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The National Audubon Society | Audubon Texas
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Abstract

Texas colonial waterbirds depend heavily on coastal dredge spoil islands for nesting, many of which have not been replenished with material for years. This research aimed to provide a scientific basis for coastal managers to plan and implement more strategic island management activities and use restoration dollars more effectively. This analysis examined erosion rates of 186 rookery islands (grouped into 61 units) located within 2500 meters of the Gulf Intracoastal Waterway (GIWW) along 10 coastal Texas counties from 2004-2014. Islands were ranked by risk of becoming unusable by waterbirds within 5, 10, 25 and 50 years. The results of this predictive statistical analysis were then compared to historical colonial waterbird data and ground-truthed to test for accuracy. Islands of high conservation-priority were identified using the island risk ranking and bird population densities of seven waterbird species common to the area of study. The study found **NUM islands at risk of disappearing entirely within 5 years, putting NUM birds/species at risk of decline.**

Keywords

GIS, rookery islands, Texas, coast, colonial waterbirds, predictive statistics, erosion, Gulf Intracoastal Waterway, Gulf of Mexico, sea-level rise, ship traffic, shoreline change

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Background

The coastal islands of Texas provide critical habitat for over 26 species of colonial waterbirds and a variety of other coastal flora and fauna. Colonial waterbirds specifically seek out these islands as "rookeries," places to nest and raise their chicks in large groups and find protection from predators and human disturbance. Prior to the Gulf Intracoastal Waterway (GIWW) dredging projects of the early 1900s, birds were dependent on natural islands for nesting. When the GIWW was completed in the mid-20th century, dredged material heaped along its sides formed new "islands" that became replacement rookery sites. However, these GIWW dredge spoil islands also began eroding as a result of limited natural processes encouraging natural beach building and accretion. Today, few natural islands remain due to changes in hydrology and erosion rates and those artificial islands that remain are experiencing higher erosion rates due to large ship wakes, altered shorelines, disrupted hydrology, and overall sea-level rise.

Methods

This study ranked 186 Texas islands within a 2500-meter buffer around the GIWW centerline from highest to lowest risk of being unusable by waterbirds within a 5, 10, 25 and 50-year time span using variables including elevation, sea-level rise, distance to open water, habitat type and ship traffic in an effort to aid in future coastal restoration planning. The Texas Colonial Waterbird Society (TCWS) has been surveying rookery islands in Texas since 1973 using rookery identification numbers based on a latitude/longitude grid system. This analysis followed these TCWS grid blocks, combining sites into the 600 (Galveston Bay), 609, 610, 614 and 618 ID groups. Previously Audubon sought to perform these analyses by bay system; however, low sample sizes per bay required the use of larger groups. The Sabine Lake area was not included in the predictive analysis due to the absence of rookery sites within the 2500m buffer of the GIWW centerline. Data were gathered for analysis from National Agriculture Imagery Program (NAIP) Orthophoto rasters (years 2004, 2008, 2014) and from LiDAR generated shoreline, Digital Elevation Model (DEM) and canopy height rasters (years 2009, 2013-2015). The project examined data spanning from 2004 to 2014.

1) LiDAR Analysis

Light Detection and Ranging (LiDAR) is a remote sensing tool that detects characteristics of the Earth's surface. The intent of the LiDAR analysis was to obtain and create raster files from LiDAR to establish high accuracy shoreline, elevation and vegetation/canopy cover data. The 2009 US Army Corps of Engineers (USACE) Joint Airborne LiDAR Bathymetry Technical Center for Expertise (JALBTCX) Topographic LiDAR: Post Hurricane Gustav and Post Hurricane Ike dataset was used for historical comparison. Recent LiDAR was provided partially from a Texas General Land Office (GLO) Oil Spill Prevention & Response Program funded project through the University of Texas Bureau of Economic Geology flown from 2014-2015. A few upper coast island sites were overlooked by this project. Audubon contracted to McKim and Creed Inc. to fly five of these missing locations. It was decided to reanalyze the area lost on each island once additional LiDAR data was added in.

2) NAIP Orthophoto Analysis

Due to limited historic LiDAR availability, it was decided to use past National Agriculture Imagery Program (NAIP) orthophotos to gather information on island area and habitat types to include additional years of data. NAIP photos were run through an Iso Cluster Unsupervised Classification in ArcMap 10.3.1. This analysis forms unsupervised classification on a series of input raster bands using the Iso Cluster and Maximum Likelihood Classification tools. The NAIP photos were reclassified in this way into 6 habitat categories. These categories were then examined one TCWS ID group area at a time to assign these 6 categories into vegetation, open ground or other habitat types. NAIP files did not provide enough consistent detail to divide vegetation cover into more distinct classes like marsh, grass or shrub.

