Colonial Waterbird Monitoring with Aerial Photographic Surveys in the Northern Gulf of Mexico, 2010–2021

October 2023

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Regionwide Trustee Implementation Group

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Suggested Citation

Capitolo, P. J., J. N. Davis, M. W. Parker, W. A. Williams, N. Yorba, B. M. Ramirez, and R. G. Ford. 2023. Colonial Waterbird Monitoring with Aerial Photographic Surveys in the Northern Gulf of Mexico, 2010–2021. Colibri Ecological Consulting, LLC, Fresno, CA, and R. G. Ford Consulting, Portland, OR. Prepared for Regionwide Trustee Implementation Group.

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Executive Summary

This report summarizes colonial waterbird (CWB) monitoring data collected from seven years of aerial photographic surveys in the northern Gulf of Mexico (nGOM) from 2010 to 2021, as requested in the *Monitoring and Adaptive Management Activity Implementation Plan: Colonial Waterbird Monitoring* developed by the Regionwide Trustee Implementation Group (RW TIG) in 2020 (RW TIG 2020). The report summarizes the abundance, distribution, and breeding status of more than 20 CWB species. The monitoring and adaptive management activity implementation plan (RW TIG 2020) also proposed that regionwide surveys be conducted in 2021 from Brownsville, Texas, through the Big Bend of Florida, resulting in the broadest survey coverage among all years. All count data and photographs from all years are available through the Avian Data Monitoring Portal, which can be accessed through a designated link within the *Colonial Waterbird Monitoring* activity (DIVER Project #257) or directly (https://arcg.is/09LCra).

In 2021, more than 450,000 nests (or 900,000 breeding birds; nests multiplied by two) of 33 species were counted throughout the selected region of the nGOM. More than 90% of the nests were in Texas and Louisiana. Individual birds of another 22 species for which evidence of nesting was not observed also were counted. Species with evidence of nesting represented five taxonomic groups, principally seabirds and wading birds, but also raptors (one species), shorebirds (two species), and waterfowl (three species). Laughing Gull (*Leucophaeus atricilla*) was the most abundant species (more than 160,000 nests) followed by Royal Tern (*Thalasseus maximus*), Sandwich Tern (*Thalasseus sandvicensis*), and Brown Pelican (*Pelecanus occidentalis*). More than 53,000 Brown Pelican nests were counted regionwide in 2021. These same four species were the most abundant in all survey years, though their rank varied. Among wading bird species in 2021, White Ibis (*Eudocimus albus*) was the most abundant (> 19,000 nests), with just three colonies (South Deer Island in Texas, Bird Island East in Louisiana, and Gaillard Island in Alabama) accounting for 76% of all nests. Tricolored Heron (*Egretta tricolor*) was the second most abundant wading bird species (> 14,000 nests) and was more widely distributed. The only breeding shorebird species regularly documented in aerial photographs was the American Oystercatcher (*Haematopus palliates*), because of its large size.

Among all survey years, available data (given variable survey coverage) indicate that nest totals appear to have been highest in 2011 and 2018. For example, in Louisiana, notable peaks in statewide nest totals for Brown Pelican and Tricolored Heron were documented in 2018; Laughing Gull and Sandwich Tern peaks seemed to occur in both 2011 and 2018.

Ongoing CWB breeding habitat loss at marsh and barrier islands in Louisiana was well documented. Post-restoration colony count data are discussed for selected islands in Louisiana, Mississippi, and Alabama, including Year 1 post-restoration (2021) data for Queen Bess Island in Louisiana.

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1.0 Introduction

Colonial waterbirds (CWB or waterbird) and their important habitats incurred substantial injuries during and following the 2010 *Deepwater Horizon* oil spill (the Spill) in the northern Gulf of Mexico (nGOM). These injuries were documented, in part, by 2010–2013 aerial photographic surveys (surveys) and subsequent analyses (Colibri and Ford 2015). Colonial waterbirds continue to be affected in the region, especially due to habitat loss at historical nesting islands. To help inform, monitor, and evaluate future restoration, the Regionwide Trustee Implementation Group (RW TIG) developed and implemented the *Monitoring and Adaptive Management Activity: Colonial Waterbird Monitoring* (DIVER 257; RW MAM activity; RW TIG 2020).

Information generated from this RW MAM activity is intended to assist Trustees in the estimation of CWB relative abundance, distribution, and breeding status across selected geographic regions of the nGOM. Implementing the plan involved (1) conducting regionwide aerial photographic surveys and analysis of waterbird nesting colonies in 2021, (2) analysis of 2015 aerial photographs, and (3) summarizing aerial photographic survey data from all survey years (2010–2013, 2015, 2018, and 2021). All survey data were collected by Colibri Ecological Consulting and R. G. Ford Consulting.

This report includes a broad overview of 2010–2021 CWB colony count data in the nGOM, describing the regional distribution and abundance of nesting species, identifying large colonies, discussing restored islands and beneficial use projects, other habitat changes, and annual variation in nest numbers. Distribution and abundance are principally treated in species accounts in Appendix A of the report, for 26 of the 35 species for which nesting was documented during the 2010–2021 period. The other nine species accounted for very few nests and are described in the Introduction of Appendix A.

All data presented in this report are publicly available through the Avian Data Monitoring Portal (https://arcg.is/09LCra) which can be accessed via link within the National Oceanic and Atmospheric Administration's Data Integration Visualization Exploration and Reporting (DIVER) Explorer and the Louisiana Coastal Protection and Restoration Authority's Coastal Information Management System (CIMS). The portal includes an interactive dashboard intended to assist end users' ability to query CWB nest and bird counts by species, survey dates and years, colony, and other spatial criteria. The dashboard also allows end users to view original high resolution aerial photographs that were used for determining colony counts, along with corresponding annotated screen captures. Using designated tabs, end users can download a summary file of nest totals, a Microsoft Access® database of all 2010–2021 count data, a ReadMe file to assist in navigation and understanding of the database, and protocols for surveys and image analysis.

2.0 Methods

2.1 Survey Coverage and Target Species

The spatial extent of aerial photographic surveys varied from 2010 to 2021 (Table 1, Appendix B). In 2010, survey coverage extended from Corpus Christi, Texas, through the Dry Tortugas in Florida. In 2011–2013 and in 2015, survey coverage extended from Vermilion Bay, Louisiana, to a variable endpoint in Apalachicola Bay or western Apalachee Bay, Florida. In 2018, surveys were limited to only Louisiana. In 2021, survey coverage extended from South Texas (near Brownsville) to the Big Bend of Florida.

Colonies were surveyed in both May and June, except in 2010 due to conflicting priorities for air space during oil spill response and because the need for surveys in Texas and Florida was not determined by Trustees until June (Table 1). Only seven colonies were surveyed more than once in 2010, all in Louisiana (see 2.4 Nest and Bird Enumeration (Dotting)). Because south Florida colonies, from Cedar Key (at the southeastern end of the Big Bend coast) to the Dry Tortugas, were surveyed only in June 2010, with no subsequent data for comparison, the associated data are not represented in this report. Numbers of species presented in this report do not include species that were documented only in south Florida, such as Brown Noddy (*Anous stolidus*) and Roseate Tern (*Sterna dougallii*) in the Florida Keys. Nor do total numbers of nests presented in this report include colony counts from south Florida. All south Florida colony counts are available online through the Avian Data Monitoring Portal (https://arcg.is/09LCra).

Target species for this RW MAM activity included colonial-breeding seabirds and wading birds (RW TIG 2020). Target seabirds included but were not limited to Brown Pelican (*Pelecanus occidentalis*), Royal Tern (*Thalasseus maximus*), Sandwich Tern (*Thalasseus sandvicensis*), Caspian Tern (*Hydroprogne caspia*), Gull-billed Tern (*Gelochelidon nilotica*), and Black Skimmer (*Rynchops niger*). Laughing Gull (*Leucophaeus atricilla*) and Forster's Tern (*Sterna forsteri*) were considered secondary target species given the challenges of detecting and completely surveying all colonies (where only these target species breed) in the vast offshore marsh areas of Louisiana. However, at other discrete or traditional colonies both species were surveyed well with aerial photography. Because of their small size, nesting Least Terns (*Sternula antillarum*) were mostly captured in aerial photographs incidentally. However, in 2021, Least Terns nesting on Mississippi and Florida mainland beaches were surveyed for comparison with ground data (Appendix A). Target wading birds included but were not limited to Reddish Egret (*Egretta rufescens*), Little Blue Heron (*Egretta caerulea*), Tricolored Heron (*Egretta tricolor*), Roseate Spoonbill (*Platalea ajaja*), Great Blue Heron (*Ardea Herodias*), and Black-crowned Night-Heron (*Nycticorax nycticorax*). Great Egret (*Ardea alba*), Snowy Egret (*Egretta thula*), and White Ibis (*Eudocimus albus*) also were surveyed with aerial photography.

Among solitary, breeding shorebird species, only the American Oystercatcher (*Haematopus palliates*) was regularly observed in aerial photographs. Smaller breeding shorebird species such as Wilson's Plover (*Charadrius wilsonia*) typically could not be detected during surveys or during inspection of aerial photographs. Ruddy Turnstone (*Arenaria interpres*), a migrant species with conspicuously contrasting plumage, was the one smaller shorebird species that could be consistently identified in aerial photographs.

Table 1. Survey dates and states by year, including each year's photographers, navigators, and pilot.

Year	May	June	Photographers	Navigators	Pilot	States Surveyed
2010	7–8 17–18	8–9 11–14 23–27	P. Capitolo M. Parker L. Henkel	J. Davis G. Ford G. Himes-Boor	I. Ufford	TX[1], LA, MS, AL, FL[1]
2011	17–20	13–15 17–18	P. Capitolo M. Parker	J. Davis	I. Ufford	LA, MS, AL, FL
2012	27–30	18–21	P. Capitolo M. Parker	J. Davis G. Ford	A. Blasingame	LA, MS, AL, FL
2013	23–25	17–19	P. Capitolo M. Parker	J. Davis	A. Blasingame	LA, MS, AL, FL
2015	16–18	20–22	P. Capitolo M. Parker	J. Davis	A. Blasingame	LA, MS, AL, FL
2018	19–21	23–25	P. Capitolo K. Robison	J. Davis	B. Eastin	LA
2021	17–18 20 22–25	14–20	P. Capitolo J. Medley	J. Reece	J. Blais	TX, LA, MS, AL, FL

[1]Surveyed only in June.

