens*	14	0.27 ± 0.08
Double-crested Cormorant[3]	*Phalacrocorax auritus*	3	0.06 ± 0.04
American White Pelican[3]	*Pelecanus erythrorhynchos*	4	0.08 ± 0.06
Brown Pelican[2]	*Pelecanus occidentalis*	174	3.35 ± 1.11
Least Bittern[2]	*Ixobrychus exilis*	11	0.21 ± 0.06
Great Blue Heron[2]	*Ardea Herodias*	5	0.10 ± 0.04
Snowy Egret[2]	*Egretta thula*	30	0.58 ± 0.14
Great Egret[2]	*Ardea alba*	21	0.40 ± 0.10
Tricolored Heron[2]	*Egretta tricolor*	12	0.23 ± 0.07
Little Blue Heron[2]	*Egretta caerulea*	3	0.06 ± 0.04
Reddish Egret[2]	*Egretta rufescens*	2	0.04 ± 0.04
Green Heron[2]	*Butorides virescens*	1	0.02 ± 0.02
Black-crowned Night Heron[2]	*Nycticorax nycticorax*	8	0.15 ± 0.10
Yellow-crowned Night Heron[2]	*Nyctanassa violacea*	2	0.04 ± 0.04
Glossy Ibis[2]	*Plegadis falcinellus*	1	0.02 ± 0.02
White Ibis[2]	*Eudocimus albus*	83	1.61 ± 0.66
Osprey[2]	*Pandion haliaetus*	2	0.04 ± 0.04
Merlin[3]	*Falco columbarius*	1	0.02 ± 0.02
Eastern Kingbird[2]	*Tyrannus tyrannus*	18	0.35 ± 0.11
Barn Swallow[2]	*Hirundo rustica*	120	2.31 ± 1.12
Common Yellowthroat[2]	*Geothlypis trichas*	21	0.40 ± 0.13
Magnolia Warbler[3]	*Setophaga magnolia*	1	0.02 ± 0.02
Red-winged Blackbird[2]	*Agelaius phoeniceus*	1,154	22.19 ± 2.65
Boat-tailed Grackle[2]	*Quiscalus major*	83	1.61 ± 0.29
Brown-headed Cowbird[2]	*Molothrus ater*	2	0.04 ± 0.04
Orchard Oriole[2]	*Icterus spurius*	39	0.75 ± 0.19
TOTAL BIRDS		77,474	11,489 ± 476.89

[1] Focal species for this study.
[2] Breeding species on the islands or likely to be breeding in the local area.
[3] Nonbreeding species; wintering or transient migrants unlikely to be breeding in the local area.

Table 3-2. Repeated measures analysis of variance (ANOVA) and Tukey's multiple-range test results on mean (±StdErr) cumulative detections per survey (excluding flyovers) and species richness for species groups during the breeding season on the dredged-material islands on the Baptiste Collette Bayou, US Army Corps of Engineers (USACE), New Orleans District, Louisiana, 5 May—19 August 2021.

	ANOVA Results							
Species Groups	Open Area 1 (*n* = 8)	Paul Island / Open Area 2 (*n* = 8)	Karen Island (*n* = 6)	Plover Island (*n* = 7)	Shea Island (*n* = 8)	Willet Island (*n* = 7)	Gunn Island (*n* = 8)	*P*
Mean Counts								
Focal species	247.13 ± 89.39B	33.50 ± 9.09B	3.33 ± 1.50B	15.00 ± 4.63B	9.25 ± 3.53B	10.57 ± 2.05B	1,779.63 ± 313.05A	<0.0001
Breeding species	353.88 ± 77.87B	114.75 ± 19.61B	43.00 ± 7.31B	68.29 ± 12.25B	222.50 ± 161.51B	54.29 ± 10.58B	8,453.00 ± 1,567.09A	<0.0001
Nonbreeding species	241.88 ± 90.95A	48.88 ± 15.04B	1.83 ± 1.01B	1.71 ± 1.25B	8.50 ± 6.41B	1.43 ± 0.62B	10.13 ± 9.98B	<0.0001
Total species	595.75 ± 164.51B	163.63 ± 27.26B	44.83 ± 7.41B	70.00 ± 11.74B	231.00 ± 169.88B	55.71 ± 10.42B	8,463.13 ± 1,560.12A	<0.0001
Mean Species Richness								
Focal species	4.88 ± 0.55A	3.25 ± 0.53AB	1.33 ± 0.42BCD	1.57 ± 0.20D	2.00 ± 0.33CD	0.29 ± 0.18D	1.88 ± 0.23ABC	<0.0001
Breeding species	16.13 ± 0.93A	12.38 ± 0.73AB	8.50 ± 0.99B	8.29 ± 0.52B	10.00 ± 0.71B	8.43 ± 1.21B	9.13 ± 1.46B	<0.0001
Nonbreeding species	6.38 ± 0.98A	5.00 ± 0.63A	0.83 ± 0.48B	0.86 ± 0.55B	1.50 ± 0.68B	0.86 ± 0.34B	0.50 ± 0.38B	<0.0001
Total species	22.50 ± 1.68A	17.38 ± 0.96B	9.33 ± 1.23B	9.14 ± 0.91B	11.50 ± 1.16B	9.14 ± 1.39B	9.63 ± 1.55B	<0.0001

Note: Tukey's multiple-range test results; means with the same letter are not significantly different.

Figure 3-3. Cumulative moving averages of breeding behaviors of the Black Skimmer (*Rynchops niger*) on Gunn Island, coastal Louisiana, 2021.

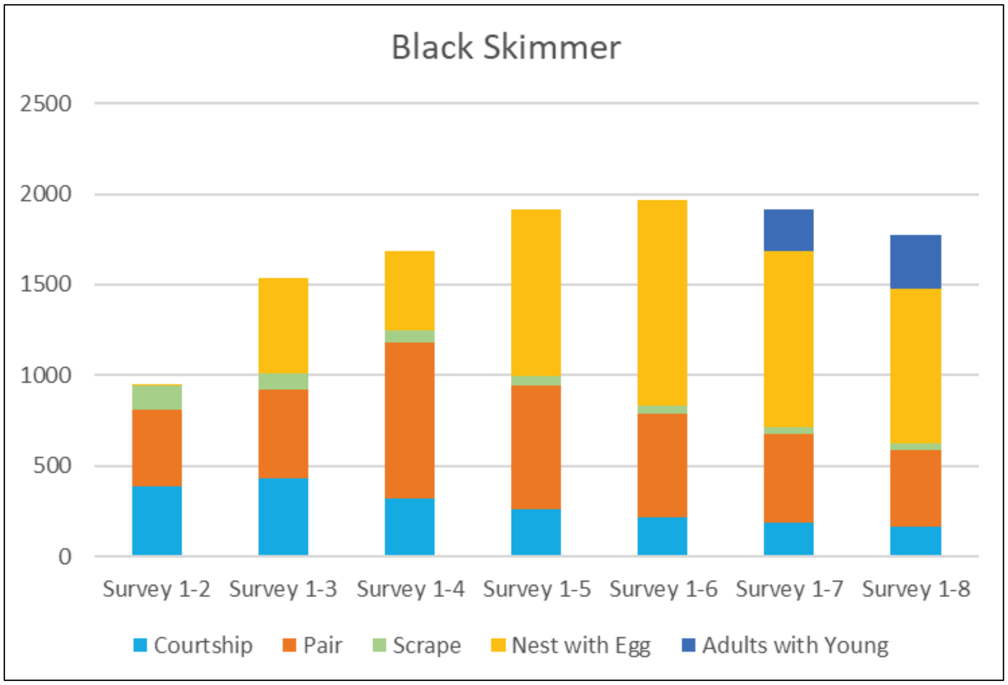


Figure 3-4. Cumulative moving averages of breeding behaviors of the Caspian Tern (*Hydroprogne caspia*) on Gunn Island, coastal Louisiana, 2021.

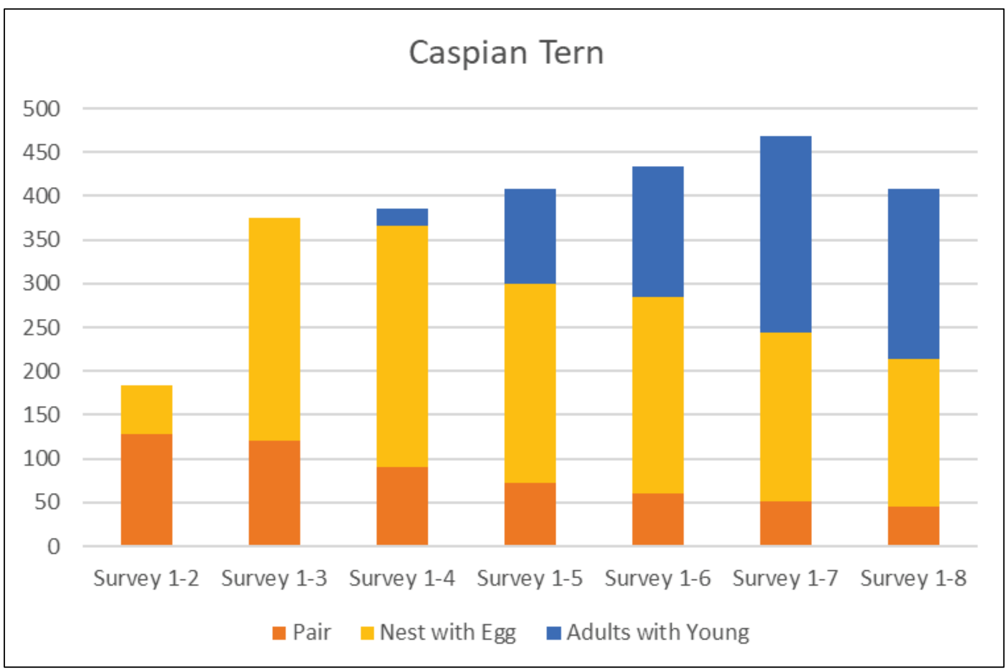


Figure 3-5. Cumulative moving averages of breeding behaviors of the Forster's Tern (*Sterna forsteri*) on Gunn Island, coastal Louisiana, 2021.

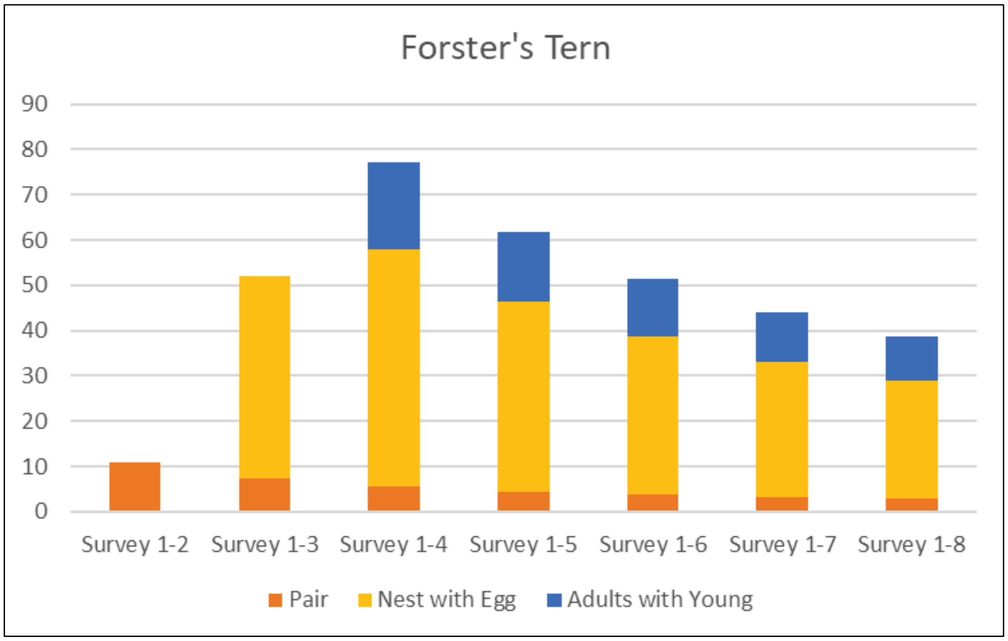


Figure 3-6. Cumulative moving averages of breeding behaviors of the Gull-billed Tern (*Gelochelidon nilotica*) on Gunn Island, coastal Louisiana, 2021.