3) Shoreline Change Analysis

A shoreline change GIS tool was used to run computations on island boundary changes over time. The Digital Shoreline Analysis System (DSAS) version 4.3.4730 for ArcGIS 10 was developed and is maintained by the U.S. Geological Survey. The Digital Shoreline Analysis

System is computer software that computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS.

A total of 61 TCWS ID island groups were examined in the DSAS analysis using shorelines from 2004, 2006, 2008 and 2014. A baseline measuring polygon was created by making a 30m buffer around the 2004 shoreline file to which all years were compared. DSAS created transects every 10 m along this baseline and transects were 60 m long. Shorelines were programmed to the farthest intersection instructing DSAS to use the last transect/shoreline measurement location when calculating change statistics. A linear regression rate-of-change statistic was determined by fitting a least-squares regression line to all shoreline points for a particular transect (see Table 3). The following statistics were used to examine island changes over time:

- Net Shoreline Movement (NSM)- Reports the distance between the oldest and youngest shorelines for each transect.
- End Point Rate (EPR)- Calculated by dividing the NSM value by time elapsed between the oldest and youngest shoreline.
- Linear Regression Rate (LRR)- A linear regression rate of change statistic can be determined by fitting a least-squares regression line to all shoreline points for a particular transect. LRR represents the slope of the regression line and can be interpreted as the number of meters gained or lost per year. LRR is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics.
- Standard Error of the Estimate (LSE)- LSE assesses the accuracy of the best fit regression line in predicting the position of a shoreline for a given point in time.
- R-Squared Value (LR2)- Percentage of variance in the data that is explained by a regression. LR2 values closer to 1.0 indicate the best fit line explains most of the variation in the dependent variable. LR2 values closer to 0.0 suggest the best fit line explains little of the variation in the dependent value and it may not be a useful calculation.
- Least Median of Squares (LMS)- Similar to the LRR value, the LMS is determined by a process of fitting a line to the data points and calculating all possible values of slope (the rate of change) within a restricted range of angles. In ordinary linear regression, each input data point has an equal influence on the determination of the best fit regression line. The offset of each point is squared and these squares are added. In the LMS calculation, the offsets are squared and the median value is selected. This reduces the influence of shoreline points with larger offsets (outliers) on the best fit regression line. LMS can also be interpreted as the number of meters gained or lost per year, but is not influenced as heavily by extreme outlier data.

4) Ranking Island Risk using Predictive Statistics

The LMS values for each island were extrapolated into the future to estimate island areas in 5, 10, 25 and 50 years. Previously islands were ranked based on how many meters the shoreline was retreating. In order to better compare need across various sized islands this method was replaced with one that looked at percentage of area expected to be lost. Island ID units were classified as follows: Completely Gone (loss of 100%), Extremely High (loss of greater than 75%), High (loss of 50-75%), Medium (loss of 25-50%), Low (loss of 5-25%), and Minimal (loss of less than 5%) risk for loss based on the change in percentage of area predicted by the LMS value (see Tables 1 & 4). Islands were then symbolized using the same risk classification system on several maps (Figures 3-6) that highlight islands of high concern for each of the four year predictions (5, 10, 25 and 50).

5) *Ground-Truthing the Statistical Prediction*

In order to evaluate the accuracy of the island-risk predictions in comparison to the habitat type data generated from NAIP imagery, on-site surveying was done in 19 grid cells on 9 different islands along the Texas coast (see Figure 7). Several steps were involved in selecting which islands to include in the surveys. Firstly, a general area of interest (AOI) was created using a polygon that completely contained the TCWS grid cell numbers 600, 601, 609, 610, 614, and 618. These grid cells were chosen mainly because they encompass all islands included in the study. Next, the fishnet tool in ArcMap was used to draw 50-meter by 50-meter grid cells within the AOI. These cells were then spatially intersected with the islands included in the study to eliminate the grid cells where no islands existed. The grid cells that contained islands were then clipped with respect to the islands. The area of each remaining grid cell was calculated and any cell smaller than 1000 square meters was removed. A new field was added to the survey cell data set, which was then populated with random numbers generated using a Python script. A range of values was selected and resulted in a final list of grid cells to be surveyed.

Field teams visited each grid cell included in the final list and collected data on dominant vegetation and vegetation heights. Four vegetation classifications were used, including "cactus", "grass", "scrub/shrub", and "open". In some cases, visual ground-truthing from the boat was conducted in order to prevent the disturbance of many birds that were nesting on the islands earlier than had been expected.