2.2 Colony Inventory

Utilizing colony locality information provided by state and federal agency partners, a geographic information systems (GIS) database of nGOM colony locations was developed by R.G. Ford Consulting in 2010. The GIS database was regularly updated as new colonies were discovered and as former colonies became submerged over time (see 3.2.1 Natural Islands). The GIS database was also imported as a colony inventory table into a relational database of aerial photographic count data (*See Section 2.5 – Archiving and Summarizing Data)*.

Each CWB colony was characterized by a unique Colony Name, typically synonymous with island name, as well as multiple levels of spatial information. When an island name was not known, mostly in Louisiana, colonies were named referencing the closest geographic feature, such as the nearest mainland point from which an island eroded or the bayou in which an island resided. If no nearby geographic feature was distinctive, colonies were named according to the Geographic Region in which they resided and were numbered sequentially (e.g., Terrebonne Bay 1, Biloxi North 3). To better organize colonies across the nGOM and provide possible future analysis areas, 34 Geographic Regions (referred to as GeoRegions in the GIS database and throughout this report) were created from Texas through the Florida Keys (Figure 1). Demarcation of these boundaries was enhanced using the physical and ecological features of the Level IV Terrestrial Ecoregion (EPA 2022) and Level 12 HUC Watershed layers (USGS 2022). Further descriptions of colony naming and colony location information are provided in a ReadMe file available through the Data Management tab within the Avian Data Monitoring Portal (

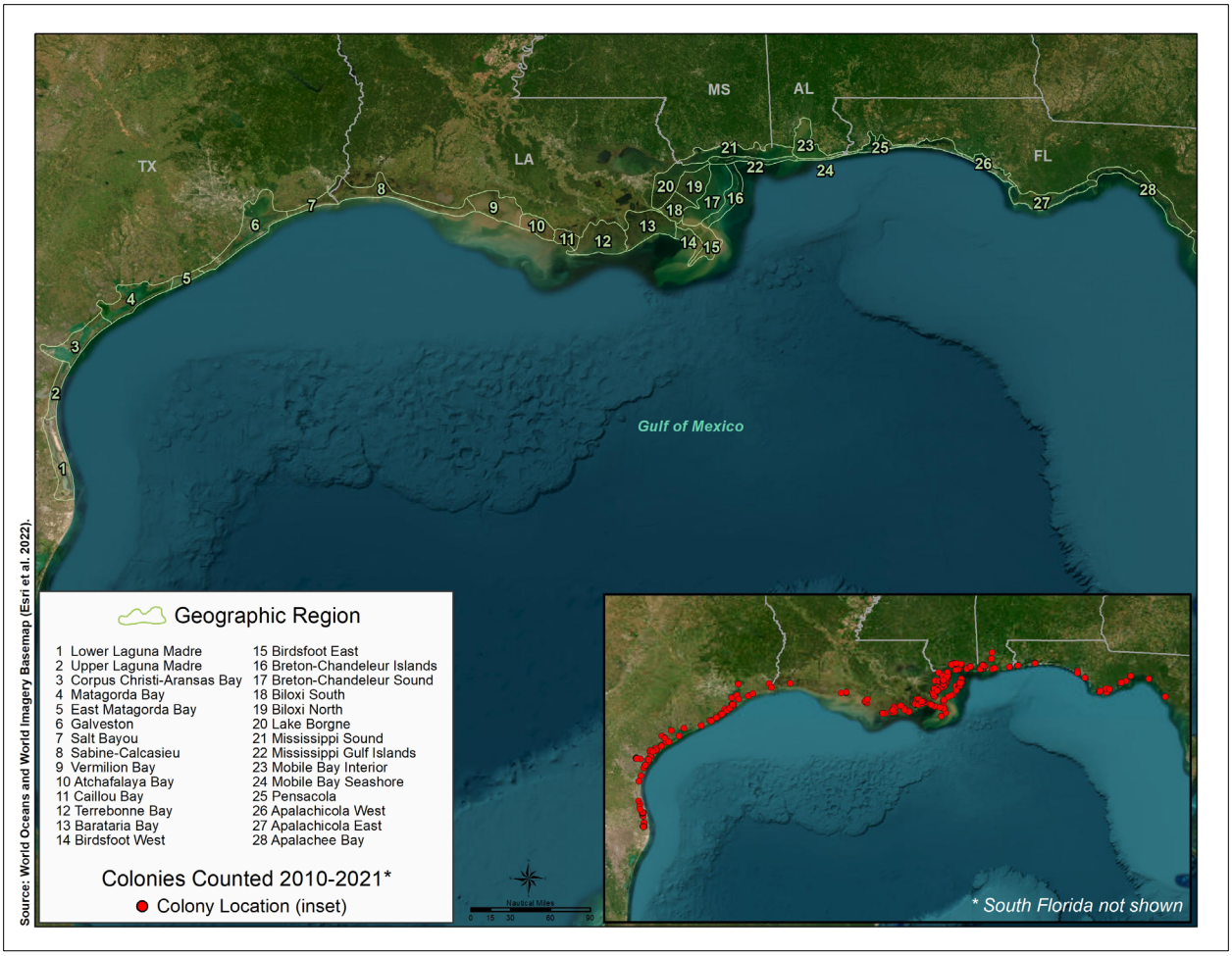

Figure 1. Geographic Regions (GeoRegions) from South Texas to the Big Bend of Florida.

2.3 Aerial Photography

Aerial photographic surveys in the nGOM were conducted with methods adapted from those used in California for long-term monitoring of seabird colonies (Capitolo et al. 2014, 2019; Barton et al. 2017).

Surveys were conducted from a fixed-wing, twin engine, high-wing Partenavia (PN68) Observer aircraft. The Observer model features a plexiglass nose (Figure 2), which allowed the pilot and navigator to see and efficiently approach breeding colonies. The aircraft was equipped with a belly port for vertical/nadir photography and configured such that two photographers could work simultaneously. Oblique photographs through side windows were taken only in May 2010, during the Spill and before the aircraft had been configured for vertical photography. All photographers were familiar with both aerial survey and image analysis protocols, necessary to ensure photograph quality was adequate for determining colony counts of nests and birds (*See Section 2.4 - Nest and Bird Enumeration (Dotting)*). Surveys typically were flown at altitudes of 700 to 1000 feet above ground level at a ground speed less than 90 knots. As of 2021, full-frame,

digital single-lens reflex cameras (Canon® EOS-1D X Mark III) equipped with zoom and prime lenses (focal length range = 16–300 millimeters) were used to acquire photographs. Digital crop-sensor cameras (Canon® D series) were used in previous years. Ground sample distances were typically < 1 cm, with longer focal length lenses needed on full-frame cameras. Aircraft waypoints and time were recorded automatically at intervals of 5 seconds or less. Photograph times were downloaded from exchangeable image file format (EXIF) data, and image file names were interpolated into tracklines to estimate the position of each photograph. As of 2021, latitude and longitude coordinates of photographs, generated from a global positioning system unit attached to each camera, were included among EXIF data.

Survey crews consisted of a pilot, a navigator/data recorder in the co-pilot's seat, and two photographers in the rear of the plane (Table 1). The navigator coordinated with the pilot to determine the sequence of colony visits. During transit between known colonies, observers in the aircraft also searched the surroundings for other potential CWB breeding habitat or conspicuously active new breeding colonies. Similarly, colonies that had become submerged over time were still approached during surveys so that other nearby potential breeding habitat could be inspected (see 3.2.1 Natural Islands). One photographer captured context photographs showing a relatively wide-area view of colonies, while the other photographer concentrated on taking more detailed close-up shots. The context photographer also typically zoomed in to obtain mid-focal length coverage, often useful for counting nests and birds. The navigator recorded the aircraft altitude, the range of frame numbers shot for both cameras for each pass over a colony, and any relevant notes about colonies.

As the aircraft approached a target colony, the crew determined the spatial distribution of birds at the colony. Photographers, navigator, and pilot conferred to determine the best angle of approach and the ideal altitude for photographic census. Altitudes and flight paths were determined based on the extent of the colony, the species present at the colony, the strength and direction of the wind, vegetation around the colony, and angle of the sun. Multiple approaches from different directions or altitudes were often necessary to obtain sufficient photographic coverage. For example, colony areas which included only larger species such as Brown Pelican could be surveyed first from an altitude of about 1000 feet, followed by areas with smaller CWB such as terns at around 700 feet. Lower altitudes were avoided to prevent disturbing breeding birds. For optimal lighting, photography was typically conducted from approximately 3 hours after sunrise to 3 hours before sunset, when solar altitude was at least about 35 degrees. Photographs (Joint Photographic Experts Group [JPEGs]) were downloaded daily to external data-storage devices.

Figure 2. The Observer model of a Partenavia aircraft.

2.4 Nest and Bird Enumeration (Dotting)

Photographs from May and June surveys were evaluated for their representation of peak breeding by each species at a given colony. For some species, such as Brown Pelican and Great Egret, photographs from May surveys often represented peak breeding numbers and were selected for analysis. For other species, especially Black Skimmer, photographs from June surveys better represented peak breeding numbers and were used for analysis. On occasion, in all years, May and June nests counts of different nesting groups within a colony needed to be summed to obtain a total number of nests and the best estimate of breeding population size for a certain species. For example, Brown Pelican, Royal Tern, and Sandwich Tern sometimes had large, well-developed nesting groups that were counted using May photographs, but also new nesting groups that formed after the May survey that were counted from June photographs. Instances of summing May and June nest totals occurred for 20 CWB species (Appendix A; Avian Data Monitoring Portal (https://arcg.is/09LCra)).