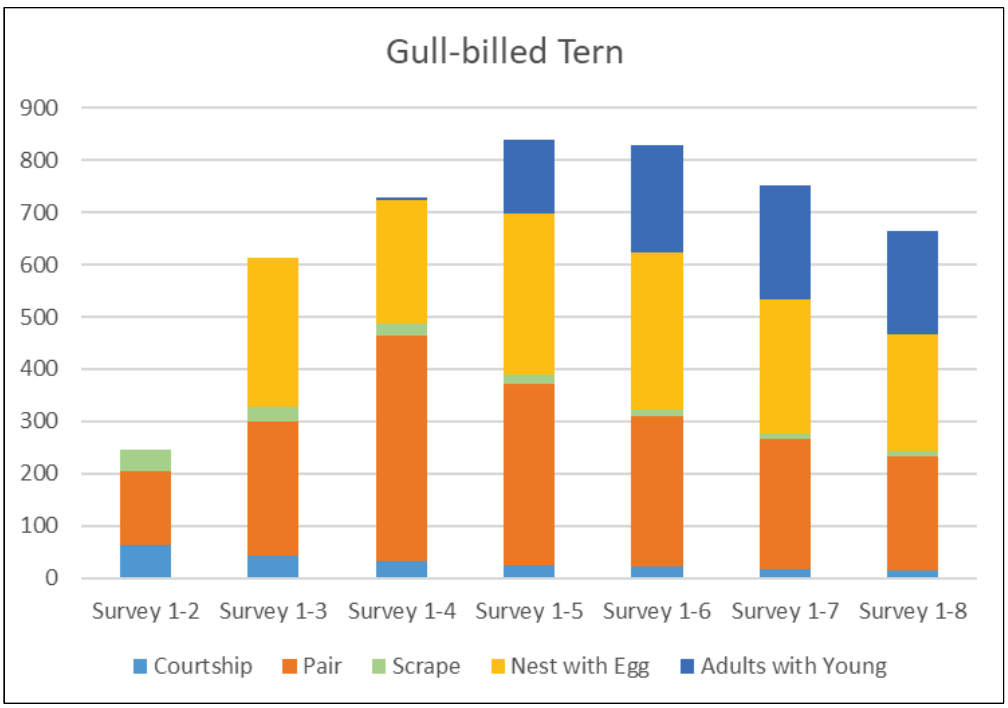


Figure 3-7. Cumulative moving averages of breeding behaviors of the Laughing Gull (*Leucophaeus atricilla*) on Gunn Island, coastal Louisiana, 2021.

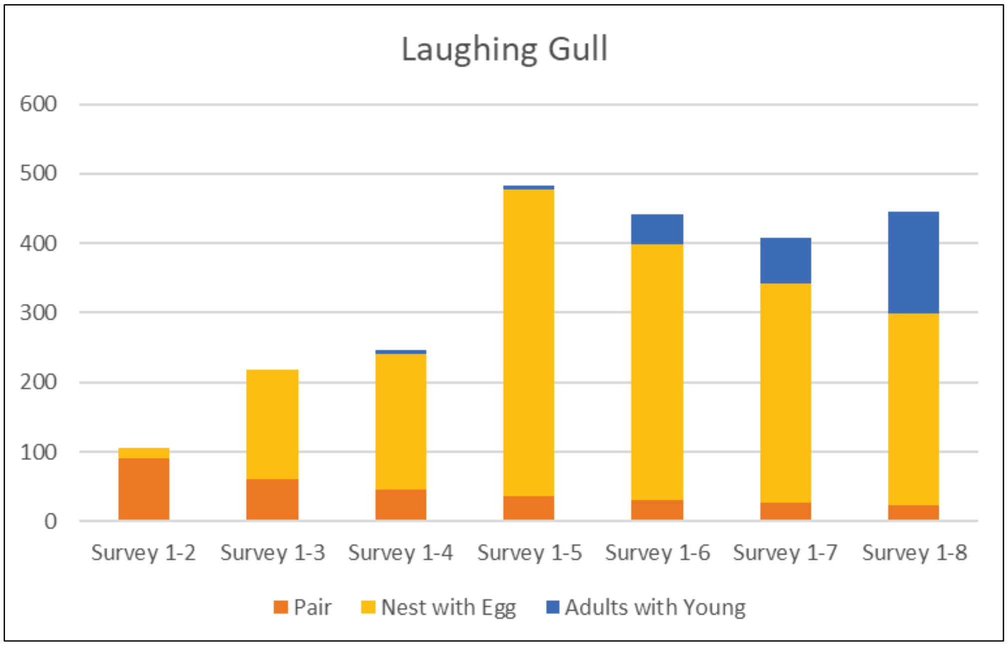


Figure 3-8. Cumulative moving averages of breeding behaviors of the Royal Tern (*Thalasseus maximus*) on Gunn Island, coastal Louisiana, 2021.

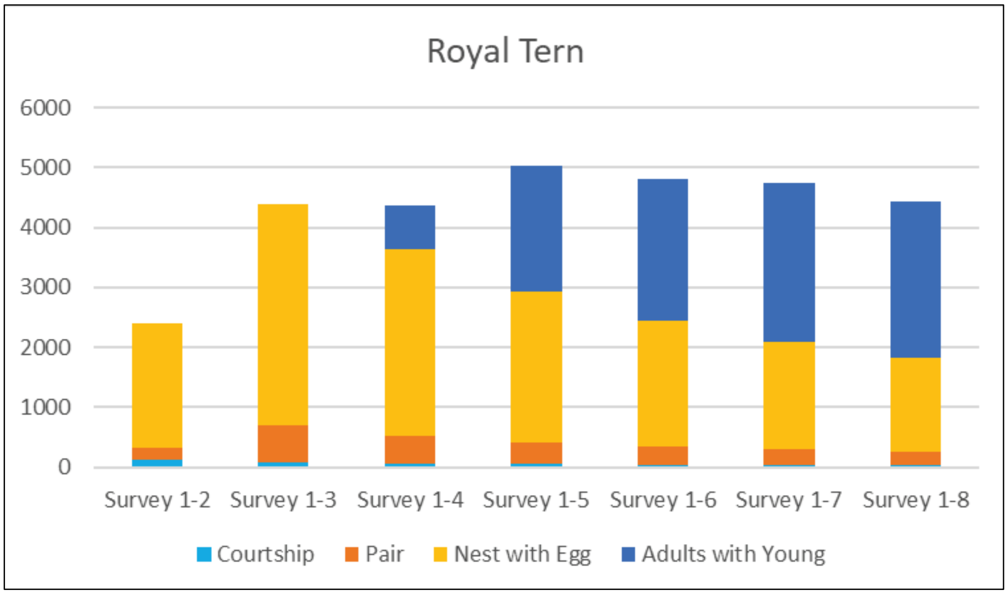


Figure 3-9. Cumulative moving averages of breeding behaviors of the Sandwich Tern (*Thalasseus sandvicensis*) on Gunn Island, coastal Louisiana, 2021.

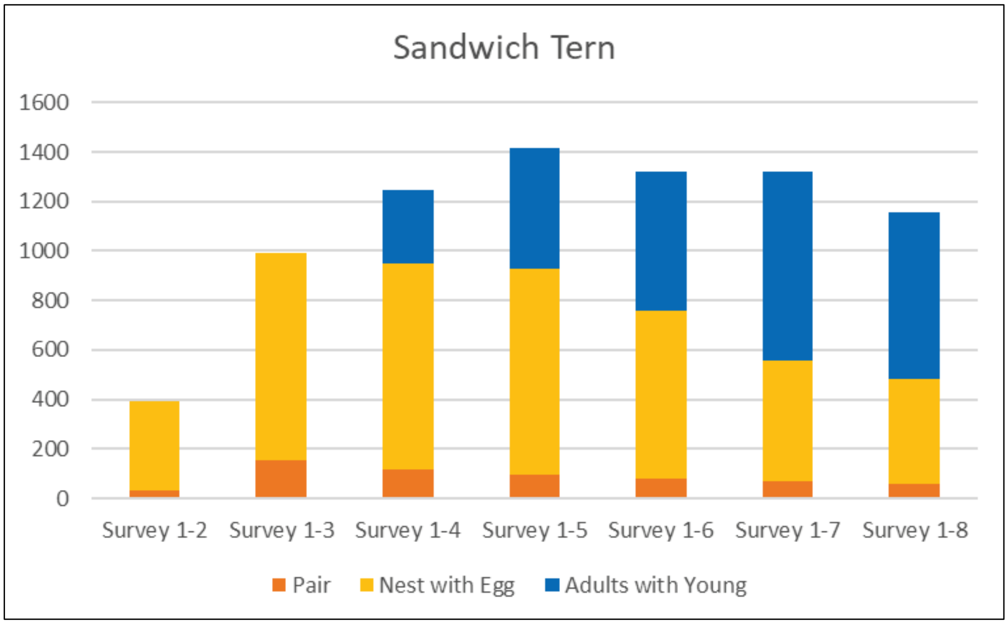


Table 3-3. Breeding behavior of other species detected on the dredged-material islands and deposition areas in the Baptiste Collette Bayou, coastal Louisiana, 2021.

Species	Behavior	Paul Island / Area 2	Karen Island	Plover Island	Shea Island	Gunn Island
Least Tern	Courtship	14	0	0	0	0
	Nest with eggs	51	0	0	0	0
Black-necked Stilt	Defensive	1	0	4	0	12
	Scrape	0	1	0	0	0
	Pair	0	0	0	0	2
	Nest with eggs	0	0	2	0	5
	Adult with young	0	0	0	0	6
Common Nighthawk	Defensive	0	1	0	0	0
	Nest with eggs	0	0	1	1	0
	Adult with young	0	3	2	2	0
American Oystercatcher	Pair	0	0	0	0	4

3.2 UAS Imagery and Lidar

3.2.1 Habitat Classification

ISODATA habitat classification on the islands and areas identified four main habitats, including open water, sand, mudflat and vegetation. Imagery for Karen Island could not be orthorectified, and therefore, image tiles could not be stitched together. Therefore, habitat classification could not be completed for this island. An area of 12.5 acres could not be analyzed on Paul Island (Table 3-5) for the same reason. However, the general physical appearance of Karen Island, Plover Island, and Paul Island (when Area 2 is excluded) are very similar. All these islands are close in size and dominated by *Phragmites*. Willet and Shea Islands are smaller, but they also have significant areas of vegetation; however, these islands also supported some small marsh areas with some native vegetation. UAS imagery was collected in mid-June; at this time, open sand and mudflat areas on Open Area 1 and Gunn Island dominated the habitat classification (Table 3-4). By August, these study areas were dominated by *Phragmites* as well. Table 3-4 presents habitat classification results, and Appendix B (Figure B-1 to Figure B-6) presents habitat classification figures.

Table 3-4. Summary of hybrid image classification area (acres) by habitat type (cover class).

Island	Water	Sand	Mudflat	Vegetation	Total
Gunn Island	8.0	7.3	24.7	1.0	41.0
Willet Island	2.6	0.5	1.2	8.0	12.3
Shea Island	2.1	1.0	1.4	7.2	11.7
Plover Island	2.0	1.0	1.3	15.7	20.0
Paul Island / Area 2	1.5	1.7	12.5	19.1	34.8*
Open Area 1	7.7	1.0	8.2	4.4	21.3

*Total island area is 47.3 acres (Paul Island) and includes 12.5 acres unclassified as no data due to missing imagery.

3.2.2 Lidar Analysis Results

Lidar analyses revealed that all the islands had low elevation, with Open Area 1 and Willet Island having the lowest mean elevation of all islands and areas (Table 3-5). Both Gunn Island and Open Area 1 had the lowest mean slope and the lowest TRI values (Table 3-5). Gunn Island had the highest mean elevation of all the islands, with Paul and Plover Islands having slightly lower elevation. Willet and Shea Islands and Open Area 1 had the lowest elevations (Table 3-5).

Table 3-5. UAS lidar-derived elevation statistics and surface topography metrics summarized by island or open area.

Island / Open Area	Elevation Statistics[1] Digital Elevation Model (DEM)				Surface Topography Metrics[2]	
	Min. (m)	Max. (m)	Mean (m)	Standard Deviation (m)	Mean Slope	Mean TRI
Gunn Island	−0.03	3.13	0.85	0.36	1.40	0.05
Willet Island	−0.25	1.52	0.37	0.27	5.46	0.22
Shea Island	−0.27	1.54	0.48	0.29	5.27	0.21
Plover Island	−0.35	2.36	0.71	0.38	6.78	0.27
Paul Island	−0.53	2.57	0.73	0.33	5.71	0.23
Open Area 1	−0.35	1.55	0.40	0.25	1.57	0.07

[1] Elevation statistics calculated from DEM and represent the bare earth elevation (in meters) above mean sea level.

[2] Surface topography metrics include mean slope (in degrees) and mean TRI derived from the DEM of each island.

Gunn Island and Open Area 1 are the most recently created of all the islands (USACE 2020), and both were largely unvegetated when the season began. Both Gunn Island (Figure 3-10) and Open Area 1 (Figure 3-11) became dominated by *Phragmites* by the end of the monitoring period. Open Area 2, which is part of Paul Island, remained unvegetated throughout the season. Paul (excluding Area 2), Karen, and Plover Islands were similar in age and dominated by *Phragmites* during the entire season. Shea and Willet Islands also supported *Phragmites*, but Shea Island also supported small areas of native marsh habitat.

Figure 3-10. Gunn Island in May (*left*), prior to breeding by coastal birds. Gunn Island in late July (*right*), showing dominant growth of *Phragmites* during the 2021 breeding season. (Photos by [*left*] Michael Guilfoyle, ERDC-EL; [*right*] Jacob Jung, ERDC-EL.)

Figure 3-11. Open Area 1 in May (*left*) and again in July (*right*), showing dominant growth of *Phragmites* during the 2021 breeding season. Vegetation was much denser by August. (Photos by [*left*] Michael Guilfoyle, ERDC-EL; [*right*] Amanda Anderson, USGS.)