6) *Comparison to Historical TCWS Data*

Historical tabular bird species count data collected by the TCWS in 2004, 2008 and 2014 for each of the seven species of birds included in this study (brown pelican, Forster's tern, laughing gull, roseate spoonbill, royal tern, sandwich tern and snowy egret) was averaged to find the average maximum pairs for each island polygon included in this study. The "MaxPairs" values used came with some restriction because they only reported the higher value between the number of nests and the number of pairs. They did not take into account the count of adult birds from each site, but were meant to serve as a rough count of the number of birds within each species found on each island. These average max pairs values were then used to display bird population data on a map for each species using graduated colors.

The symbolization of this bird population data is important to note because it determined what the population cutoff would be for defining “dense populations” of each species. For example, Figure 9 highlights the two species of most concern and shows that medium to max populations of Forster’s terns ranged from 20.000001 to the highest recorded “MaxPairs” per island polygon, which was 329. Figure 9 also highlights the roseate spoonbill, whose medium to max population ranged from 19.00001 to 255.67. This demonstrates how each of the seven species in the study had different population ranges, which influenced their ranking and comparison to island-risk in the phase explained below. The population values used for classifying "dense populations" for each species can be found in the far left column of Table 5 (ex: Forster's tern used >20 and roseate spoonbill used >19). Figure 9 demonstrates how two islands can be very close together yet have very different bird populations (shown as darkest purple islands nearest lightest purple islands). Bird dispersion is most-likely determined by many variables, including habitat type, island area, and many more.

The medium to max bird population data for each species was then intersected with all islands ranked as "Medium", "High", and "Extremely High" risk by the year 2019 to identify islands with both dense bird populations and island-risk rankings of Medium or higher. (No islands were ranked as "Completely Gone" within this 5-year time span, hence its exclusion from this stage of analysis.) Island Risks for the year 2019 (5-year time span) were the only predictions used in this portion of the study because islands that will be at a risk of "Medium" or above within this time span are of most concern and are the most likely to need immediate conservation efforts.

7) Data Dissemination

The island erosion risk prediction layers (for 5, 10, 25 and 50 years), historical bird population layers (for each of the seven waterbird species), and a final story map were chosen to be published online for public consumption to aid the conservation efforts of other environmental organizations in the area of the study as well as present our research to those interested in a format that is both easy to download and understand.

Results

1) LiDAR Analysis

Texas coastal LiDAR data was difficult to locate for years prior to 2014. Most LiDAR projects did not cover areas where rookery islands were located. Coverage by the 2009 and 2006 LiDAR was extremely limited in regards to rookery island locations. The 2009 files did not cover any island study sites completely and were not used in this project. The 2006 LiDAR only covered four sites, mainly in the mid-coast region. The lack of historical data highlights the need for regularly scheduled GIS data collection in our inner bay systems. Due to the lack of coast-wide coverage we were not able to do a direct comparison in shorelines generated between the 2006 and 2014-2015 data sets. However, current shorelines and vegetation coverage were generated with the newer LiDAR.

2) NAIP Orthophoto

NAIP photos for all years 2004-2014 were initially gathered and classified. Poor image quality in most of these years prevented their use in analysis. The years 2004, 2008 and 2014 produced the most accurate habitat classifications and were kept for further use. These classified rasters were converted to polygons for editing and to perform area calculations. Each island was then hand inspected, with irregular polygons removed (such as offshore polygons that were remnants of orthophoto irregularities) or edited to be as correct as possible. Lastly predominant habitat types were classified as a number 1-4 for “vegetation”, “open”, “cactus”, and “scrub/shrub”. Area for all polygons was calculated in square meters (see Table 2).

3) Shoreline Change Analysis

Figure 1 depicts the baseline that was established around every site and 60m long transects contracted every 10m. Relationships between these transect lines, the baseline, and predicted future shorelines provided data for statistical analysis in DSAS.

Figure 2 depicts a close-up of North Deer Island shoreline changes. Using the established transects, measured the distance between the oldest shoreline (2004) and the most recent (2014). Shoreline change is illustrated along the transect lines. Outward transects indicate growth/ accretion while transects pointed towards the interior of the island (downward in figure) indicate loss/erosion.

The results of the DSAS Analysis are shown in Table 3. All transect values for an island were averaged to represent the average rates for each TCWS identified site. The analysis was unable to return results on five sites due to insufficient data inputs. Most of these areas lacked coverage in NAIP orthophotos and multiple years of data could not be gathered.

4) Ranking Island Risk using Predictive Statistics

The final erosion risk predictions are displayed visually in Figures 3-6. One map was made for each of the prediction years (2019, 2024, 2039, and 2065). Pie charts are included in each of the maps to show the total percentage of islands within each risk category for that year. For example, in the 2024 prediction, over half of this islands are ranked as "Medium" risk, and by 2039, almost half are ranked as "High" risk, leaving only a fraction (less than one fourth) of total islands ranked as "Low" or "Minimal".