All images of each individual colony were inspected for clarity, location within the colony, and extent of colony coverage. Those best suited for determining nest counts and collectively comprising all breeding areas were analyzed using counting software (Image-Pro, Media

Cybernetics®). Nests and birds were marked manually ("dotted"), and the software automatically tallied total counts for each category (See ReadMe and Dotting Protocol). Although the primary objective was to determine numbers of nests, individual adult and subadult birds within colonies were also counted.

For Brown Pelicans, nests were categorized based on stage of development:

1. Well Built Nest (with attending adult typically in incubation posture)
2. Poorly Built Nest (pre-egg laying, but considered a breeding pair)
3. Nest with Chicks, with attending adults
4. Nest with Chicks, without attending adults
5. Brood (dependent chicks away from an obvious nest and not attended by an adult)
6. Abandoned Nest (with eggs, but unattended)
7. Empty Nest (unattended and without eggs or chicks)
8. Territory (in breeding habitat and territorial spacing, but not judged to be a breeding pair)

Together, these categories often provided numbers of pelican nests at a colony from a single survey, even though egg laying dates may have spanned a period of months, given that chicks do not fledge until they are approximately three months old. Empty Nests and Territories were not included in colony nest totals because they were not considered to have been, or to have later become, egg laying sites and therefore were not considered appropriate to include in a breeding population estimate.

Because of their small body size (e.g., terns and gulls), scrape-nesting habits (e.g., terns and skimmers), or partial concealment by vegetation (e.g., waders and gulls), the various nest categories used for pelicans could not always be identified for other species. Therefore, due to the lack of consistently visible nest structures, a bird in incubation posture for all other species was typically categorized as a Site (See ReadMe). For the 2021 image analyses, however, the three nest categories indicating the presence of chicks (categories 3, 4, and 5 in the above list) were used in a standardized manner for all species, not just for Brown Pelicans. The ReadMe file available through the Data Management tab within the Avian Data Monitoring Portal (https://arcg.is/09LCra) specifies the use of nest categories since 2010.

Marking a nest category also accounts for an attending adult, rather than marking the nest and the bird separately. Other birds were also counted, such as a second adult attending a nest, or birds along the shoreline or in colony areas not obviously associated with a breeding group (See ReadMe). Doing so allowed the total number of birds in attendance at the time of the survey to be summed and forced the photo analyst to inspect all attending birds closely for possible breeding status. Exceptions included roosting birds in non-breeding habitat, which were not always dotted due to time constraints. However, these areas were still closely inspected to ensure they did not include chicks that had wandered away from nests that otherwise may not have been accounted for.

Using the dotting annotation software, unique symbol-color combinations were assigned to different nest and bird categories for each species. Where overlapping images were used to analyze portions of a colony, one or more lines were drawn on the selected image to delineate the area to be counted using that image. Areas outside any such lines were counted using different images. This process continued until the colony was counted completely with available photographs.

2.5 Archiving and Summarizing Data

After analyzing each image, a screen capture was saved as a JPEG file. Screen captures showed all manual markings of nests and birds, as well as total counts for each category. Image number, colony name, area number, photo analyst initials, the date the image was analyzed, and any other text annotations are also included. All screen captures were archived with standardized file names in colony-specific folders.

Data from each screen capture were manually entered into a table in a Microsoft Access® database (See ReadMe). Queries were designed to calculate total numbers of nests and birds for individual species or for all species combined at an individual colony. Nest totals can also be queried by GeoRegion and state. Annual, statewide nest totals for individual species are provided in Appendix A. The database and related information are available using the Data Management tab at the Avian Data Monitoring Portal (https://arcg.is/09LCra).

2.6 Statistical Analyses

Statistical analyses were not within the scope of this report. Models could be developed to generate 95% confidence intervals and temporal estimates of percent change for nest totals for species at individual colonies, colony complexes, or regions of interest (Capitolo et al. 2014, 2019; Barton et al. 2017).

3.0 Results

3.1 Nest Counts

3.1.1 Overview

During the seven survey years processed from the 2010–2021 period, over 1.9 million nests of 35 species of birds were documented at approximately 326 colonies, excluding South Florida (i.e., Cedar Key to the Florida Keys along Florida's western coast) data from 2010 (Appendix A; Avian Data Monitoring Portal, https://arcg.is/09LCra). For another 27 species, individual birds were occasionally documented in the aerial photographs, but no evidence of nesting was detected. The 35 nesting species represented five taxonomic groups, principally seabirds and wading birds, but also raptors (one species), shorebirds (two species), and waterfowl (three species). In 2021, 456,049 nests of 33 species were documented, equivalent to more than 900,000 breeding birds (nests multiplied by two). Of those nests, 49% were in Louisiana representing 23 species, 43% were in Texas representing 27 species, 5% were in Alabama representing 20 species, 3% were in Florida representing 17 species, and < 1% were in Mississippi representing six species. The most abundant species in 2021 were Laughing Gull, Royal Tern, Sandwich Tern, and Brown Pelican (Figure 3).

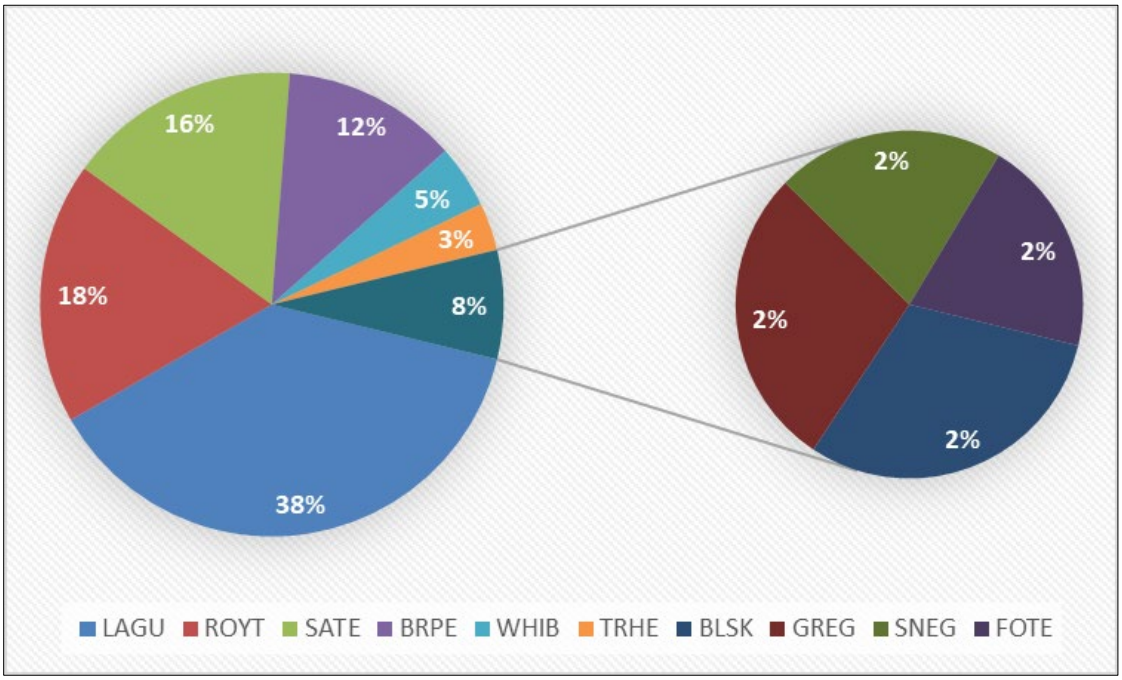

Figure 3. Percentages of the total number of nests counted regionwide in 2021 for the 10 most abundant species. Pie chart on the right is an expansion of the 8% from the left chart. *Species Codes: LAGU = Laughing Gull; ROYT = Royal Tern; SATE = Sandwich Tern; BRPE = Brown Pelican; WHIB = White Ibis; TRHE = Tricolored Heron; BLSK = Black Skimmer; GREG = Great Egret; SNEG = Snowy Egret; FOTE = Forster's Tern.*

3.1.2 Largest Colonies

Among all years, eight colonies had at least one annual count of more than 20,000 nests. Raccoon Island, in the Terrebonne Bay GeoRegion in Louisiana, was the largest colony, with more than 50,000 nests in 2011 and more than 60,000 nests in 2018. Five of the colonies had high species richness (> 10 breeding species), namely North Deer Island in Texas (Galveston); Raccoon, Felicity (Terrebonne Bay), and Queen Bess (Barataria Bay) islands in Louisiana; and Gaillard Island in Alabama (Mobile Bay Interior). Gunn Island (Birdsfoot East), North Breton Island, and one colony at Chandeleur Islands North (Breton-Chandeleur Islands), all in Louisiana, also exceeded 20,000 nests, but with fewer breeding species (Figures 4 and 5).

At the Chandeleur Islands North and South colony groups(within the greater Breton-Chandeleur Islands GeoRegion), tern and skimmer colony locations shifted annually and were named with letters from north to south (See ReadMe file at the Avian Data Monitoring Portal, https://arcg.is/09LCra). At Chandeleur Islands South, all colonies therein exceeded 20,000 nests in 2015 and 2018, though no individual colony did (Figures 6 and 7). In 2018, the colonies from Gunn Island north through Chandeleur Islands North totaled nearly 80,000 nests (Figure 7).

Rabbit Island (Sabine-Calcasieu) and Houma Navigation Canal Island (Terrebonne Bay) in Louisiana, major colonies where restoration has been completed and is planned, respectively, did not have a count of 20,000 nests but also had high overall species richness (Figures 4 and 5).