4 Discussion and Recommendations

4.1 Discussion

Coastal ecosystems can provide significant ecological services. Wetlands can reduce flood risks, recharge aquifers, and act as dynamic sediment-based resources that protect inland areas from flooding and storm surge. The dynamic nature of coastal systems promotes biodiversity due to the sheer number and diversity of species specifically adapted to coastal extremes of heat, salinity, and lack of soil nutrients. Local conditions change continuously due to the constant shifting and settling of sediment resources from winds, tides, and changing inland and longshore currents. Coastal bird populations are adapted to these conditions because they must contend with the marine–terrestrial interface to meet daily nutritional needs while attempting to secure breeding partners and nesting sites. In addition, they must also engage in the colonial or solitary conspecific interactions inherent to their species and as needed to ensure their own survival (Burger 2017). Seabirds forage in open bays, estuaries, and nearshore waters, but they require large sand areas, such as beaches, islands, and other sediment-based habitats, for nesting. These coastal habitats are critical for migratory, breeding, and nonbreeding coastal bird populations.

The Gulf of Mexico is particularly important due to the large availability of coastal habitats, its warm tropical to subtropical ocean waters, and its direct flight line between North, South, and Central America for Nearctic and Neotropical migrants (Burger 2017). The Gulf of Mexico is home to several federally and state-listed species, including the migratory Red Knot, the nonbreeding Piping Plover, and the breeding Least Tern; numerous other species are experiencing documented declines and are species of concern for the region, including the Black Skimmer, Reddish Egret, and Mottled Duck (Winn et al. 2013). Semipalmated Sandpipers, Short-billed Dowitchers, and Greater Yellowlegs are all migratory shorebirds that have experienced documented declines (Winn et al. 2013) and are dependent upon habitats in the Gulf of Mexico (Burger 2017). Populations of coastal birds in North America, including many shorebirds, have declined by nearly 40% since 1970 (Rosenberg et al. 2019), highlighting our need to manage coastal resources to protect these species.

The coast of Louisiana has experienced more loss of coastal habitat than other coastal states due to sea-level rise, an increase in the frequency and severity of storms, and human disturbance (Visser et al. 2005; Burger 2017). Within the coastal regions of New Orleans, USACE is responsible for the creation and maintenance of coastal infrastructure. This includes the maintenance of the Gulf ICWW and associated navigation channels, shoreline stabilization efforts, and access to the Port of New Orleans. Coastal structures may include jetties, groins, dikes, and sea walls that may alter coastal sedimentation processes and be designed to shift sediment away from the channel. Increased channel depths and shifts or alterations to the local or regional sedimentation process may result in sediment deficits that in turn result in erosion and loss of sediment-based habitats (Guilfoyle et al. 2019). Depositing dredged material in the local area of a channel is an effective technique to retain sediment in the system and can represent a beneficial use of dredged material (EPA and USACE 2007a, 2007b) that can create habitat for seasonal coastal waterbirds (Soots and Landon 1978; Fischer et al. 2004; Guilfoyle et al. 2006, 2007).

In the Baptiste Collette Bayou, in southern Louisiana, USACE New Orleans District has regularly used material dredged from navigation channels to create marsh and open-sand habitats to benefit coastal waterbirds (USACE 2000, 2020). However, little effort has been made recently to document the use of these dredged-material areas for coastal birds. In 2020, an active hurricane season stimulated the colonization of Gunn Island by colonial nesting waterbirds. Following nesting success at Gunn Island during the 2020 breeding season, it became apparent that inventory and monitoring was needed to document the importance of these areas in supporting regional populations of coastal birds.

Most of the islands, including Paul (excluding Area 2), Karen, Plover, Shea, and Willet, were too overgrown with *Phragmites* to provide nesting habitat for terns and skimmers in 2021. The vast majority of terns and skimmers nested on Gunn Island. Some of the studied islands had open beaches that supported solitary species, including the Common Nighthawk, Black-necked Stilt, and American Oystercatcher, plus marsh areas that provided habitat for marsh birds, including the Least Bittern and Clapper Rail. By reducing the invasive *Phragmites* and creating additional marsh and wetland habitat (as was done on Area G; USACE 2020), these areas may be able to support nonbreeding rail species, such as the Virginia Rail (*Rallus limicola*) and the federally listed Black Rail (*Laterallus jamaicensis*).

Brown Pelicans nested on Plover in 2000 and 2001, at times numbering over 10,000 birds (USACE 2000, 2020); this bird remains a species of concern in the region (Burger 2017) and is largely dependent upon dredged-material habitats for nesting (Soots and Landon 1978; Visser et al. 2005). Brown Pelicans will nest on the ground, but they often require stiff woody vegetation to support nests (Visser et al. 2005). Planting suitable woody vegetation on some of these islands may eventually provide important habitats for pelicans and for other colonial herons and egrets, particularly the Reddish Egret—also a regional species of concern.

Perhaps most important, maintaining nesting habitats is critical for the survival of regional sea birds, including terns, gulls, and skimmers. Many of these species are regional species of concern and are focal species in this study. These species require open sand habitats for breeding. The tremendous growth of *Phragmites* is a concern because these species will likely not breed on these islands if the vegetation persists through the winter months. Future efforts to redeposit sediment on these islands as a way to control vegetation, as was done earlier for these birds on other islands (USACE 2000, 2020), could increase the probability of these birds breeding on these dredged-material islands in the future. The growth in vegetation on Open Area 1 may also reduce habitat suitability for other foraging and roosting species, including many of the migratory and nonbreeding shorebirds documented in this study.

In general, the technique employed by USACE to create tidally influenced channels and pools on Open Area 1 appears effective in attracting large numbers of foraging shorebirds and other waterbirds. Perhaps the exposure to tidal processes aided the recolonization of the area by benthic organisms (Rosov et al. 2016); more research to assess the effects of dredged-material deposition and other engineering techniques on benthic communities could help determine this effect. Creating tidally influenced areas using finer sediments that may not be suitable for island construction or waterbird nesting substrate may be a useful option. Control of *Phragmites* will be required on Open Area 1 to maintain the suitability of the area as foraging habitat. In general, managing coastal habitats for a diverse community of waterbirds is successful when there is a mix of foraging, roosting, and breeding habitats in relatively close proximity (Gillespie and Fontaine 2017). The use of Open Area 1 and Open Area 2 by foraging shorebirds indicates the importance of such areas for a larger suite of nonbreeding coastal birds. Many shorebirds are migratory and require suitable foraging habitat all year. The documentation of these birds using these areas during the summer months likely suggests that such areas will also be important for many species during the spring and fall migration seasons and for those species that overwinter in the region. Additional monitoring during the nonbreeding season could help in assessing and documenting the use of these areas by the seasonal bird community.

Paul Island / Open Area 2 was likely not suitable nesting habitat due to the adjacent vegetated land that supported canines and other mammalian predators. The sediment and elevation of the island were sufficient to attract Least Terns, but mammalian disturbances, as indicated by canine footprints and the presence of feral pigs, likely threatened nesting success. Successful nesting by Least Terns was documented on these islands in the past (USACE 2000, 2020). Habitat creation for the Least Tern, which consists of elevated, open, sandy habitat, may require depositing additional dredged material of similar quality to one or more of the islands that are isolated from the mainland and mammalian predators. Regardless, similar to Open Area 1, Open Area 2 was important to nonbreeding waterbirds and shorebirds. This area provided a large area of mixed sand and mudflat habitats that supported multiple taxa of foraging and roosting coastal birds and was second to Open Area 1 in supporting nonbreeding shorebirds. Additionally, the large beach shoreline was particularly used by foraging shorebirds and loafing seabird adults and fledglings.

4.2 Recommendations

Based on this research, we recommend all of the following:

1. Regularly add additional dredged material on Gunn Island and Open Area 1 to help control vegetation and maintain the sites as viable breeding and foraging sites for coastal birds.
2. Continue to monitor the islands and open depositional areas to document changes that occur with vegetative growth and subsequent control of vegetation through dredged-material deposition.

3. Continue running water through the dredge pipes on deposited material to create tidally influenced channels and pools on Open Area 1, and other areas, as options arise to increase available foraging habitat. Use of finer sediments in this approach may be an option.
4. Consider creating nesting habitat for Least Terns by adding dredged material on more isolated islands. Karen and Plover Islands may be good candidates for this effort.
5. Brown Pelicans have nested on the islands before, particularly Plover Island (USACE 2000, 2020). Adding more dredged material to some of the islands, such as Plover, Karen, and Willet Islands, with subsequent plantings of native shrubs as nesting substrate, may attract pelicans to nest on these islands again.
6. Identify and protect existing native marsh habitats on the islands and, as possible, consider expanding native marsh habitats on these islands. Remove *Phragmites* and replant with native marsh plants. Use ongoing monitoring to document the presence of rails, soras, and other marsh birds during the breeding and nonbreeding seasons.

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Appendix A: Common and Scientific Names, Cumulative Counts, and Means for all Birds Detected During Breeding Season on the Dredged-Material Areas in the Baptiste Collette Bayou, Coastal Louisiana, 2021

Table A-1. A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr]) by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Open Area 1 (*n* = 8)			
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	22	2.75 ± 1.80
Fulvous Whistling Duck[2]	*Dendrocygna bicolor*	1	0.13 ± 0.13
Mottled Duck[1,2]	*Anas fulvigula*	551	68.88 ± 32.67
Blue-winged Teal[3]	*Spatula discors*	49	6.13 ± 5.56
Common Nighthawk[2]	*Chordeiles minor*	1	0.13 ± 0.13
Clapper Rail[1,2]	*Rallus crepitans*	6	0.75 ± 0.31
Common Gallinule[2]	*Gallinula galeata*	7	0.88 ± 0.41
Black-necked Stilt[2]	*Himantopus mexicanus*	268	33.50 ± 14.08
Black-bellied Plover[2]	*Pluvialis squatarola*	10	1.25 ± 0.41
Wilson's Plover[1,2]	*Charadrius wilsonia*	10	1.25 ± 1.25
Semipalmated Plover[3]	*Charadrius semipalmatus*	26	3.25 ± 2.45
Whimbrel[1,3]	*Numenius phaeopus*	1	0.13 ± 0.13
Marbled Godwit[1,3]	*Limosa fedoa*	198	24.75 ± 11.80
Ruddy Turnstone[1,3]	*Arenaria interpres*	1	0.13 ± 0.13
Red Knot[1,3]	*Calidris canutus*	2	0.25 ± 0.25
Sanderling[3]	*Calidris alba*	28	3.50 ± 2.19
Semipalmated Sandpiper[1,3]	*Calidris pusilla*	379	47.38 ± 27.40
Western Sandpiper[1,3]	*Calidris mauri*	396	49.50 ± 28.16
Least Sandpiper[3]	*Calidris minutilla*	295	36.88 ± 22.66
White-rumped Sandpiper[3]	*Calidris fuscicollis*	16	2.00 ± 1.86
Dunlin[1,3]	*Calidris alpina*	54	6.75 ± 4.56
Short-billed Dowitcher[1,3]	*Limnodromus griseus*	303	37.88 ± 33.96
Spotted Sandpiper[3]	*Actitis macularius*	1	0.13 ± 0.13
Willet[1,2]	*Tringa semipalmata*	264	33.00 ± 12.88
Greater Yellowlegs[3]	*Tringa melanoleuca*	17	2.130 ± 1.39
Lesser Yellowlegs[3]	*Tringa flavipes*	49	6.13 ± 4.43

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Laughing Gull[2]	*Leucophaeus atricilla*	199	24.88 ± 5.79
Least Tern[1,2]	*Sternula antillarum*	2	0.25 ± 0.16
Black Tern[3]	*Chlidonias niger*	129	16.13 ± 7.12
Forster's Tern[2]	*Sterna forsteri*	41	5.13 ± 1.16
Gull-billed Tern[2]	*Gelochelidon nilotica*	403	50.38 ± 16.05
Sandwich Tern[2]	*Thalasseus sandvicensis*	4	0.50 ± 0.27
Royal Tern[2]	*Thalasseus maximus*	361	45.13 ± 25.76
Caspian Tern[2]	*Hydroprogne caspia*	195	24.38 ± 13.62
Black Skimmer[1,2]	*Rynchops niger*	76	9.50 ± 4.50
American White Pelican[3]	*Pelecanus erythrorhynchos*	1	0.13 ± 0.13
Brown Pelican[2]	*Pelecanus occidentalis*	20	2.50 ± 1.96
Snowy Egret[2]	*Egretta thula*	11	1.38 ± 0.53
Great Egret[2]	*Ardea alba*	5	0.63 ± 0.32
Tricolored Heron[2]	*Egretta tricolor*	6	0.75 ± 0.25
Reddish Egret[2]	*Egretta rufescens*	1	0.13 ± 0.13
Black-crowned Night Heron[2]	*Nycticorax nycticorax*	5	0.63 ± 0.63
Glossy Ibis[2]	*Plegadis falcinellus*	1	0.13 ± 0.13
White Ibis[2]	*Eudocimus albus*	17	2.13 ± 1.78
Osprey[2]	*Pandion haliaetus*	1	0.13 ± 0.13
Eastern Kingbird[2]	*Tyrannus tyrannus*	6	0.75 ± 0.41
Barn Swallow[2]	*Hirundo rustica*	88	11.00 ± 6.62
Common Yellowthroat[2]	*Geothlypis trichas*	5	0.63 ± 0.26
Red-winged Blackbird[2]	*Agelaius phoeniceus*	264	33.00 ± 7.98
Boat-tailed Grackle[2]	*Quiscalus major*	10	1.25 ± 0.49
Orchard Oriole[2]	*Icterus spurius*	2	0.25 ± 0.16
TOTAL COUNTS		4,807	600.88 ± 163.44
Paul Island/Area 2 (*n* = 8)			
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	1	0.13 ± 0.13
Mottled Duck[1,2]	*Anas fulvigula*	71	8.88 ± 4.67
Mourning Dove[2]	*Zenaida macroura*	1	0.13 ± 0.13
Common Nighthawk[2]	*Chordeiles minor*	14	1.75 ± 0.73
Clapper Rail[1,2]	*Rallus crepitans*	4	0.50 ± 0.19
Common Gallinule[2]	*Gallinula galeata*	2	0.25 ± 0.25
Black-necked Stilt[2]	*Himantopus mexicanus*	18	2.25 ± 0.88
Black-bellied Plover[2]	*Pluvialis squatarola*	38	4.75 ± 1.59
Killdeer[2]	*Charadrius vociferus*	1	0.13 ± 0.13