Table 4 depicts the final island erosion risk levels for each of 60 TCWS ID groups of islands (i.e. “sites”). As shown by this table, by 2019, one site (614121) is at an Extremely High risk of loss mainly due to a small initial area. During this prediction period, two sites are categorized as High risk, 13 as Medium, 30 as Low and 14 as Minimal. By 2024, six sites are predicted to be at Extremely High risk of loss, five at High risk, 20 at Medium, 19 at Low and 10 at Minimal. By 2039, six sites are predicted to be ranked as Completely Gone, 10 as Extremely High, 14 as High, 13 as Medium, 12 as Low, and five as Minimal risk of erosion. Lastly, by 2064, it is predicted that 15 sites will be Completely Gone, 13 are ranked as Extremely High risk, 12 as High, nine as Medium, eight as Low, and three as Minimal risk of erosion.

5) Ground-Truthing the Statistical Prediction

The results of the ground-truthing proved that the majority of the risk predictions were reasonable. Those sites that revealed high-variance between NAIP imagery-inferred habitat types and those habitat types recorded through field surveying were appropriately improved in preparation for the comparison to the historical TCWS data.

If more thorough ground-truthing were to be completed, an approach using proportionate stratified random sampling could be used (see Figure 8 and Table 6). This sampling technique would break up the study area into blocks (or strata) based on hydrological characteristics (i.e. subwatersheds), then select a number of random grid cells from each block that is proportionate to the block's size in relation to all blocks. This would ensure that no large sections of the coast are left out of the surveying altogether, and would weight each block appropriately. This method would have been more appropriate, if more time had been allotted, because some areas that were left out of the ground-truthing may have had vastly different hydrological characteristics than those included in the surveying, and therefore would be more or less susceptible to erosion over time. Proportionate stratified random sampling would more evenly distribute sampled sites throughout all hydrologically different areas of the coast. Table 6 shows that when using this method, 2 grid cells from Strata 1 would need to be randomly selected, 3 from Strata 2, 38 from Strata 3, and 21 from Strata 4 if 20 percent of all grid cells were to be sampled (a statistically significant percentage). Grid cells were drawn using a 50-meter by 50-meter grid, then intersected with islands included in the study, and lastly any grid cells under 1,250 meters squared were eliminated (so that all final cells are at least 50% land). Regardless of this improved approach to field-surveying, the ground-truthing completed in this study offered a reasonable guide as to the accuracy of the island-risk predictions and allowed for risk prediction improvement.

6) Comparison to Historical TCWS Data

Table 5 shows High Conservation Priority Islands for seven waterbird species. The three bird species of most concern when taking into consideration predicted island erosion risks and historical bird populations are Forster's tern, roseate spoonbill and snowy egret. The former two have high populations recorded on two islands ranked as "Extremely High" risk in addition to many other islands ranked as "Medium" risk of eroding by 2019. The snowy egret is of concern because high population counts have been recorded on 13 islands ranked as "Medium" risk of eroding.

The top islands in need of consideration for conservation efforts are Causeway Island, Causeway Island Platforms, Big Bayou 1B-1L, East Flats Spoil, Three Humps 614-362F, Chaney 614-362C, and West Bay Mooring Facility. The first two in this list are both listed as "Extremely High" risk of eroding by 2019 and the rest in the list are listed as "Medium" risk for at least two bird species.

Figure 10 depicts the High Conservation Priority Islands and species populations. It is important to note that in this map, each bird species is symbolized as a transparent purple so that when all seven species are overlaid on top each other, the darker the purple, the higher the concentration of dense bird populations. For example, in Figure 10, data frame number one depicts an island with a very high concentration of birds but only a medium risk of erosion, whereas data frame three depicts a moderate concentration of birds on many islands ranking as "Extremely High" risk of erosion. The list of islands of highest concern are listed in Figure 10, and include the following: West Bay Mooring Facility, Second Chain of Islands, Causeway Islands, Big Bayou Islands, Chaney, Three Humps, East Flats Spoil, and Green Hill Spoil Islands 1 &2.

7) *Data Products*

The following GIS data layers were published in ArcGIS Online as feature services with FGDC compliant metadata for consumption by all agencies, NGOs, partnerships and the general public. They can be accessed through the National Audubon Society's REST end (https://gis.audubon.org/arcgisweb/rest/services/Texas/TexasCMPService/MapServer).