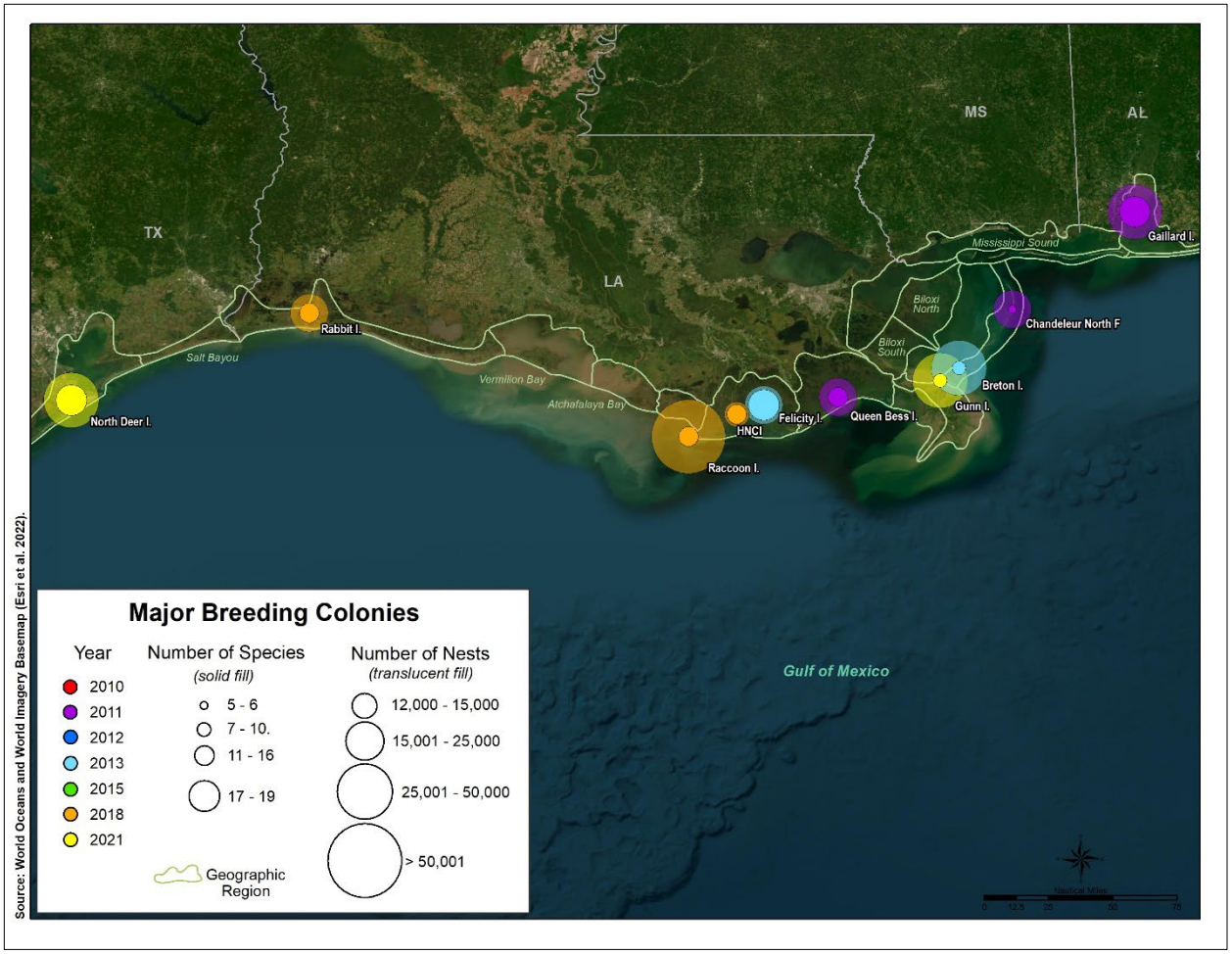

Figure 4. Year of the largest nest total and the total number of breeding species documented at 10 major colonies, eight with at least one count of > 20,000 nests, 2010-2021, plus Rabbit Island and Houma Navigation Canal Island, given completed and planned restoration, respectively.

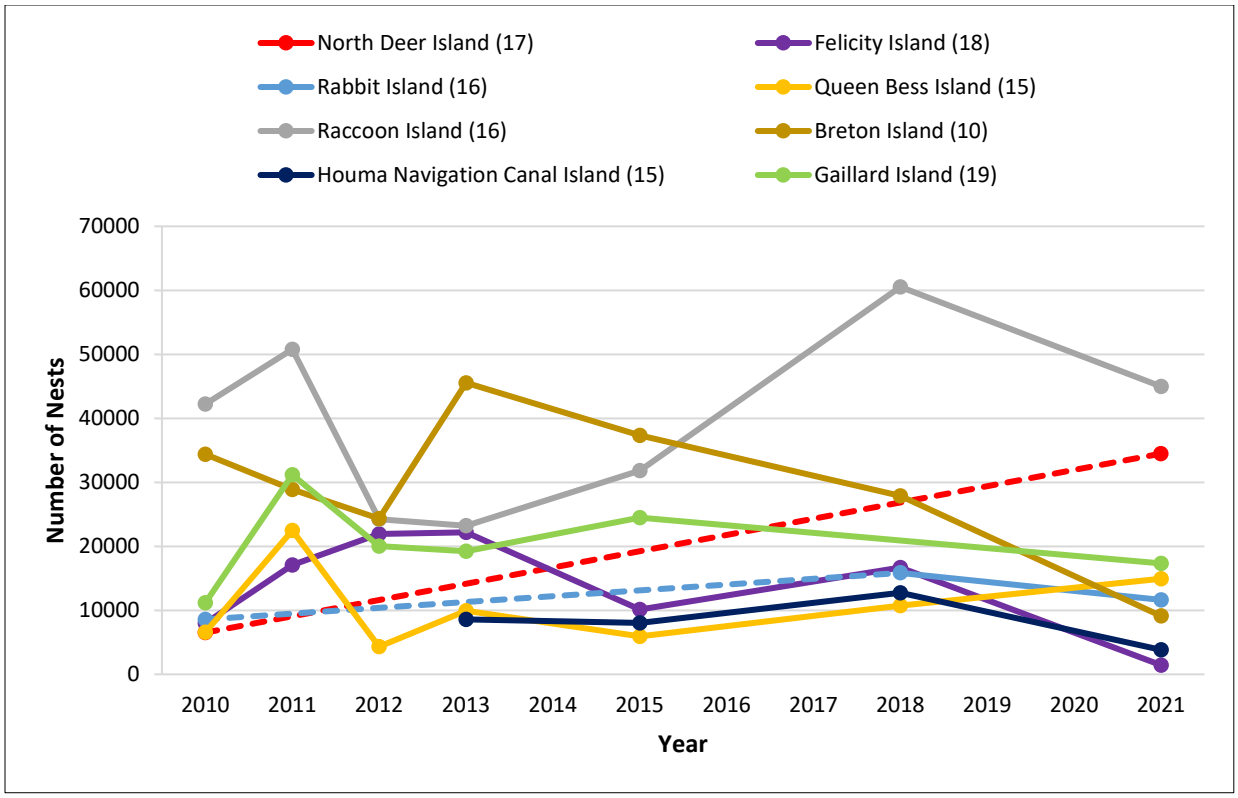

Figure 5. Total numbers of nests counted at eight major colonies with high species richness, 2010–2021. *(X) = number of species; Dashed line = colony not in survey area that year.*

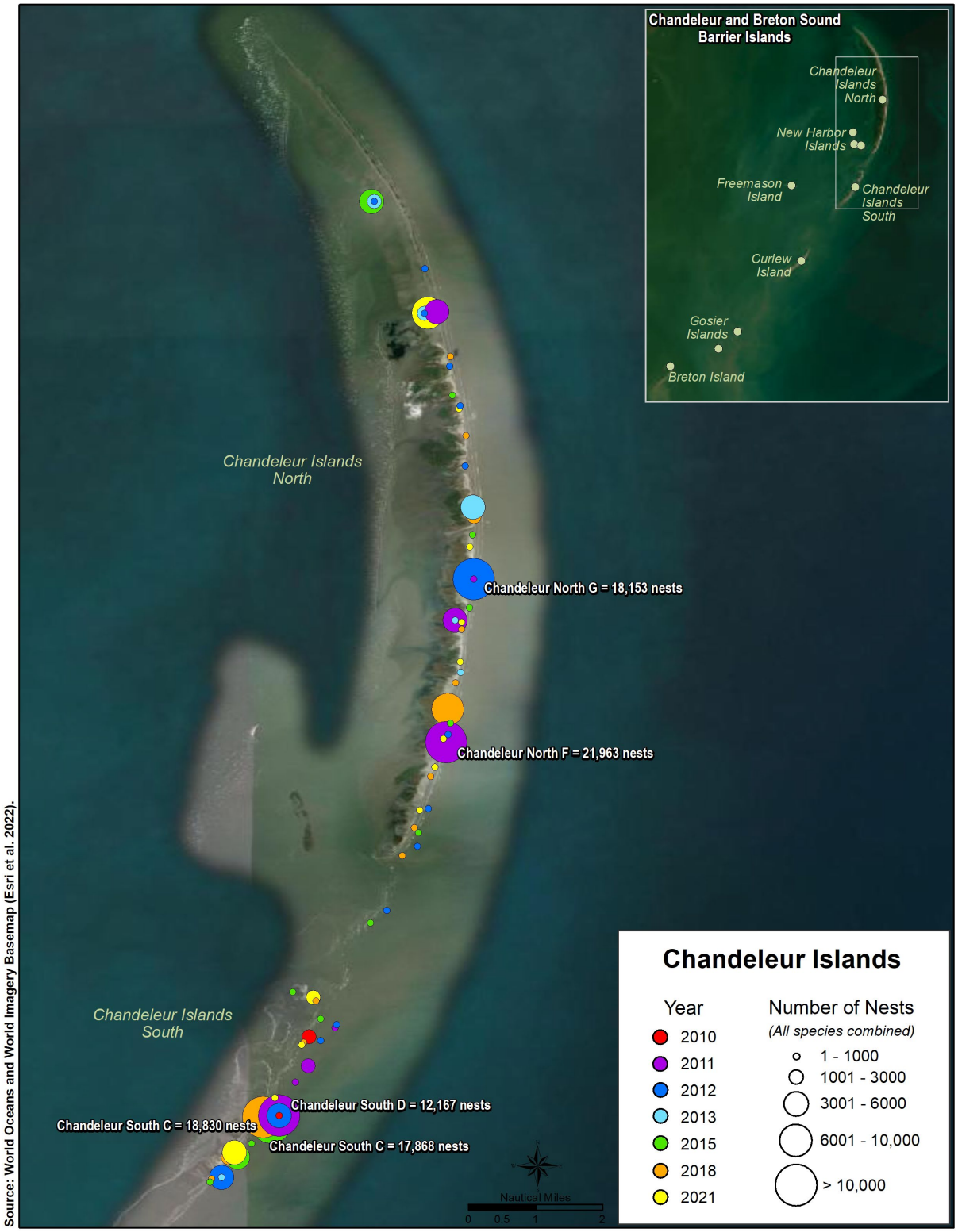

Figure 6. Annual locations and sizes of colonies in the Chandeleur Islands North and South groups.