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Semipalmated Plover[3]	*Charadrius semipalmatus*	89	11.13 ± 6.96
Marbled Godwit[1,3]	*Limosa fedoa*	12	1.50 ± 1.50
Ruddy Turnstone[1,3]	*Arenaria interpres*	10	1.25 ± 0.49
Sanderling[3]	*Calidris alba*	28	3.50 ± 2.44
Semipalmated Sandpiper[1,3]	*Calidris pusilla*	35	4.38 ± 1.93
Western Sandpiper[3]	*Calidris mauri*	63	7.88 ± 5.20
Least Sandpiper[3]	*Calidris minutilla*	89	11.13 ± 5.40
Dunlin[1,3]	*Calidris alpina*	1	0.13 ± 0.13
Short-billed Dowitcher[1,3]	*Limnodromus griseus*	1	0.13 ± 0.13
Spotted Sandpiper[3]	*Actitis macularius*	8	1.00 ± 0.50
Willet[2]	*Tringa semipalmata*	64	8.00 ± 3.53
Greater Yellowlegs[3]	*Tringa melanoleuca*	9	1.13 ± 1.13
Lesser Yellowlegs[3]	*Tringa flavipes*	7	0.88 ± 0.48
Laughing Gull[2]	*Leucophaeus atricilla*	166	20.75 ± 11.16
Least Tern[1,2]	*Sternula antillarum*	67	8.38 ± 5.11
Black Tern[3]	*Chlidonias niger*	4	0.50 ± 0.33
Forster’s Tern[2]	*Sterna forsteri*	4	0.50 ± 0.27
Gull-billed Tern[2]	*Gelochelidon nilotica*	129	16.13 ± 7.43
Sandwich Tern[2]	*Thalasseus sandvicensis*	10	1.25 ± 0.84
Royal Tern[2]	*Thalasseus maximus*	54	6.75 ± 3.73
Caspian Tern[2]	*Hydroprogne caspia*	45	5.63 ± 2.98
Black Skimmer[1,2]	*Rynchops niger*	11	1.38 ± 0.68
Magnificent Frigatebird[3]	*Fregata magnificens*	2	0.25 ± 0.16
Brown Pelican[2]	*Pelecanus occidentalis*	10	1.25 ± 0.86
Great Blue Heron[2]	*Ardea Herodias*	1	0.13 ± 0.13
Snowy Egret[2]	*Egretta thula*	1	0.13 ± 0.13
Great Egret[2]	*Ardea alba*	3	0.38 ± 0.18
Tricolored Heron[2]	*Egretta tricolor*	1	0.13 ± 0.13
Green Heron[2]	*Butorides virescens*	1	0.13 ± 0.13
White Ibis[2]	*Eudocimus albus*	19	2.38 ± 2.38
Osprey[2]	*Pandion haliaetus*	1	0.13 ± 0.13
Eastern Kingbird[2]	*Tyrannus tyrannus*	5	0.63 ± 0.32
Barn Swallow[2]	*Hirundo rustica*	17	2.13 ± 0.69
Common Yellowthroat[2]	*Geothlypis trichas*	12	1.50 ± 0.42

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Red-winged Blackbird[2]	*Agelaius phoeniceus*	178	22.25 ± 6.75
Boat-tailed Grackle[2]	*Quiscalus major*	21	2.63 ± 0.63
Orchard Oriole[2]	*Icterus spurius*	17	2.13 ± 0.85
TOTAL COUNTS		1,334	166.75 ± 27.20
Karen Island (*n* = 6)			
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	2	0.33 ± 0.33
Mottled Duck[1,2]	*Anas fulvigula*	10	1.67 ± 1.09
Common Nighthawk[2]	*Chordeiles minor*	7	1.17 ± 0.48
Clapper Rail[1,2]	*Rallus crepitans*	2	0.33 ± 0.33
Common Gallinule[2]	*Gallinula galeata*	2	0.33 ± 0.33
Black-necked Stilt[2]	*Himantopus mexicanus*	1	0.17 ± 0.17
American Avocet[3]	*Recurvirostra americana*	2	0.33 ± 0.33
Sanderling[3]	*Calidris alba*	2	0.33 ± 0.33
Western Sandpiper[3]	*Calidris mauri*	1	0.17 ± 0.17
Least Sandpiper[3]	*Calidris minutilla*	7	1.67 ± 0.83
Spotted Sandpiper[3]	*Actitis macularius*	1	0.17 ± 0.17
Willet[2]	*Tringa semipalmata*	6	1.00 ± 0.82
Laughing Gull[2]	*Leucophaeus atricilla*	8	1.33 ± 0.76
Black Tern[3]	*Chlidonias niger*	1	0.17 ± 0.17
Forster's Tern[2]	*Sterna forsteri*	7	1.17 ± 1.17
Gull-billed Tern[2]	*Gelochelidon nilotica*	10	1.67 ± 0.56
Sandwich Tern[2]	*Thalasseus sandvicensis*	3	0.50 ± 0.34
Royal Tern[2]	*Thalasseus maximus*	28	4.67 ± 4.47
Caspian Tern[2]	*Hydroprogne caspia*	1	0.17 ± 0.17
Black Skimmer[1,2]	*Rynchops niger*	4	0.67 ± 0.42
Magnificent Frigatebird[3]	*Fregata magnificens*	1	0.17 ± 0.17
American White Pelican[3]	*Pelecanus erythrorhynchos*	3	0.50 ± 0.50
Great Blue Heron[2]	*Ardea Herodias*	1	0.17 ± 0.17
Snowy Egret[2]	*Egretta thula*	9	1.50 ± 0.62
Great Egret[2]	*Ardea alba*	3	0.50 ± 0.34
Tricolored Heron[2]	*Egretta tricolor*	2	0.33 ± 0.21
Little Blue Heron[2]	*Egretta caerulea*	3	0.50 ± 0.34
Yellow-crowned Night Heron[2]	*Nyctanassa violacea*	1	0.17 ± 0.17
White Ibis[2]	*Eudocimus albus*	13	2.17 ± 1.11
Eastern Kingbird[2]	*Tyrannus tyrannus*	1	0.17 ± 0.17
Red-winged Blackbird[2]	*Agelaius phoeniceus*	135	22.50 ± 5.10

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Boat-tailed Grackle[2]	*Quiscalus major*	19	3.17 ± 1.25
Orchard Oriole[2]	*Icterus spurius*	3	0.50 ± 0.34
TOTAL COUNTS		297	49.50 ± 7.958
Plover Island (*n* = 7)			
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	8	1.43 ± 0.552
Mottled Duck[1,2]	*Anas fulvigula*	102	14.57 ± 4.69
Common Nighthawk[2]	*Chordeiles minor*	13	1.86 ± 0.67
Clapper Rail[1,2]	*Rallus crepitans*	3	0.43 ± 0.30
Black-necked Stilt[1,2]	*Himantopus mexicanus*	3	0.43 ± 0.43
Black-bellied Plover[3]	*Pluvialis squatarola*	2	0.29 ± 0.29
Semipalmated Plover[3]	*Charadrius semipalmatus*	1	0.14 ± 0.14
Whimbrel[1,3]	*Numenius phaeopus*	1	0.14 ± 0.14
Sanderling[3]	Calidris alba	5	0.71 ± 0.71
Short-billed Dowitcher[3]	*Limnodromus griseus*	2	0.29 ± 0.29
Spotted Sandpiper[3]	*Actitis macularius*	1	0.14 ± 0.14
Willet[2]	*Tringa semipalmata*	10	1.43 ± 0.57
Laughing Gull[2]	*Leucophaeus atricilla*	14	2.00 ± 0.98
Black Tern[3]	*Chlidonias niger*	2	0.29 ± 0.29
Gull-billed Tern[2]	*Gelochelidon nilotica*	26	3.71 ± 1.67
Sandwich Tern[2]	*Thalasseus sandvicensis*	1	0.14 ± 0.14
Royal Tern[2]	*Thalasseus maximus*	47	6.71 ± 4.12
Caspian Tern[2]	*Hydroprogne caspia*	8	1.14 ± 0.63
Black Skimmer[1,2]	*Rynchops niger*	1	0.14 ± 0.14
Magnificent Frigatebird[3]	*Fregata magnificens*	3	0.43 ± 0.20
Brown Pelican[2]	*Pelecanus occidentalis*	32	4.57 ± 3.80
Least Bittern[2]	*Ixobrychus exilis*	1	0.14 ± 0.14
Great Egret[2]	*Ardea alba*	2	0.29 ± 0.18
White Ibis[2]	*Eudocimus albus*	27	3.86 ± 3.53
Eastern Kingbird[2]	*Tyrannus tyrannus*	6	0.86 ± 0.46
Barn Swallow[2]	*Hirundo rustica*	10	1.43 ± 1.43
Common Yellowthroat[2]	*Geothlypis trichas*	4	0.57 ± 0.57
Red-winged Blackbird[2]	*Agelaius phoeniceus*	225	32.14 ± 10.28
Boat-tailed Grackle[2]	*Quiscalus major*	6	0.86 ± 0.60
Brown-headed Cowbird[2]	*Molothrus ater*	2	0.29 ± 0.29
Orchard Oriole[2]	*Icterus spurius*	7	1.00 ± 0.38
TOTAL COUNTS		575	82.14 ± 12.77

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Shea Island (n = 8)			
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	2	0.25 ± 0.25
Mottled Duck[1,2]	*Anas fulvigula*	30	3.75 ± 0.98
Common Nighthawk[2]	*Chordeiles minor*	13	1.63 ± 0.46
Clapper Rail[1,2]	*Rallus crepitans*	5	0.63 ± 0.26
Common Gallinule[2]	*Gallinula galeata*	9	1.13 ± 0.40
Black-necked Stilt[2]	*Himantopus mexicanus*	5	0.63 ± 0.32
American Oystercatcher[1,2]	*Haematopus palliatus*	2	0.25 ± 0.25
Black-bellied Plover[3]	*Pluvialis squatarola*	6	0.75 ± 0.75
Semipalmated Plover[3]	*Charadrius semipalmatus*	4	0.50 ± 0.50
Sanderling[3]	*Calidris alba*	13	1.63 ± 1.36
Semipalmated Sandpiper[1,3]	*Calidris pusilla*	1	0.13 ± 0.13
Western Sandpiper[1,3]	*Calidris mauri*	1	0.13 ± 0.13
Least Sandpiper[3]	*Calidris minutilla*	21	2.63 ± 1.45
Spotted Sandpiper[3]	*Actitis macularius*	2	0.25 ± 0.16
Willet[1,2]	*Tringa semipalmata*	67	8.38 ± 5.81
Laughing Gull[2]	*Leucophaeus atricilla*	183	22.88 ± 20.75
Herring Gull[2]	*Larus argentatus*	2	0.25 ± 0.25
Least Tern[1,2]	*Sternula antillarum*	3	0.38 ± 0.26
Forster's Tern[2]	*Sterna forsteri*	10	1.25 ± 1.25
Gull-billed Tern[2]	*Gelochelidon nilotica*	88	11.00 ± 7.74
Sandwich Tern[2]	*Thalasseus sandvicensis*	158	19.75 ± 18.21
Royal Tern[2]	*Thalasseus maximus*	641	80.13 ± 68.36
Caspian Tern[2]	*Hydroprogne caspia*	437	54.63 ± 53.01
Black Skimmer[1,2]	*Rynchops niger*	9	1.13 ± 0.74
Magnificent Frigatebird[3]	*Fregata magnificens*	2	0.25 ± 0.25
Brown Pelican[2]	*Pelecanus occidentalis*	61	7.63 ± 5.20
Least Bittern[2]	*Ixobrychus exilis*	6	0.75 ± 0.25
Great Blue Heron[2]	*Ardea Herodias*	1	0.13 ± 0.13
Snowy Egret[2]	*Egretta thula*	4	0.50 ± 0.38
Great Egret[2]	*Ardea alba*	1	0.13 ± 0.13
Tricolored Heron[2]	*Egretta tricolor*	2	0.25 ± 0.16
Black-crowned Night Heron[2]	*Nycticorax nycticorax*	2	0.25 ± 0.16
Yellow-crowned Night Heron[2]	*Nyctanassa violacea*	1	0.13 ± 0.13
White Ibis[2]	*Eudocimus albus*	1	0.13 ± 0.13
Merlin[3]	*Falco columbarius*	1	0.13 ± 0.13