- Island erosion risk for 2019 (5-year prediction)
- Island erosion risk for 2024 (10-year prediction)
- Island erosion risk for 2039 (25-year prediction)
- Island erosion risk for 2064 (50-year prediction)
- brown pelican average populations from 2004, 2008 and 2014
- Forster's tern average populations from 2004, 2008 and 2014
- laughing gull average populations from 2004, 2008 and 2014
- roseate spoonbill average populations from 2004, 2008 and 2014
- royal tern average populations from 2004, 2008 and 2014
- sandwich tern average populations from 2004, 2008 and 2014
- snowy egret average populations from 2004, 2008 and 2014

Discussion

The results of this research indicate that there are 15 Texas rookery island groups within 25 meters of the GIWW that are at risk of completely disappearing within 50 years, 31 of which are predicted to experience erosion of at least "Medium" classification within only 10 years. Several of these high erosion-risk islands have been recorded to serve as habitat for dense populations of several prominent waterbird species in the study area including the Forster's tern and roseate spoonbill. The final list of high conservation-priority islands is as follows, in order of highest to lowest priority: Causeway and Big Bayou Islands, West Bay Mooring Facility, East Flats Spoil, Second Chain of Islands, Chaney and Three Humps Islands, and Green Hill Spoil Islands 1 & 2. All of these islands have medium or higher bird populations and a 5-year erosion risk of "Medium" or above, making them good areas to focus current and future conservation efforts.

It is important to clarify that just because dense populations of certain colonial waterbird species have been documented on particular islands over time does not necessarily mean that without those islands, the birds would have no access to alternative rookeries. Therefore, this study can only suggest that particular islands are "high conservation-priority areas", not necessarily "conservation-mandatory areas". Future research could attempt to quantify the strengths of the relationships between particular species and islands to determine whether they are statistically significant.

Future studies could also improve on this research by better dispersing the randomly selected ground-truthed sites using proportionate stratified random sampling as outlined in the Results and in Figure 8 and Table 6. It is important to note that Sundown (Chester's) Island was not included in the risk prediction. This exclusion does not indicate low erosion risk, but rather the addition of beneficial use material on the island during the study period. Another improvement that could be made would be to add an additional section to this study that analyzes bird species using the same count cutoff for each species when calculating population density (ex: use a cutoff of population > 50 for all species instead of differing cutoffs for each species). An alteration in methodology such as this one could result in different high conservation-priority islands, but may not be as attuned to individual species trends as the method used in this study.

Conclusion

Current and future conservation efforts made on Texas rookery islands near the GIWW should be focused on the following islands because they are predicted to experience severe erosion within the next 5 years and have been recorded to serve as habitat for dense populations of at least one waterbird species: Causeway and Big Bayou Islands, West Bay Mooring Facility, East Flats Spoil, Second Chain of Islands, Chaney and Three Humps Islands, and Green Hill Spoil Islands 1 & 2. If the erosion of these islands can be prevented or slowed, or if artificial islands with similar habitat type can be built nearby, the less the waterbird species in this area will have to adapt to, or move because of, loss of habitat.