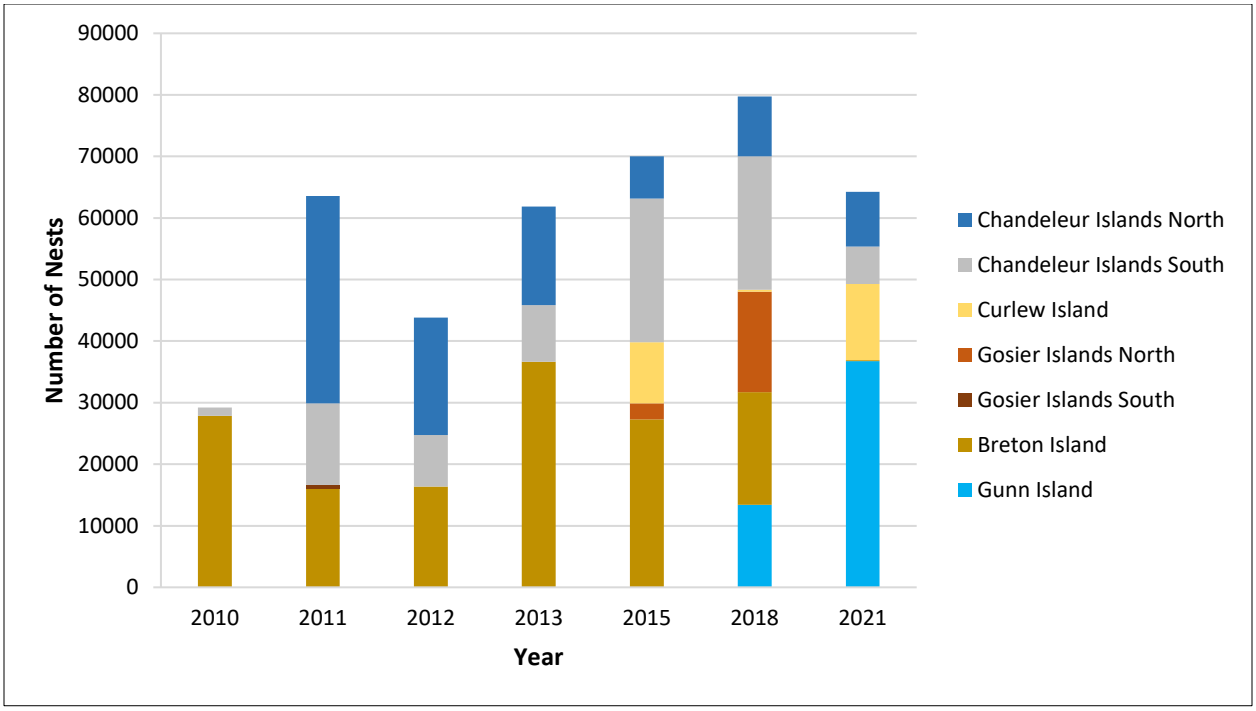

Figure 7. Total numbers of nests of Black Skimmer and all tern species combined in the Breton-Chandeleur Islands GeoRegion, including Gunn Island from the nearby Birdsfoot East GeoRegion. Small numbers of skimmer nests in certain years at Freemason Island and New Harbor Island 1 are not included.

In Texas, aside from North Deer Island (Figures 4 and 5), the other largest colonies were Shamrock Island, Black Skimmer Strip (Corpus Christi-Aransas Bay), Evia Island, South Deer Island (Galveston), and Lavaca Bay Spoils E (Matagorda Bay), each with more than 10,000 nests in 2021. Chester Island (Matagorda Bay) fell just short of 10,000 nests, and another 21 colonies had more than 1000 nests. Most of the region's Reddish Egrets nested in Texas, with white morphs outnumbering dark morphs in the Laguna Madre GeoRegions. At White Pelican Island (Upper Laguna Madre), the only American White Pelican (*Pelecanus erythrorhynchos*) colony in the nGOM, 725 nests were counted in 2021, a sum of May and June counts of distinct groups.

In Louisiana, in addition to the largest overall colonies described above (Figures 4–7), several other colonies or regions were important for individual species. For example, the largest colony of White Ibis (range: 1855 nests in 2011 to 9843 nests in 2021) was in Atchafalaya Bay every year, though the island where the colony was found changed over time. The largest Black Skimmer colonies were typically on newly constructed dredge spoil islands in the Birdsfoot GeoRegions.

In Mississippi, the largest colony was at Ship Island (Mississippi Sound Gulf Islands) in 2021, following its restoration. At New Round Island (Mississippi Sound), few nests were documented in 2021 aerial photographs,. See Section *3.2.3 – Restored Islands and New Beneficial Use Projects* for further details about both colonies.

In Alabama, aside from Gaillard Island (Figures 4 and 5), Marsh Island became a large colony by 2021 after it was restored by 2018, while Cat Island nesting declined as the island shrank and vegetative cover decreased over time. Both colonies are in the Mississippi Sound GeoRegion.

In Florida, Saint George Causeway (Apalachicola East) was the largest colony in all years, although it was not surveyed in 2011. Brown Pelicans were first documented nesting there in 2013. By 2021, the pelican colony size had doubled to 1076 nests.

3.1.3 Annual Variation

Annual variation in nest totals was evident at individual colonies (Figure 5) as well as for individual species at those colonies and regionwide. In Louisiana for example, Brown Pelican (> 38,500 nests) and Tricolored Heron (> 11,500 nests) had clear peaks in statewide nest totals in 2018. Laughing Gull and Sandwich Tern nest totals were at similar peak levels in Louisiana in both 2011 and 2018 (Appendix A; Avian Data Monitoring Portal, https://arcg.is/09LCra).

Annual variation in average timing of breeding was also noted for Brown Pelican, given the consistent use of chick nest categories for that species (Appendix A). At five major Brown Pelican colonies in Louisiana, the percentage of nests with visible chicks was much higher in 2018 than in 2015 and 2021. Most of these colony counts were determined from May photographs, but in 2021 three of the five were determined from June photographs. These data indicate that nesting peaked earlier in 2018. Similarly, at Gaillard Island in Alabama, timing of breeding was on average later in 2021, with just 4% of nests with visible chicks in June, compared with 20% in May 2015 (see 2.4 Nest and Bird Enumeration (Dotting) and Appendix A).

3.2 Habitat Loss

3.2.1 Natural Islands

Habitat and land loss at CWB breeding colonies that was documented during the 2010–2013 period (Colibri and Ford 2015) and was most conspicuous among islands located within Louisiana's vast offshore marshes. All five colonies in Barataria Bay, Louisiana, for which land loss was previously quantified, have since been submerged (identified with an "S_" prefix to their ColonyID in the Microsoft Access® database (https://arcg.is/09LCra), as have another seven Barataria Bay islands that supported waterbird colonies (Table 2). Among these 12 submerged islands, seven had a maximum combined count of 2597 Brown Pelican nests in 2012. Similarly, a maximum combined count of 825 Tricolored Heron nests was documented among six of the islands in 2011. Colonies with nesting Brown Pelicans and Tricolored Herons were all in the vicinity of Cat Bay and Bay Ronquille, within Barataria Bay. For Roseate Spoonbill, 102 nests were counted at Cat Bay Island in 2010, but only one nest was counted at Cat Bay Island North in 2013, and no nests were counted thereafter among these Barataria Bay islands. Four of the 12 islands, three in western Barataria Bay and Manilla Island in north Barataria Bay, had habitat for Forster's Tern.

Table 2. Submerged breeding colonies in Barataria Bay and Terrebonne Bay, Louisiana, 2010–2021.

GeoRegion	Colony Name	Max Nest Count (Year)	Primary Species[1]	Submerged By[2]
Barataria Bay	Barataria Bay 7	160 (2011)	FOTE, LAGU	2019; tidally inundated by 2015
	Barataria Bay 6	194 (2011)	FOTE	2019; present through 2016
	Barataria Bay 5 AB	503 (2018)	FOTE	2019
	Manilla Island	650 (2012)	FOTE	2021
	Grand Island Point	1543 (2011)	ROYT, LAGU, TRHE, BRPE	2016
	Bay Ronquille NE I.	683 (2011)	LAGU, BRPE, TRHE	2015
	Bay Ronquille NW I.	2406 (2011)	LAGU, TRHE, BRPE, BCNH	2018
	Cat Bay North Island	1673 (2011)	BRPE, LAGU, ROYT	2018
	Cat Bay Island	1922 (2010)	BRPE, GREG, ROSP	2018
	Cat Bay South Island	6072 (2012)	ROYT, LAGU, SATE, BRPE	2018
	Barataria Bay 13	207 (2013)	FOTE, TRHE	2018; present through 2016
	Barataria Bay 3	131 (2012)	BRPE, ROSP	2016; tidally inundated by 2015
Terrebonne Bay	Raccoon Island West	1819 (2011)	BLSK	2019
	Wine Island	8678 (2010)	ROYT, SATE, BLSK	2021
	Little Bird Island[3]	2 (2013)	AMOY	2019; tidally inundated by 2015
	Terrebonne Bay 8[3]	1289 (2013)	SATE, ROYT	2019; tidally inundated by 2015
	Terrebonne Bay 1[3]	8656 (2013)	SATE, ROYT, LAGU, BRPE	2019; present through 2015
	Pelican Island	847 (2011)	BRPE	2018; tidally inundated by 2015

[1]Species Codes: FOTE = Forster's Tern; LAGU = Laughing Gull; ROYT = Royal Tern; TRHE = Tricolored Heron; BRPE = Brown Pelican; BCNH = Black-crowned Night-Heron (*Nycticorax nycticorax*); GREG = Great Egret; ROSP = Roseate Spoonbill; BLSK = Black Skimmer; SATE = Sandwich Tern; AMOY = American Oystercatcher. [2]As determined from surveys and inspection of available satellite imagery (Google 2022); present indicates that land was still visible above water in satellite imagery. [3]Little Bird Island, Terrebonne Bay 8, and Terrebonne Bay 1 were not surveyed in 2010–2012.