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Barn Swallow[2]	*Hirundo rustica*	4	0.50 ± 0.38
Red-winged Blackbird[2]	*Agelaius phoeniceus*	169	21.13 ± 4.67
Boat-tailed Grackle[2]	*Quiscalus major*	19	2.38 ± 1.07
Orchard Oriole[2]	*Icterus spurius*	7	0.88 ± 0.61
TOTAL COUNTS		2,010	251.25 ± 178.15
Willet Island (*n* = 7)			
Black-bellied Whistling Duck[2]	*Dendrocygna autumnalis*	8	1.14 ± 0.74
Mottled Duck[1,2]	*Anas fulvigula*	62	8.86 ± 1.65
Blue-winged Teal[3]	*Spatula discors*	2	0.29 ± 0.29
Clapper Rail[1,2]	*Rallus crepitans*	7	1.00 ± 0.44
Black-necked Stilt[2]	*Himantopus mexicanus*	8	1.14 ± 0.55
Black-bellied Plover[3]	*Pluvialis squatarola*	1	0.14 ± 0.14
Sanderling[3]	*Calidris alba*	1	0.14 ± 0.14
Semipalmated Sandpiper[1,3]	*Calidris pusilla*	1	0.14 ± 0.14
Spotted Sandpiper[3]	*Actitis macularius*	3	0.43 ± 0.43
Willet[2]	*Tringa semipalmata*	15	2.14 ± 1.35
Laughing Gull[2]	*Leucophaeus atricilla*	17	2.43 ± 1.53
Herring Gull[2]	*Larus argentatus*	2	0.29 ± 0.29
Black Tern[2]	*Chlidonias niger*	1	0.14 ± 0.14
Gull-billed Tern[2]	*Gelochelidon nilotica*	23	3.29 ± 1.49
Sandwich Tern[2]	*Thalasseus sandvicensis*	7	1.00 ± 0.58
Royal Tern[2]	*Thalasseus maximus*	54	7.71 ± 4.85
Caspian Tern[2]	*Hydroprogne caspia*	8	1.14 ± 0.77
Black Skimmer[1,2]	*Rynchops niger*	7	1.00 ± 0.66
Magnificent Frigatebird[3]	*Fregata magnificens*	6	0.86 ± 0.34
Brown Pelican[2]	*Pelecanus occidentalis*	37	5.29 ± 3.18
Least Bittern[2]	*Ixobrychus exilis*	4	0.57 ± 0.20
Great Blue Heron[2]	*Ardea Herodias*	1	0.14 ± 0.14
Snowy Egret[2]	*Egretta thula*	4	0.57 ± 0.20
Great Egret[2]	*Ardea alba*	6	0.86 ± 0.40
Tricolored Heron[2]	*Egretta tricolor*	1	0.14 ± 0.14
Reddish Egret[2]	*Egretta rufescens*	1	0.14 ± 0.14
Black-crowned Night Heron[2]	*Nycticorax nycticorax*	1	0.14 ± 0.14
White Ibis[2]	*Eudocimus albus*	5	0.71 ± 0.47
Barn Swallow[2]	*Hirundo rustica*	1	0.14 ± 0.14
Magnolia Warbler[3]	*Setophaga magnolia*	1	0.14 ± 0.14

Table A-1 (cont.). A list of all species detected, common and scientific names, total cumulative counts, and mean (±standard error [StdErr] by island for all species detected during semimonthly breeding season monitoring on the dredged-material islands and depositional areas on the Baptiste Collette Bayou, coastal Louisiana, 2021.

Common Name	Scientific Name	Cumulative Detections	Mean ± StdErr
Red-winged Blackbird[2]	*Agelaius phoeniceus*	173	24.71 ± 4.24
Boat-tailed Grackle[2]	*Quiscalus major*	4	0.57 ± 0.20
Orchard Oriole[2]	*Icterus spurius*	1	0.14 ± 0.14
TOTAL COUNTS		470	67.29 ± 9.81
Gunn Island (*n* = 8)			
Mottled Duck[1,2]	*Anas fulvigula*	2	0.25 ± 0.25
Common Nighthawk[2]	*Chordeiles minor*	1	0.13 ± 0.13
Clapper Rail[2]	*Rallus crepitans*	3	0.38 ± 0.38
Common Gallinule[2]	*Gallinula galeata*	1	0.13 ± 0.13
Black-necked Stilt[2]	*Himantopus mexicanus*	29	3.63 ± 1.19
American Oystercatcher[1,2]	*Haematopus palliatus*	9	1.13 ± 0.35
Ruddy Turnstone[1,3]	*Arenaria interpres*	1	0.13 ± 0.13
Sanderling[3]	*Calidris alba*	78	9.75 ± 9.61
Semipalmated Sandpiper[1,3]	*Calidris pusilla*	1	0.13 ± 0.13
Willet[2]	*Tringa semipalmata*	1	0.13 ± 0.13
Laughing Gull[2]	*Leucophaeus atricilla*	3,624	453.00 ± 154.66
Ring-billed Gull[3]	*Larus delawarensis*	1	0.13 ± 0.13
Forster's Tern[2]	*Sterna forsteri*	531	66.38 ± 33.86
Gull-billed Tern[2]	*Gelochelidon nilotica*	5,407	675.88 ± 184.69
Sandwich Tern[2]	*Thalasseus sandvicensis*	9,616	1202.00 ± 287.31
Royal Tern[2]	*Thalasseus maximus*	30,799	3849.88 ± 797.75
Caspian Tern[2]	*Hydroprogne caspia*	3,353	419.33 ± 78.69
Black Skimmer[1,2]	*Rynchops niger*	14,223	1777.88 ± 313.11
Double-crested Cormorant[2]	*Phalacrocorax auritus*	3	0.38 ± 0.38
Brown Pelican[2]	*Pelecanus occidentalis*	14	1.75 ± 1.75
Snowy Egret[2]	*Egretta thula*	1	0.13 ± 0.13
Great Egret[2]	*Ardea alba*	1	0.13 ± 0.13
White Ibis[2]	*Eudocimus albus*	1	0.13 ± 0.13
Red-winged Blackbird[2]	*Agelaius phoeniceus*	10	1.25 ± 1.25
Boat-tailed Grackle[2]	*Quiscalus major*	4	0.50 ± 0.50
Orchard Oriole[2]	*Icterus spurius*	2	0.25 ± 0.25
TOTAL COUNTS		67,716	8,464.50 ± 1,559.99

[1]Focal Species for this study.

[2]Breeding species on the islands or likely to be breeding in the local area.

[3]Non-breeding species; wintering or transient migrants unlikely to be breeding in the local area.

*Species list and all metrics include flyovers.

Appendix B: Image and Land-Cover Classification for Dredged-Material Deposition Areas in the Baptiste Collette Bayou, Coastal Louisiana, 2021

Figure B-1. Habitat classification imagery for Open Area 1.

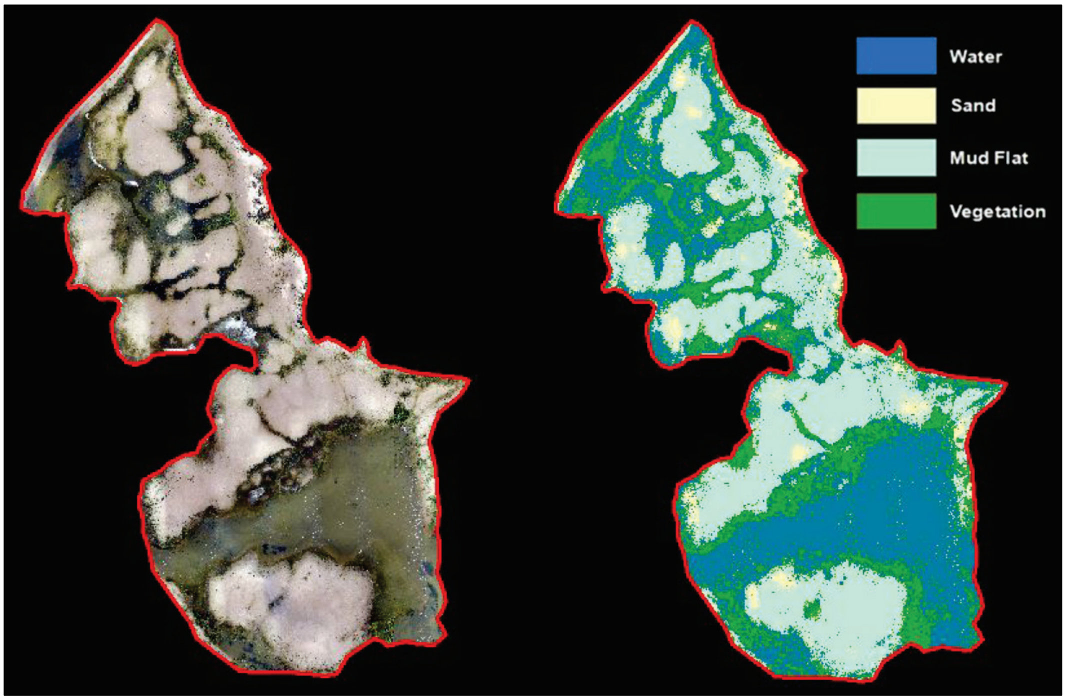


Figure B-2. Habitat classification imagery for Paul Island and Open Area 2.

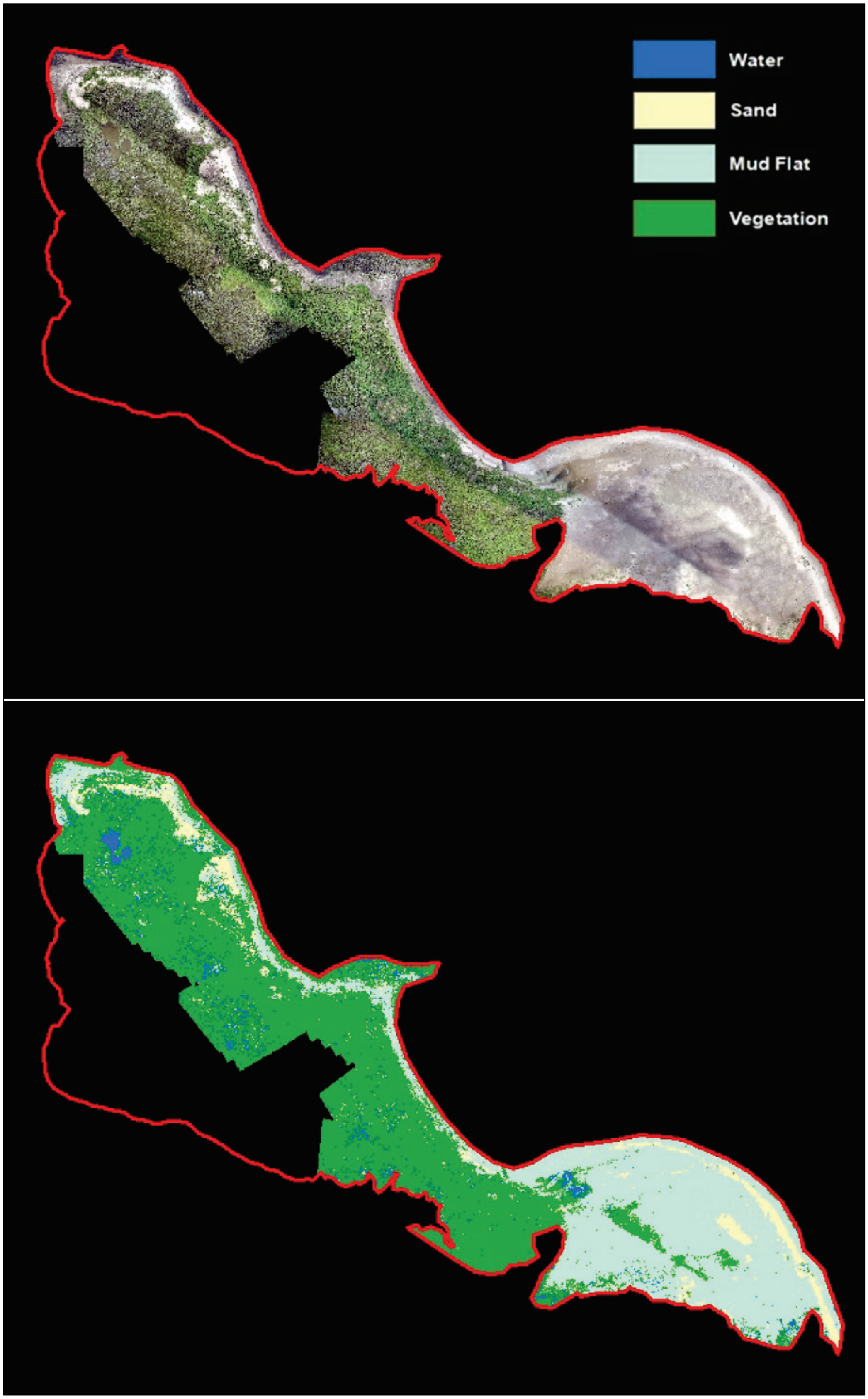


Figure B-3. Habitat classification imagery for Plover Island.