Appendix

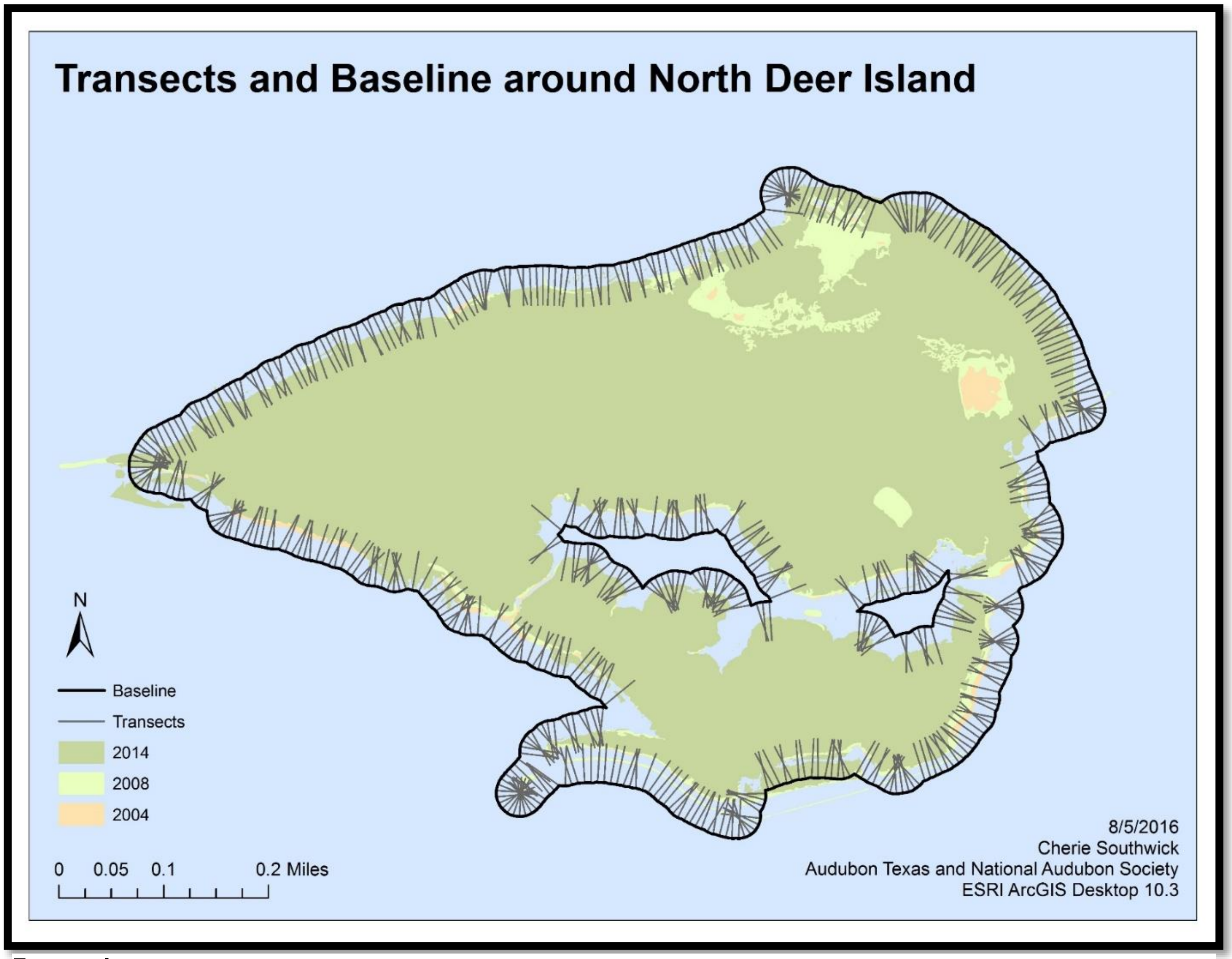


Figure 1

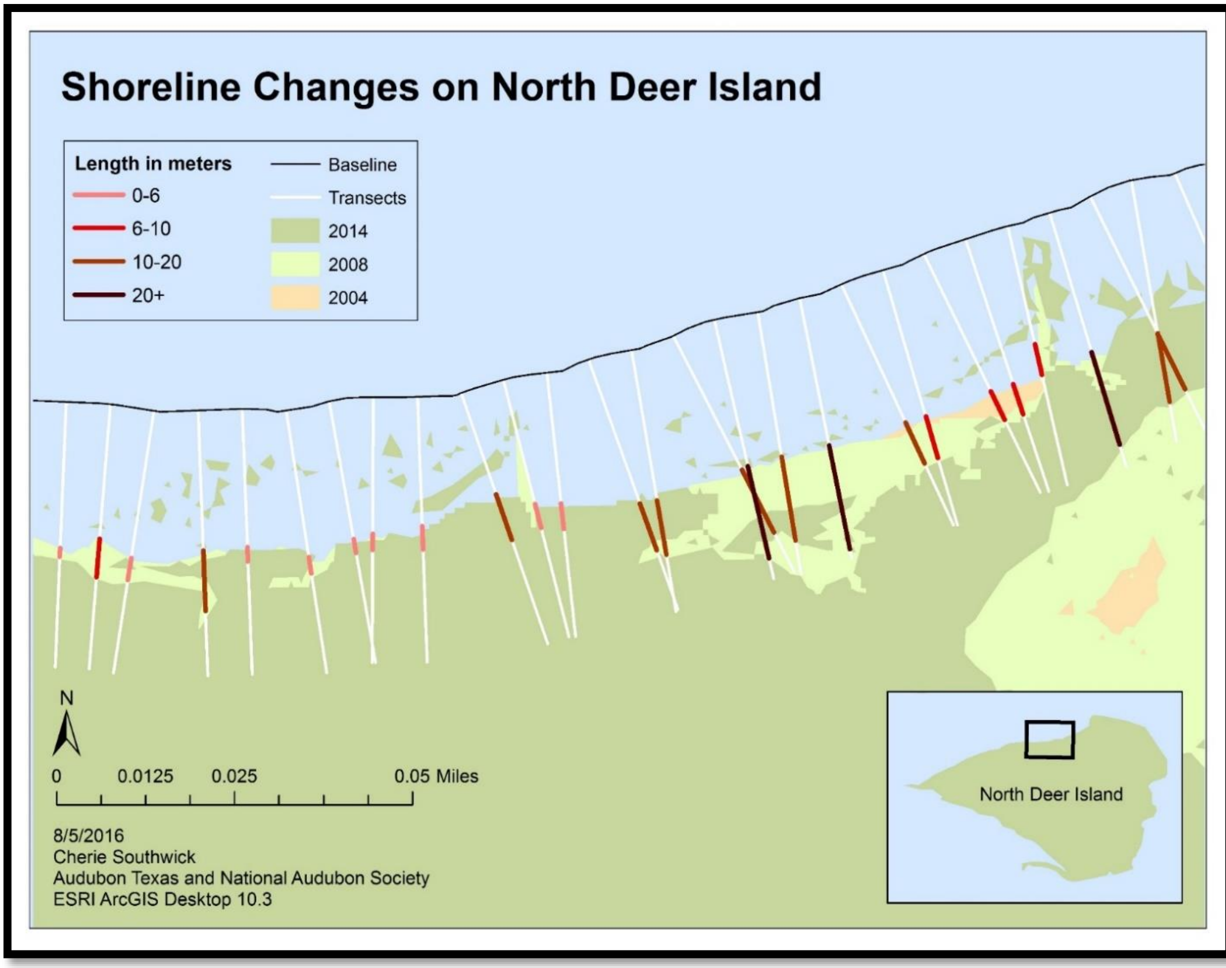

Shoreline Changes on North Deer Island
Length in meters
0-6
6-10
10-20
20+
Baseline
Transects
2014
2008
2004
N
0
0.0125
0.025
0.05 Miles
8/5/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3
North Deer Island

Figure 2