In Terrebonne Bay, Louisiana, six islands, including Pelican Island and Wine Island (Table 2, Figures 8 and 9), are now submerged, and another, Felicity Island, is greatly reduced in size (Figure 10). Among the six submerged islands, three had a maximum combined count of 994 Brown Pelican nests in 2011, and two had a maximum combined count of 8674 tern nests in 2013. Felicity Island had much higher species richness than the other six islands, with 17 species documented nesting on the island during the 2010–2021 period. Annual declines in nest totals at Felicity Island correlate with a gradual land loss by submersion starting around 2012. The highest combined nest totals of all breeding species on Felicity Island were > 20,000 nests in 2012 and 2013 (Figures 4 and 5), when the highest counts of Brown Pelicans (2620 nests in 2012) and Royal and Sandwich Terns (8497 nests in 2013) occurred. As habitat was lost at Felicity Island, nesting birds appeared to have moved to Philo Brice Islands by 2018, which also has shrunk substantially since 2010. Philo Brice Islands, about 12 km southeast of Felicity Island, was not an active colony during the 2010–2015 period. In 2018, more than 10,000 nests were counted, representing 14 CWB species.

In the Breton-Chandeleur Islands GeoRegion, mangrove habitat at New Harbor Island 1 and 2 largely disappeared, with pelican nesting shifting to New Harbor Island 3. By 2021, New Harbor Island 1 was reduced to mostly sand with little vegetation and New Harbor Island 2 consisted of just a small mangrove patch nearly submerged. Curlew Island, which hosted an estimated 5200 Brown Pelican nests in 1999 before being submerged by 2004 (Selman et al. 2016), re-emerged and was used by nesting skimmers and terns in 2015, 2018, and 2021.

In the Biloxi North and South GeoRegions, at least 10 islands have been submerged. Colony sizes were smaller than in Barataria Bay and Terrebonne Bay, and species composition differed. Primary nesting species at Biloxi Marsh submerged colonies were Laughing Gull, Forster's Tern, Caspian Tern, Gull-billed Tern, and Black Skimmer.

Other Biloxi Marsh colonies were not yet submerged by 2021 but had experienced dramatic habitat and land loss. At Martin Island, nesting Brown Pelicans had been documented by Louisiana Department of Wildlife and Fisheries in most years from 1998 to 2008 but not in 2009 and 2010 (Selman et al. 2016). In June 2010, 155 Brown Pelican nests were documented from aerial photographic surveys (Appendix A). After 2010, however, Forster's Tern, Laughing Gull, and Black Skimmer were the only breeding CWB species on the island. The island was reduced to a sandbar without vegetation by 2021, when no CWB species nested. Similarly, several wading bird species had nested at Biloxi South 11, as had Brown Pelican in 2012 and 2013, but no nests of any CWB species were documented in 2018 and 2021. Land loss was also conspicuous at Hell Pass Coast in Biloxi North, where the colony group fragmented from three islands in 2010 into five islands over time, one of which was mostly submerged in June 2021.

Outside of Louisiana, similar trends in nesting habitat loss were noted at Cat Island in Alabama. Due to land and vegetation loss, only terns and skimmers were observed nesting there by 2021.

3.2.2 Dredge Spoil Islands

In Texas, most colonies occurred on dredge spoil islands. However, with variable survey coverage only in 2010 and 2021, changes at those islands were not readily evident.

In Louisiana, existing and newly created dredge spoil islands in Vermillion Bay and the Birdsfoot GeoRegions that provided nesting habitat for terns and skimmers became increasingly vegetated over time, leading to reduced nesting and eventual colony abandonment (Appendix A).

In Alabama, habitat loss was not noted at Gaillard Island. The dredge spoil island was created in 1981 and has been a regular site for deposition of spoils from dredging of the Theodore Ship Channel (Landin 1987, USACE 2021).

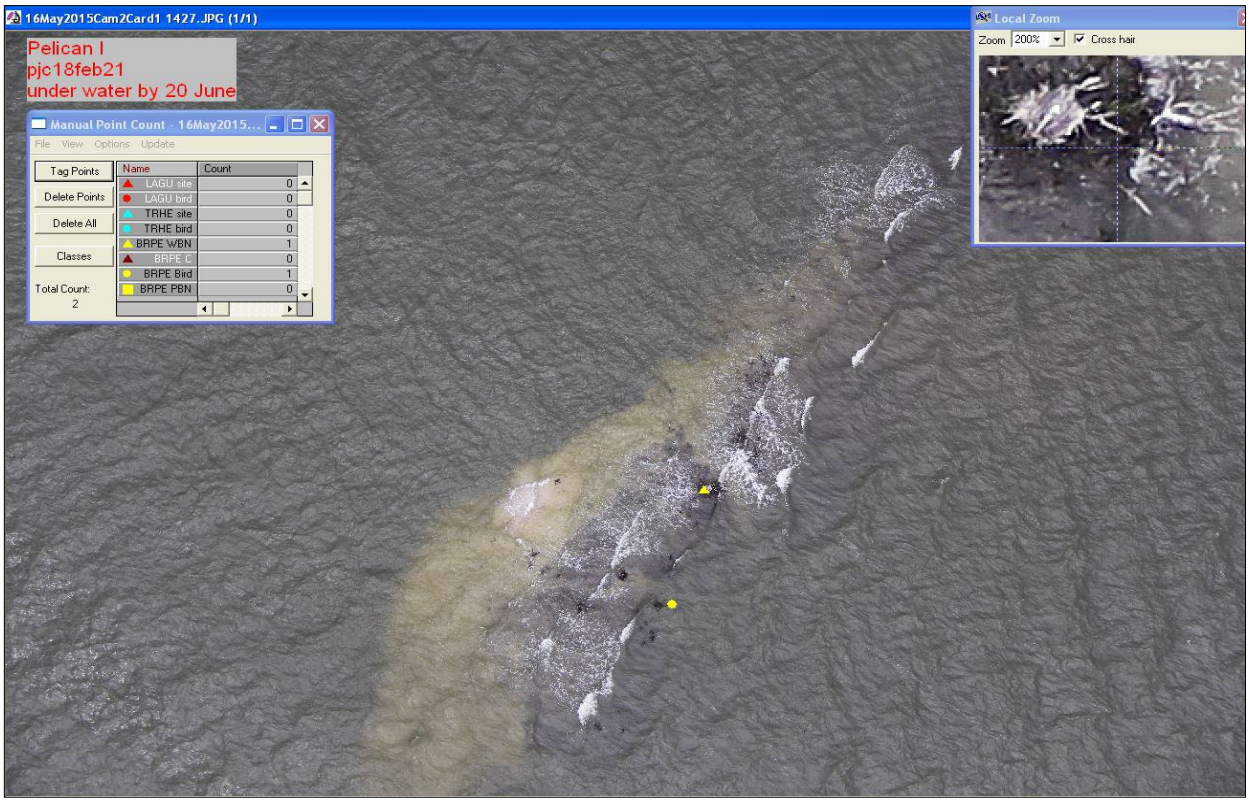

Figure 8. Screen capture of a single Brown Pelican nest at tidally inundated Pelican Island in Terrebonne Bay, Louisiana, May 2015.

Figure 9. Remnants of Wine Island in Terrebonne Bay, Louisiana, June 2018.