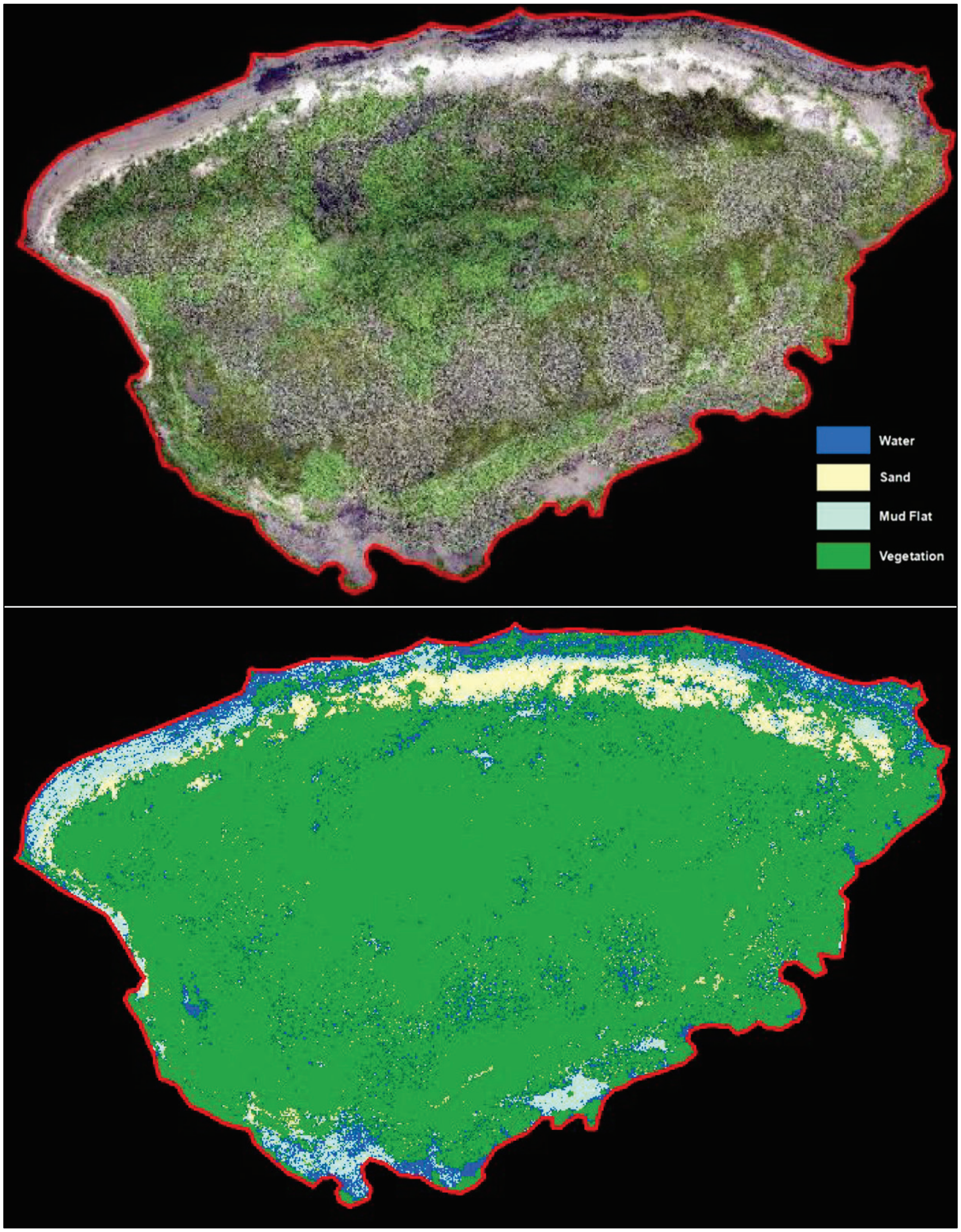


Figure B-4. Habitat classification imagery for Shea Island.

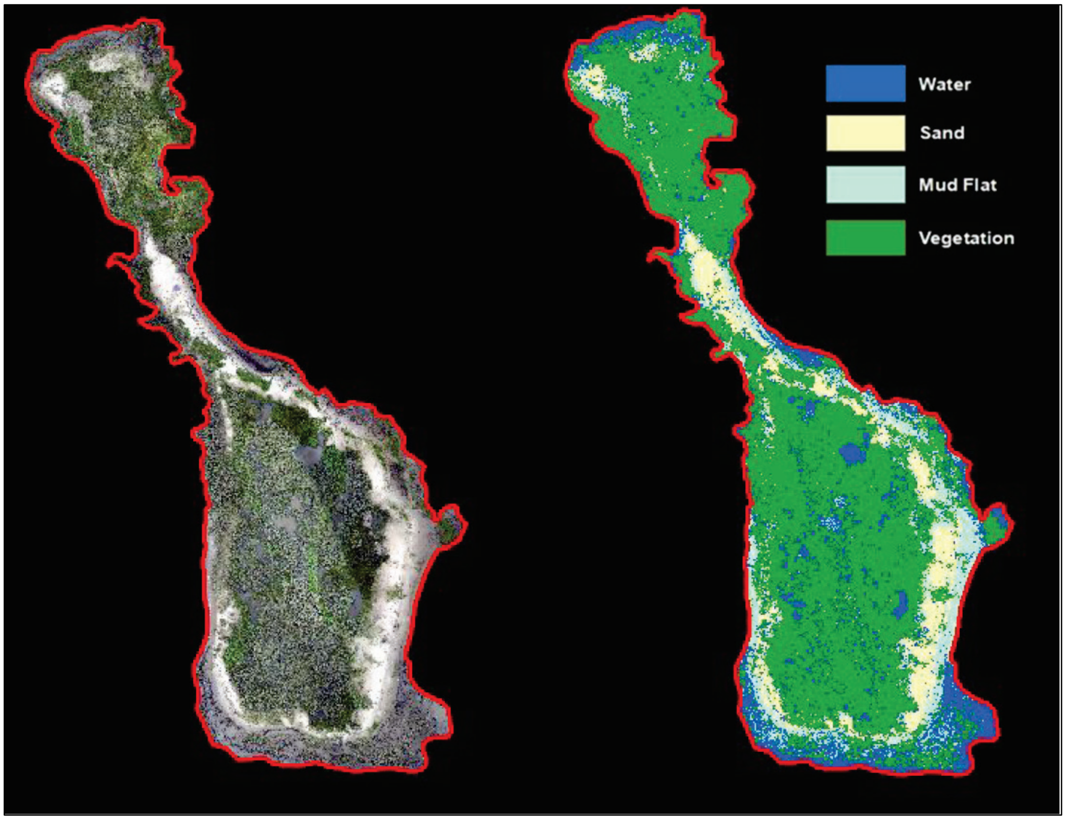


Figure B-5. Habitat classification imagery for Willet Island.

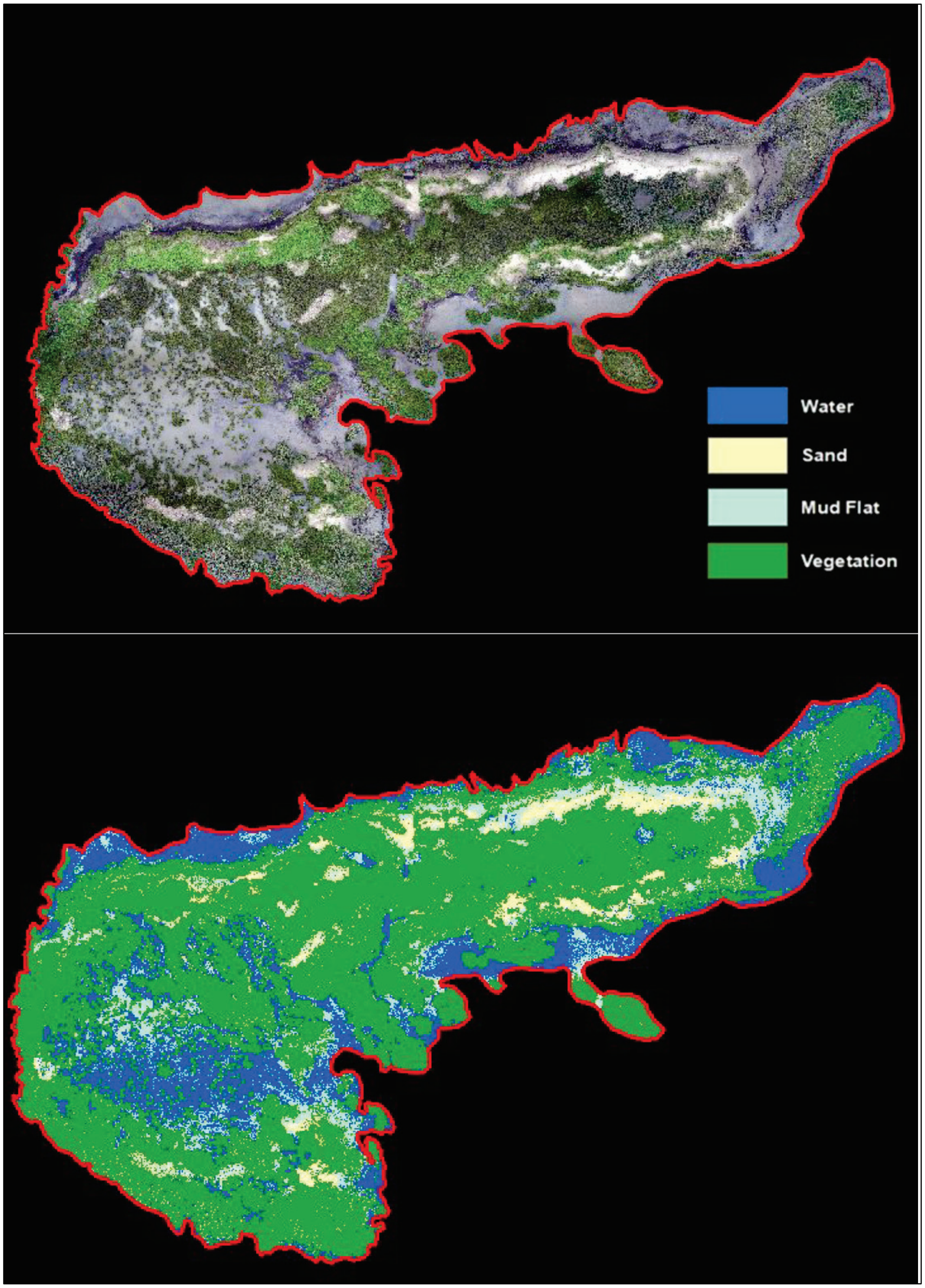
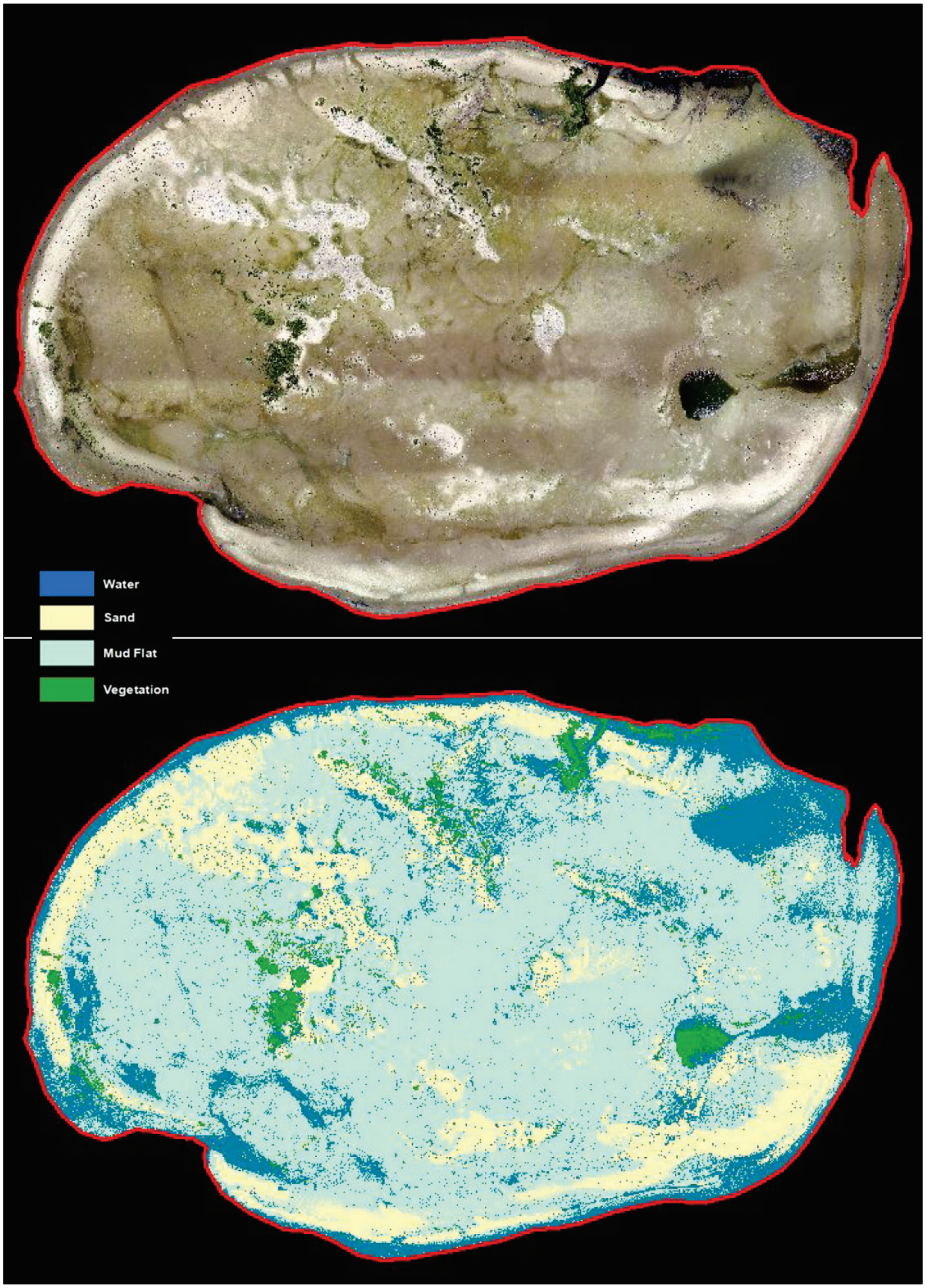


Figure B-6. Habitat classification imagery for Gunn Island.