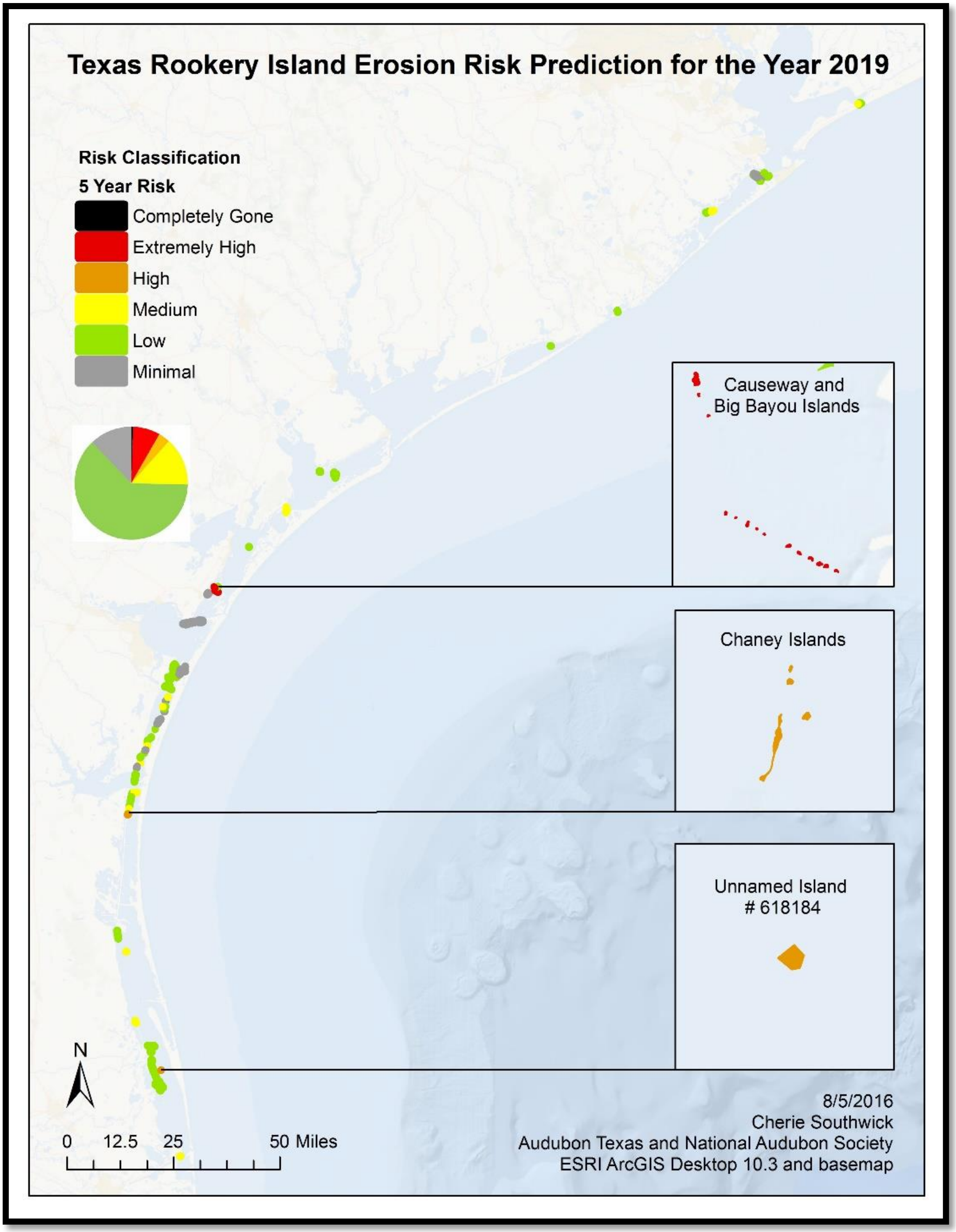

Texas Rookery Island Erosion Risk Prediction for the Year 2019
Risk Classification
5 Year Risk
Completely Gone
Extremely High
High
Medium
Low
Minimal
Causeway and
Big Bayou Islands
Chaney Islands
Unnamed Island
618184
N
0
12.5
25
50 Miles
8/5/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3 and basemap