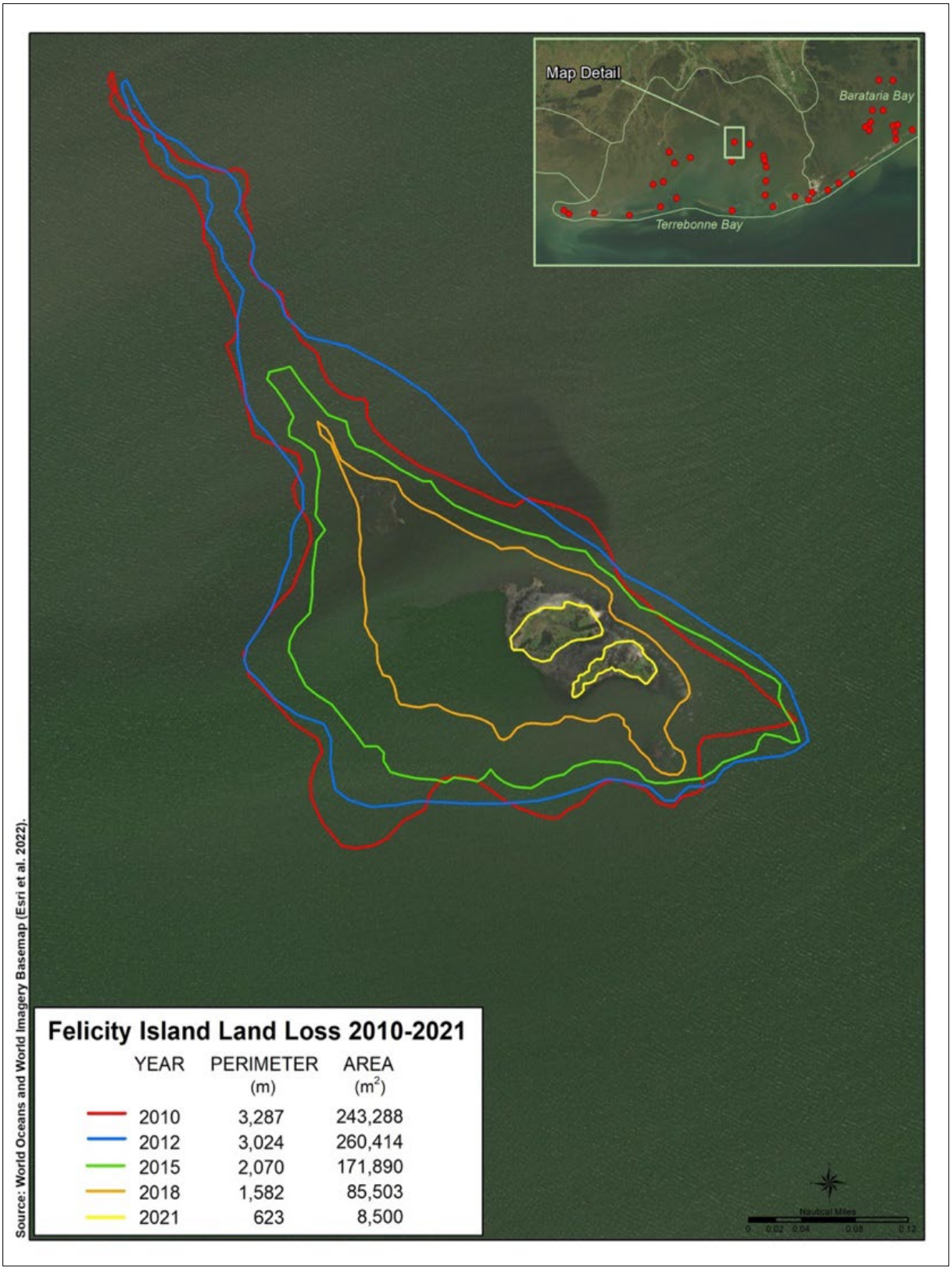

Figure 10. Land loss at Felicity Island in Terrebonne Bay, Louisiana, 2010–2021. Google Earth imagery was used for shoreline delineation, but tidal heights for each image are unknown.

3.2.3 Restored Islands and New Beneficial Use Projects

Since 2015, broad-scale restoration and beneficial use projects resulted in conspicuous changes in waterbird distribution and abundance over time at several colonies. Aerial photographic survey data for selected colonies in Louisiana, Mississippi, and Alabama are discussed below (Table 3). In Texas, because surveys were conducted only in 2010 and 2021, with a more limited survey area in 2010, it was not possible to readily detect which islands had been recently restored or assess changes in bird distribution and abundance.

Table 3. Approximate timing of restoration or creation (shaded cells) of selected islands and aerial photographic surveys (airplane symbol). Years are divided into thirds.

State	Colony Name	2015			2016			2017			2018			2019			2020			2021		
Louisiana	Rabbit Island		✈									✈									✈	
	Whiskey Island		✈									✈									✈	
	Queen Bess Island		✈									✈									✈	
	Shell Island East		✈									✈									✈	
	Gunn Island		✈									✈									✈	
	Breton Island		✈									✈									✈	
Mississippi	Ship Island		✈																		✈	
	New Round Island		✈																		✈	
Alabama	Marsh Island		✈																		✈	

Rabbit Island

From 1955 to 2020, Rabbit Island, Louisiana's westernmost Brown Pelican breeding colony, lost roughly 35% of its 200-acre footprint due to a host of environmental and anthropogenic factors. Restoration took place from September 2020 to April 2021. Dredged sediment from the Calcasieu Ship Channel was used to restore island elevation, and native vegetation was planted throughout the project footprint (165 acres; NOAA 2021). CWB species and nests were documented by aerial photographic surveys in 2010, 2018, and 2021.

The total number of nests at Rabbit Island was 27% lower in 2021 than in 2018 (Figure 5). The timing of nest initiation occurred later than in 2018 also. For example, colony counts in 2021 were derived from June survey photographs, and no Brown Pelican nests had visible chicks, whereas 9% of nests had visible chicks in May 2018. Collectively, it appears that ongoing restoration activities which concluded in April 2021, several weeks into the typical nesting season, contributed to these observations.

For 2018 and 2021, Rabbit Island counts were categorized by subcolony. Subcolonies in 2018 were named Southeast Quadrant, Northeast Shore, East Central Shore, and South Shore. In 2021, they were named Interior Marsh, Northeast Restored area, South Marsh, and Western Restored Area. The east-west channel through the island was used as a border. These data can be queried

from the Microsoft Access® database located within the Avian Data Monitoring Portal (https://arcg.is/09LCra). The most notable change observed was that Brown Pelican nesting shifted from the Southeast Quadrant in 2018 to the Northeast Restored Area in 2021.

Though not present in either 2010 or 2018, Black Skimmer, Caspian Tern, Royal Tern, and Sandwich Tern all nested in 2021. Additionally, Forster's Tern nest numbers were nearly four times higher in 2021 than in 2018.

Among wading birds, six species nested at Rabbit Island in 2021 (Tricolored Heron, Snowy Egret, Great Egret, Black-crowned Night Heron, Reddish Egret, and Roseate Spoonbill). Great Blue Heron and White Ibis had nested in previous years but were absent in 2021. Rabbit Island remained the largest Tricolored Heron colony regionwide (1840 nests).

For more information, see Rabbit Island Restoration Project.

Whiskey Island

Restoration of Whiskey Island, also known as the Caillou Lake Headlands Barrier Island Restoration, began in October 2016 and was completed 25 April 2018, followed by sand fencing installation and vegetation planting in subsequent years. Beach, dune, and back-barrier marsh habitats were restored. From 2010–2021 aerial photographic surveys, CWB nesting was detected only in 2018, just a month following completion of construction. Breeding Black Skimmers (780 nests) and Gull-billed Terns (100 nests) were counted from photographs from the 21 May survey. Far fewer birds were present in June, though the photographs were not analyzed to determine nest counts. In earlier years, Whiskey Island may not have been completely inspected in both months (see the Black Skimmer species account in Appendix A).

For more information, see Louisiana Outer Coast Restoration Project.

Queen Bess Island

Prior to restoration, Queen Bess Island had approximately 5 acres of nesting habitat available but still supported one of Louisiana's most productive Brown Pelican colonies. Island restoration was initiated in the summer of 2019 and completed in February 2020, creating 30 acres of Brown Pelican habitat and 7 acres of habitat for tern species and Black Skimmers (CPRA 2020). For 2015, 2018, and 2021, all Queen Bess Island counts were categorized by subcolony. Subcolonies included Cells 1, 2, and 3, as well as a separate subcolony for count areas along the levee separating Cell 1 from Cell 2. These data can be queried from the Access database at the Avian Data Monitoring Portal (https://arcg.is/09LCra).

In 2021, nearly all of the 3425 Brown Pelican nests counted were in Cell 1 and along the levee separating Cell 1 from Cell 2. No nests were in Cell 3. The 2021 nest total was 50% lower than the 2018 total (6830 nests), which was the highest among all years. Just 3% of nests had visible chicks in May 2021, compared with 64% of nests in May 2018 (Appendix A). Brown Pelicans also

nested at Mendicant Island, 1 km west of Queen Bess Island, in 2021, the only year nesting was documented there. A total of 373 nests were counted, along with twice as many empty nests.

In 2021, Royal and Sandwich Tern appeared to benefit from the restoration. Both species were abundant on Queen Bess Island in 2011 (3421 and 1202 nests, respectively), declined in 2012 and 2013, and did not nest in 2015. Just 20 Royal Tern nests were counted in 2018. In 2021 both species were abundant again, with 2743 Royal Tern nests and 3653 Sandwich Tern nests counted.

Conversely, while at least five wading bird species nested at Queen Bess Island in all previous survey years, only Great Egrets nested in 2021. The most conspicuous change was for Tricolored Heron, which had counts ranging from 421 to 1136 nests during the 2010–2018 period before being absent in 2021.

For more information, see Queen Bess Island Restoration Project.

Shell Island East

Restoration of Shell Island East in Louisiana took place in three stages over multiple years. In 2010, an emergency berm was constructed in response to the Spill. This activity created an approximately 1.5-mile stretch of sandy beach with little vegetation. In 2013, the berm width was expanded with dredged sediment. From 2016 to 2017, an additional 2.7 miles of sediment was added. In total, these projects restored 1031 acres of beach, dune, and marsh habitat (Thompson 2018).

In 2011, when Shell Island East was in the berm stage, skimmers and terns nested in large numbers, with a total combined count of 10,825 nests. Sandwich Tern was the most abundant species (6330 nests), followed by Royal Tern (2516 nests), Black Skimmer (1703 nests), Gull-billed Tern; 178 nests), and Caspian Tern (98 nests). After further restoration, fewer than 10 skimmer and tern nests were documented on Shell Island East in May 2015, with no nests documented in June 2015. No nests were documented in 2018 and 2021.

For more information, see Louisiana Outer Coast Restoration Project.

Gunn Island

Gunn Island, a dredge spoil island in the Birdsfoot East GeoRegion of Louisiana, approximately 14.3 kilometers southwest of North Breton Island (see below), was newly constructed as a beneficial use project in 2016 by the U.S. Army Corps of Engineers (USACE; New Orleans District). Additional dredged sediment from the Mississippi River was deposited from 2018 to 2020 to raise the height of the island. USACE documented nesting terns and skimmers attending chicks in early August 2020, suspecting they had renested at Gunn Island after a tropical storm overwashed nests at North Breton Island (McCormack 2020). However, nesting was first documented on Gunn Island from 24 June 2018 aerial photographs, with a combined total of 13,444 nests among six species; Royal and Sandwich Tern accounted for 97% of nests. Whether nesting occurred at

Gunn Island in 2016 and 2017 is unknown, but the island was still under construction in June 2016. Nest numbers at Gunn Island had nearly tripled by 2021 (Figure 7), with a combined total of 37,001 nests among eight species. The Royal Tern (16,646 nests), Gull-billed Tern (1378 nests), and Caspian Tern (627 nests) colony sizes at Gunn Island in 2021 were the largest recorded for those species across the Study Area and all years. Furthermore, for 2021 alone, the Sandwich Tern and Black Skimmer colony sizes (16,505 and 1923 nests, respectively) were the largest regionwide.