Appendix C: Lidar Images for Dredged-Material Areas in the Baptiste Collette Bayou, 2021—Includes Lidar Digital Elevation Model (DEM) Imagery, Digital Surface Model (DSM) Imagery, and Canopy Height Model (CHM) Imagery

Figure C-1. Open Area 1 lidar images: (*a*) digital elevation model (DEM), (*b*) digital surface model (DSM), and (*c*) canopy height model (CHM).

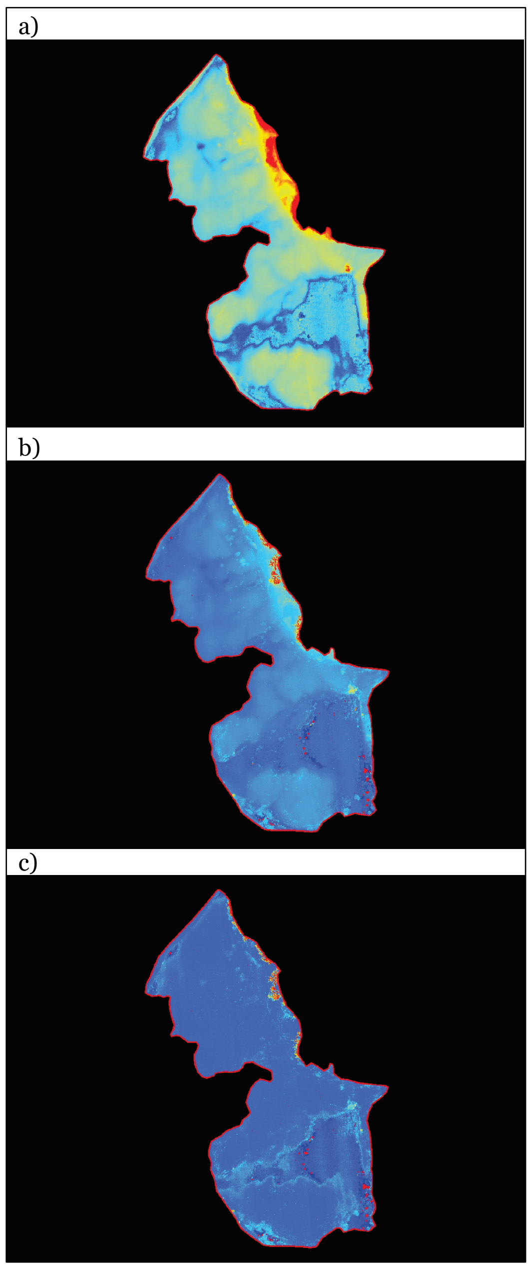


Figure C-2. Paul Island with Open Area 2 lidar Imagery: (*a*) DEM, (b) DSM, and (*c*) CHM.

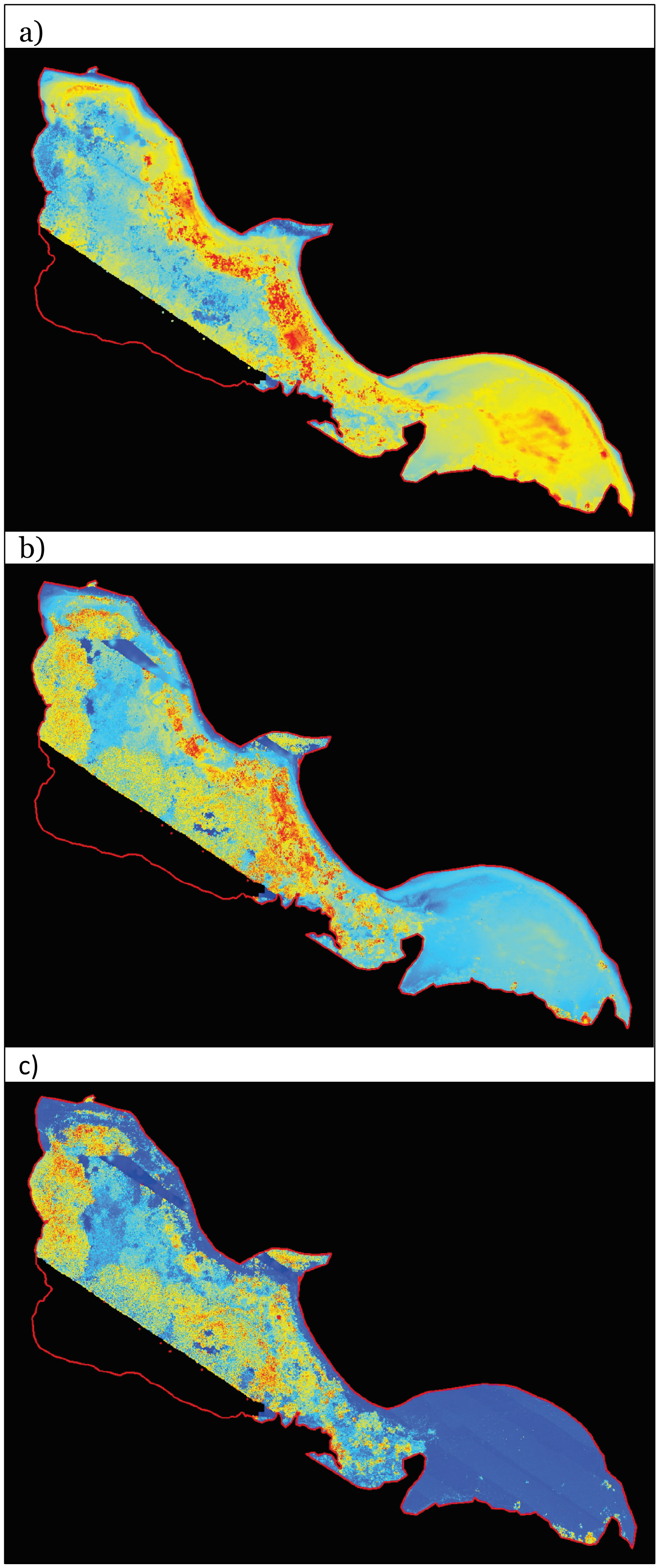


Figure C-3. Karen Island lidar imagery: (*a*) DEM, (*b*) DSM, and (*c*) CHM.

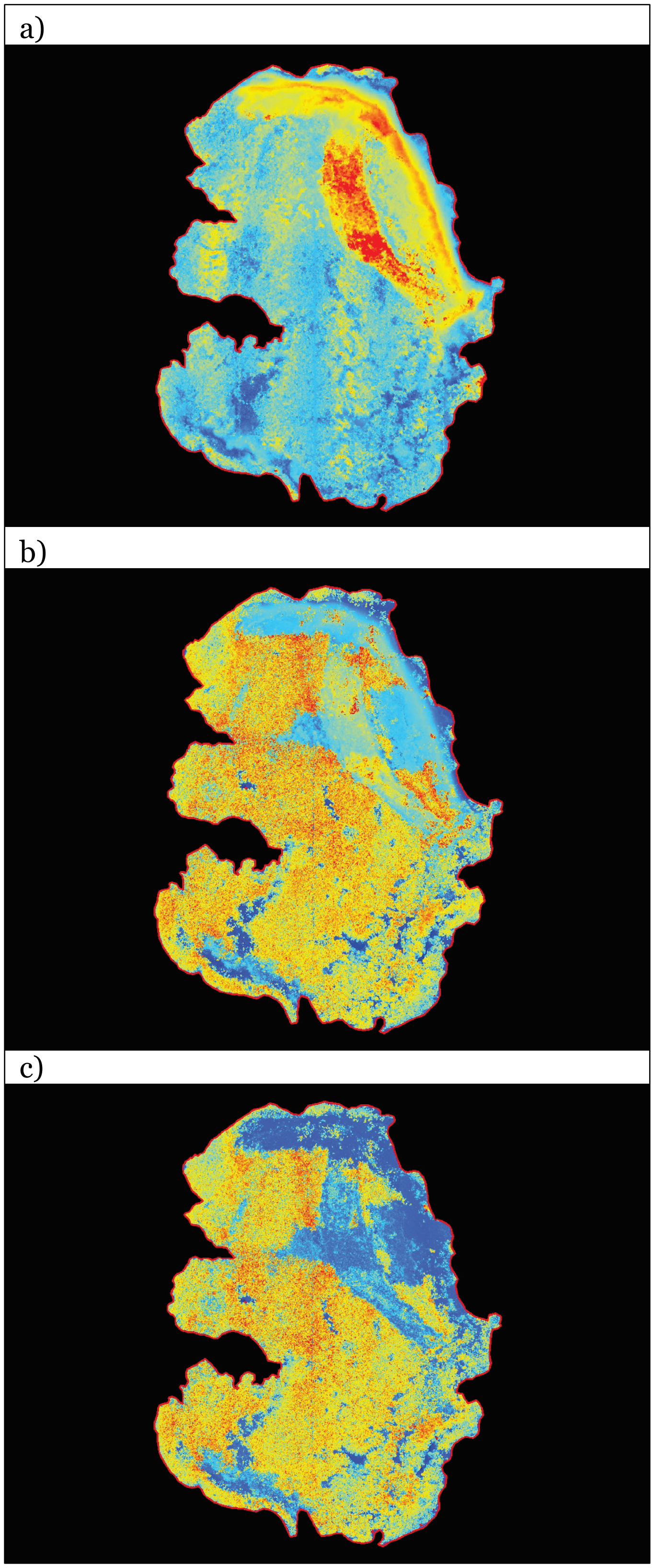


Figure C-4. Plover Island lidar imagery: (*a*) DEM, (*b*) DSM, and (*c*) CHM.

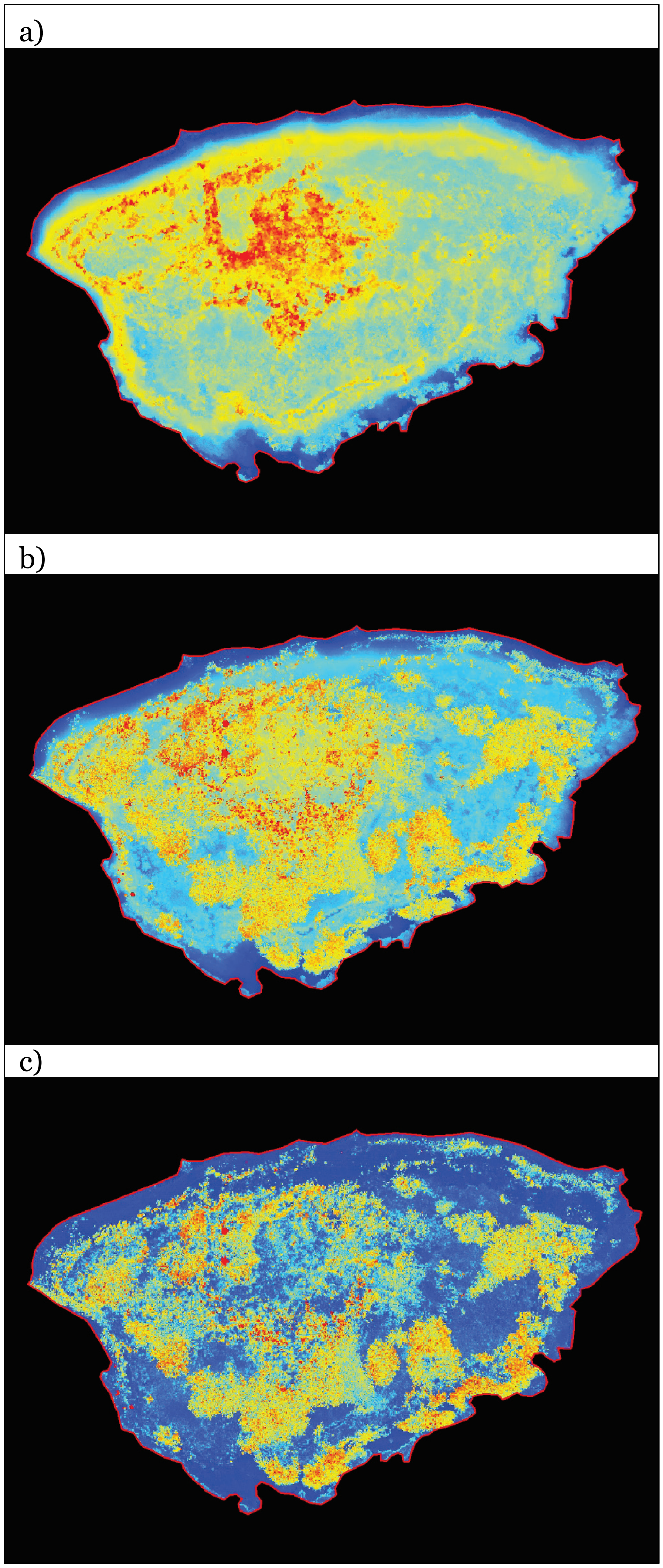


Figure C-5. Shea Island lidar imagery: (*a*) DEM, (*b*) DSM, and (*c*) CHM.

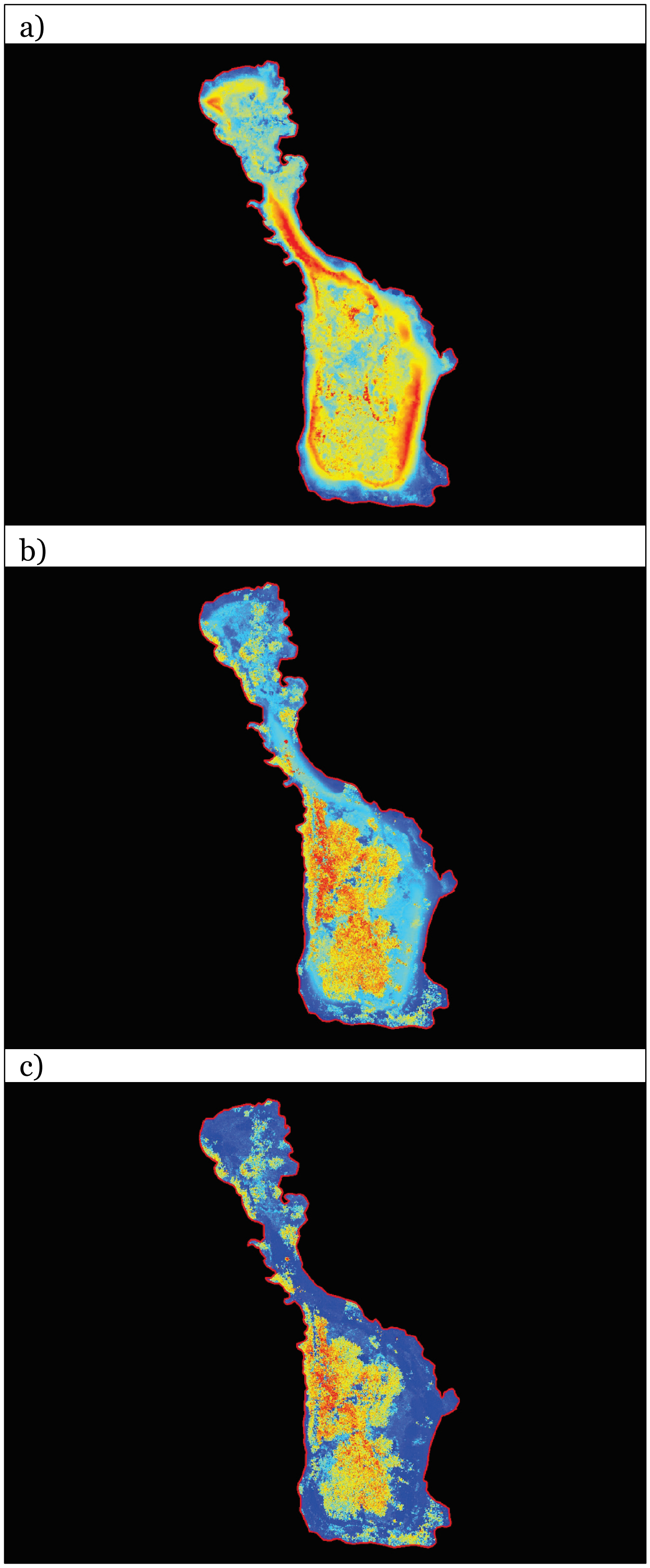


Figure C-6. Willet Island lidar imagery: (*a*) DEM, (*b*) DSM, and (*c*) CHM.

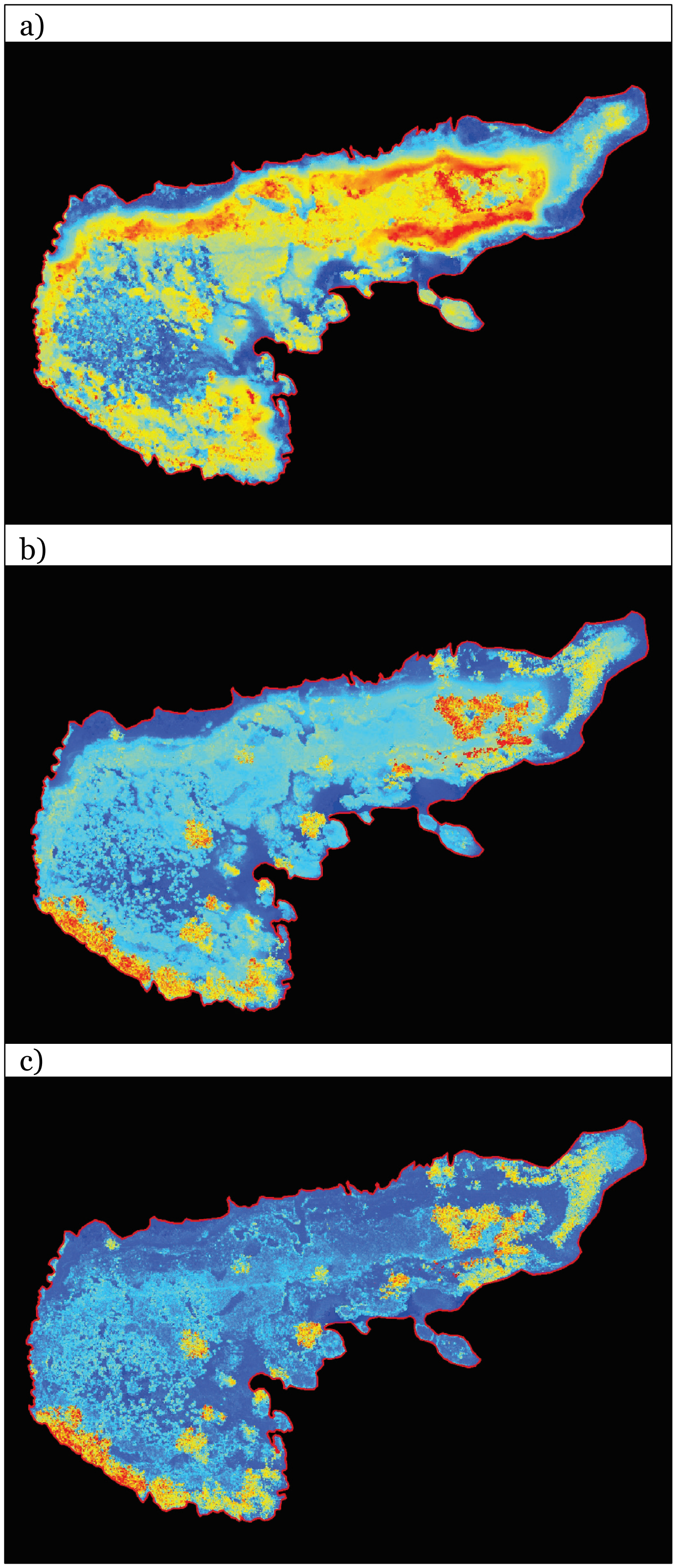
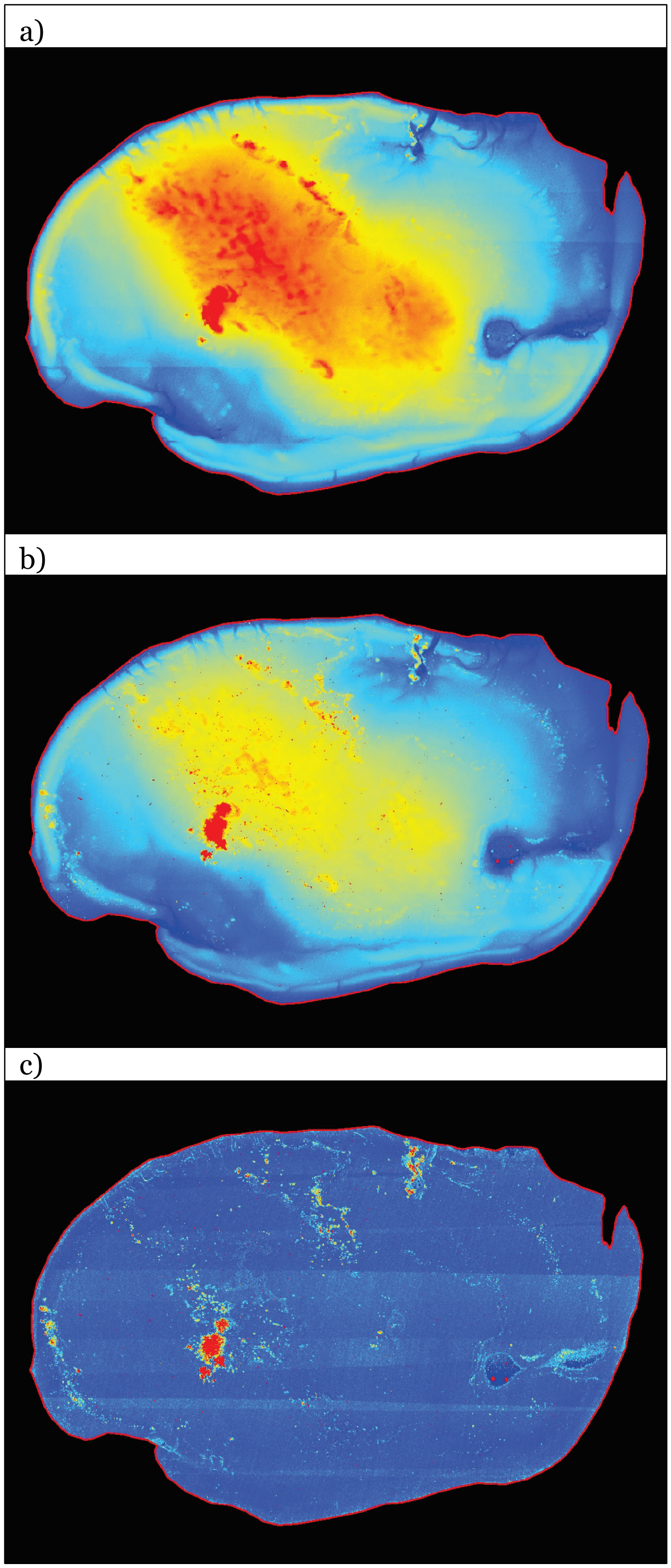


Figure C-7. Gunn Island lidar imagery: (*a*) DEM, (*b*) DSM, and (*c*) CHM.



Abbreviations

ANOVA	Analysis of variance
CHM	Canopy height model
DEM	Digital elevation model
DSM	Digital surface model
EGM	Earth Gravitational Model
EL	Environmental Laboratory
EPA	US Environmental Protection Agency
ERDC	US Army Engineer Research and Development Center
ICWW	Intracoastal Waterway System
IMU	Inertial measurement unit
ISODATA	Iterative self-organizing data analysis
MSG	Mean sea Gulf level
OPUS	Online Positioning User System
PROC GLM	General linear model procedure
SAS	Statistical Analysis System
StdErr	Standard error
TIN	Triangular irregular network
TRI	Terrain Ruggedness Index
UAS	Uncrewed aerial system
USACE	US Army Corps of Engineers
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED START DATE	3. DATES COVERED END DATE
May 2024	Final Technical Report (TR)	FY21	FY24

4. TITLE AND SUBTITLE
Coastal Breeding Bird Phenology on the Dredged-Material Islands of the Baptiste Collette Bayou, US Army Corps of Engineers, New Orleans District, Louisiana

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
Michael P. Guilfoyle, Amanda N. Anderson, Sam S. Jackson, Jacob F. Jung, Theodore J. Zenzal, Jr., Burton C. Suedel, and Jeffrey M. Corbino

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
See reverse.	ERDC/EL TR-24-7

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER(S)
Dredging Operations Technical Support (DOTS) Program US Army Engineer Research and Development Center (ERDC) 3909 Halls Ferry Road Vicksburg, MS 39180-6199		

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A. Approved for public release: distribution is unlimited.

13. SUPPLEMENTARY NOTES
Funding Account Code U4391619, AMSCO Code 086000

14. ABSTRACT
Coastal bird populations in North America have experienced significant population declines over the past four decades, and many species have become dependent upon human-made islands and other sediment-based habitats created through dredged material deposition. We monitored the breeding phenology of coastal bird populations utilizing dredged-material islands and open depositional areas in the Baptiste Collette Bayou in coastal Louisiana. Monitoring began in early May, prior to when most coastal species begin nesting, and continued through late August, when most breeding activity has ceased. Semimonthly surveys included area searches by foot and boat. Two deposition areas and one island supported large numbers of foraging, roosting, or breeding birds; surveys on these areas included using spotting scopes to identify species and count nests or young. Six islands and two open deposition areas were monitored. We also collected high-definition and lidar imagery using an uncrewed aerial system (UAS) in June, during peak nesting season. We recorded 77,474 cumulative detections of 68 species. Virtually all colonial nesting birds (terns and skimmers) nested on Gunn Island in 2021. We discuss these results in the context of dredged-material deposition by the US Army Corps of Engineers, New Orleans District, and offer recommendations for management of these areas.

15. SUBJECT TERMS
Animal phenology; Artificial islands; Birds; Dredged material; Dredging spoil; Sea birds; Water birds

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	C. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
Unclassified	Unclassified	Unclassified	SAR	72

19a. NAME OF RESPONSIBLE PERSON	19b. TELEPHONE NUMBER (include area code)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) (concluded)

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