For more information, see Gunn Island Success Story.

North Breton Island

Work to restore North Breton Island in Louisiana began in December 2020, with the goal of creating and enhancing 400 acres of bird nesting habitat. Sand was first placed on the island's north end, adjacent to existing mangroves, which is the principal nesting habitat for Brown Pelicans on the island. When nesting began in 2021, restoration work moved to the southern portion of the island in an attempt to limit disturbance (USDOI 2021). Construction equipment was still present on the island during 2021 surveys.

The lack of Royal and Sandwich Tern nesting was the most conspicuous change at North Breton Island in 2021. For the two species combined, more than 15,000 nests were counted in all previous survey years. The 2021 observations at North Breton may have been related to expected disturbance associated with ongoing habitat restoration activities, but movement of terns from North Breton to Gunn Island was suspected the previous year due to overwash from a tropical storm during the breeding season (McCormack 2020). A small colony of Black Skimmers and Gull-billed Terns did eventually form by June 2021 at North Breton Island. Nesting by Royal and Sandwich Terns at North Breton Island resumed in 2022 and increased substantially in 2023 (beyond the scope of this report).

Brown Pelican and Laughing Gull breeding populations were relatively high at North Breton Island in 2021 (more than 4000 nests for both species), though perhaps with slightly later timing of nest initiation on average than in previous years. Nest counts were determined entirely from June photographs in 2021 versus primarily May photographs in all previous years except 2010; some new nesting was also counted from June photographs in certain years. While 43% of Brown Pelican nests had visible chicks in 2021, 15 poorly built nests were counted, along with another 133 territories, indicating some egg laying likely occurred after the June survey.

For more information, see Louisiana Outer Coast Restoration Project.

Ship Island

Restoration of Ship Island in Mississippi, completed in late 2020, included the addition of sediment to connect Ship Island East and West and to raise the island to approximately 5 feet

above sea level, as well as dune vegetative planting (USACE 2020). During the 2010–2015 period, only small numbers of nesting Black Skimmers and Gull-billed Terns were documented at either the East or West islands, with a high count of 272 skimmer nests in 2015. Changes in CWB distribution and abundance in 2021 following restoration were clear. All nesting occurred on restored areas within the island's center, with a combined total of 1725 nests. The number of Black Skimmer nests (513) was nearly twice as high as in 2015, with the nests distributed in a long, linear colony in the restored area. Gull-billed Terns (51 nests) were also more abundant than in earlier years. The other conspicuous change was the presence of nesting Royal Terns (245 nests), Sandwich Terns (908 nests), and Least Terns (8 nests), none of which were detected nesting at Ship Island previously (see Appendix A for comparisons with ground-based surveys, which also detected nesting Common Terns).

New Round Island

At New Round Island in Mississippi, island construction was completed in February 2017. Only 65 Least Tern nests and 50 Black Skimmer nests were counted from 15 June 2021 aerial photographs, and the island was not inspected during 2015 aerial surveys. Ground-based surveys did, however, document greater diversity and abundance of beach-nesting birds in 2017 and 2018, including large Royal and Sandwich Tern colonies. In 2021, however, ground-based surveys detected only nesting Least Terns and Black Skimmers, consistent with aerial surveys. Two breeding shorebird species, American Oystercatcher and Wilson's Plover, were also detected from ground-based surveys (Gamblin et al. 2022). See Appendix A for comparison of aerial photographic and ground counts of Least Terns.

For more information, see DWH Regionwide TIG Final Restoration Plan/Environmental Assessment 1.

Marsh Island

Construction on Marsh Island in Alabama began in March 2016 and ended in December 2017. The project restored 50 acres of salt marsh through the placement of sediments and breakwaters, as well as the planting of native marsh vegetation (NOAA 2012). No nesting was documented at Marsh Island during surveys from 2010 to 2015, but waterbird breeding colonies were evident on Marsh Island in 2021.

Laughing Gull (2229 nests) was the most abundant species in 2021, followed by Royal Tern (1227 nests). Only small numbers of Sandwich Terns nested with the Royal Terns. Four wading bird species nested at Marsh Island (Great Egret, White Ibis, Cattle Egret, and Tricolored Heron), with White Ibis being the most abundant (404 nests). On the 24 May 2021 survey date, small proportions of the White Ibis and Great Egret nests had visible chicks. Wader nesting at Marsh Island likely reflected movements of birds from nearby Cat Island where land and vegetation loss had occurred over time. In 2021, only skimmers and terns nested at Cat Island.
For more information, see Marsh Island Restoration Project.

4.0 Discussion

During the 2010–2021 period, Laughing Gull, Sandwich Tern, Royal Tern, and Brown Pelican were consistently the most abundant breeding waterbirds documented along the nGOM, with their rank varying among years. Their habit of nesting in large aggregations on the surface of islands or on low vegetation with little concealment makes aerial photography ideally suited for estimating their breeding population sizes. Similarly, along the Pacific Coast, the U.S. Fish and Wildlife Service has identified aerial photographic surveys as the preferred method for monitoring breeding populations of two other surface-nesting seabirds, Common Murre (*Uria aalge*) and Brandt's Cormorant (*Urile penicillatus*; Bridgeland et al. 2018). For wading birds, aerial photographic surveys were also effective for estimating colony sizes at most locations regionwide. However, trees and tall shrubs at some locations can conceal some nests. Only one study with ground counts of breeding pairs of wading birds was available for a rough comparison with aerial photographic counts. Wading birds were counted at Raccoon Island, Louisiana, in late June in 2010 (Raynor et al. 2013). Aerial photographic counts of nests from 17 May were much higher for Great Egret, Tricolored Heron, and Roseate Spoonbill, whereas late June ground counts detected more nests of the less abundant Snowy Egret (30 nests), Reddish Egret (5 nests), and Black-crowned Night-Heron (15 nests). However, June aerial photographic surveys of Raccoon Island were not conducted in 2010.

Conducting surveys in both May and June (rather than in just one of the months) continues to be necessary for determining best estimates of breeding population sizes. During the 2015–2021 period, the percentage of colony nest totals for individual species that were determined from May photographs ranged from 41% in 2021 (regionwide) to 67% in 2018 in (Louisiana only). Furthermore, for the entire 2010–2021 period, 187 colony nest totals for individual species were sums of May and June counts, to account for new breeding groups in June or early breeders in May.

Annual variation in nest totals, such as the peaks observed in Louisiana in 2018 for Brown Pelican and Tricolored Heron, may be influenced by several factors. The proportion of the adult population of a species that breeds annually can vary. Some female Brown Pelicans, for example, may skip breeding in some years (Wilkinson and Jodice 2022). Skipping breeding is well described for Brandt's Cormorant and can lead to "boom or bust" breeding seasons depending on prey availability (Ainley et al. 2018). The degree of recruitment of first-time breeders can also vary depending on breeding success in previous years and survival rates until birds reach breeding age. Weather events that cause overwash and nest failures may also contribute to annual variation in nest counts from aerial photographs.

Aerial photographic surveys have been shown to be highly effective throughout the nGOM for estimating CWB breeding population sizes (Colibri and Ford 2015, Remsen et al. 2019). They are also effective in documenting CWB responses (e.g., presence/absence, habitat utilization over

time) to island restoration, as well as informing and monitoring adaptive management need and performance (e.g., Ainley et al. 2018), so much so that the State of Louisiana has memorialized aerial photographic surveys within its DWH Colonial Waterbird MAM plans.

Observations made during this activity indicated that addressing potential uncertainties such as nest detection probability for selected species may prove beneficial in assisting Trustees with future bird abundance estimates and related statistical analyses. For example, in a 1990s study of aerial photographic data in California, detection probabilities of Brandt's Cormorant nests and birds was near 100%, but detection probabilities for Common Murres was closer to 90% given that they nest shoulder-to-shoulder in great densities (Steinkamp et al. 2005). For Brown Pelicans and Royal and Sandwich Terns at most colonies in the nGOM, detection probabilities can reasonably be expected to be similar to those for Brandt's Cormorants, given the large size of pelicans and given the open habitats that pelicans and terns occupy. Among tern species, Royal and Sandwich Tern nest in the highest densities, but detection of nests and birds in aerial photographs is straightforward, as the terns do not nest shoulder-to-shoulder as Common Murres do. For other species, detection probabilities may be lower due to nest concealment by even low-lying vegetation (Laughing Gulls) or shrubs and trees (wading birds), and degree of vegetation cover may vary among colonies. Species Accounts in Appendix A provide qualitative descriptions of the detectability of nests and birds in aerial photographs. Nonetheless, nest totals determined from May and June aerial photographic surveys for some seabird and wading bird species in the nGOM, especially the most abundant ones identified in this report, are generally higher, more accurate, and more repeatable than counts conducted from ground or boat vantages or from aerial visual estimates (Colibri and Ford 2015, Remsen et al. 2019).

5.0 Acknowledgments

Funding for 2015 image analyses, 2021 surveys and image analyses, and report preparation was provided by the *Deepwater Horizon* Regionwide Trustee Implementation Group, via the Louisiana Coastal Protection and Restoration Authority, and subsequently The Water Institute (Baton Rouge, Louisiana). Jon Wiebe (Louisiana Department of Wildlife and Fisheries) and the U.S. Fish and Wildlife Service Gulf Restoration Office provided careful reviews of this report. Technical assistance and report review was also provided by several staff of The Water Institute, especially Tim Carruthers, Jessica Henkel, and Eva Windhoffer. The Water Institute developed the online Avian Data Monitoring Portal. Several other staff of Colibri Ecological Consulting, LLC, and R. G. Ford Consulting provided key efforts for data collection and management for the 2010–2013 period and for 2018. Additional staff who conducted image analyses were Sarah Luecke Flaherty, Peter Gaede, Deborah Jaques, Kriss Neumann, and Jenny Phillips. Natalie Strom and Kether Hayden provided data management assistance. Aerial photographic surveys were conducted with pilots from Aspen Helicopters, Inc. (Oxnard, California), with coordination assistance from Brad Busch.

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