Figure 3

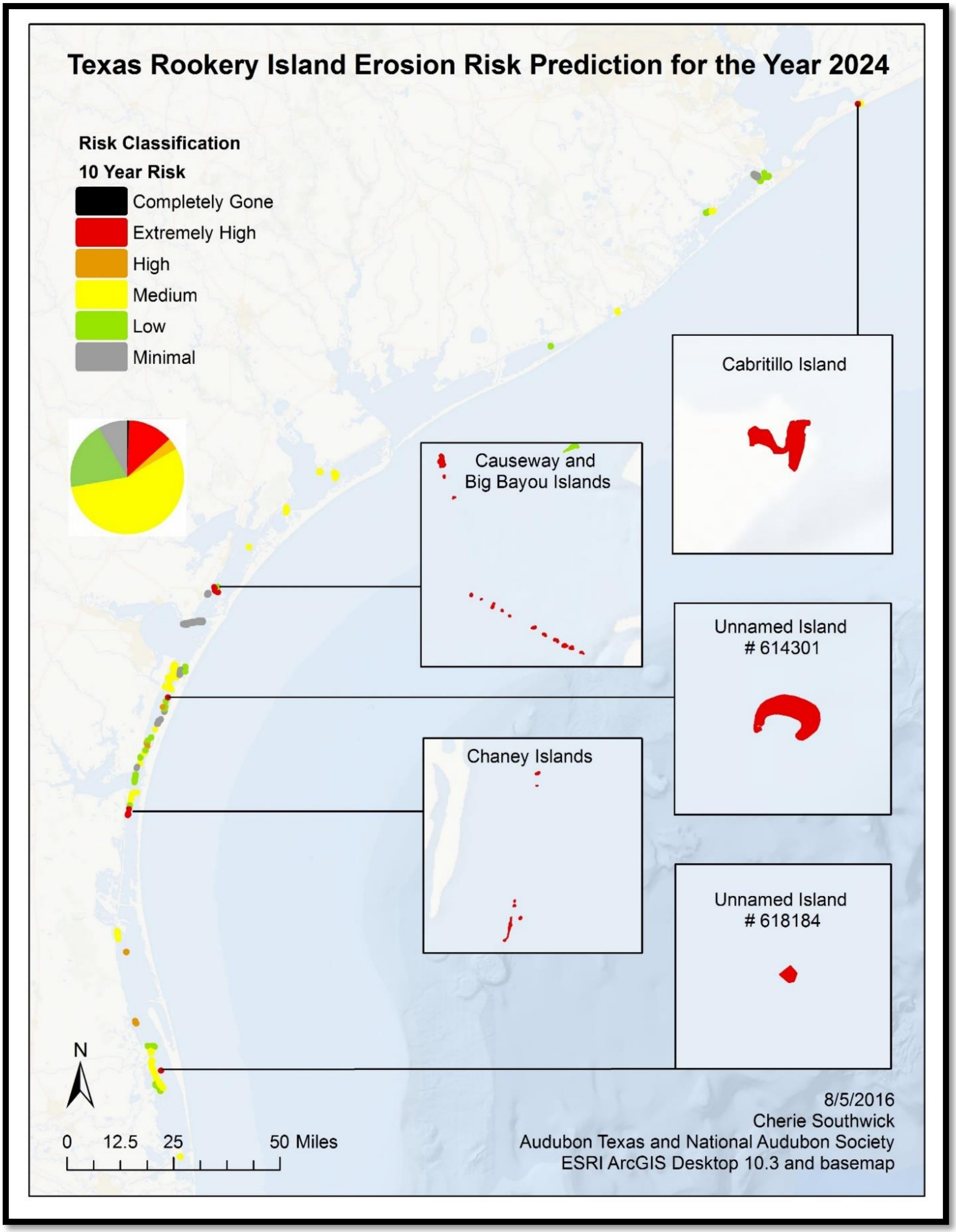

Texas Rookery Island Erosion Risk Prediction for the Year 2024
Risk Classification
10 Year Risk
Completely Gone
Extremely High
High
Medium
Low
Minimal
Cabritillo Island
Causeway and
Big Bayou Islands
Unnamed Island
614301
Chaney Islands
Unnamed Island
618184
N
0
12.5
25
50 Miles
8/5/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3 and basemap

Figure 4

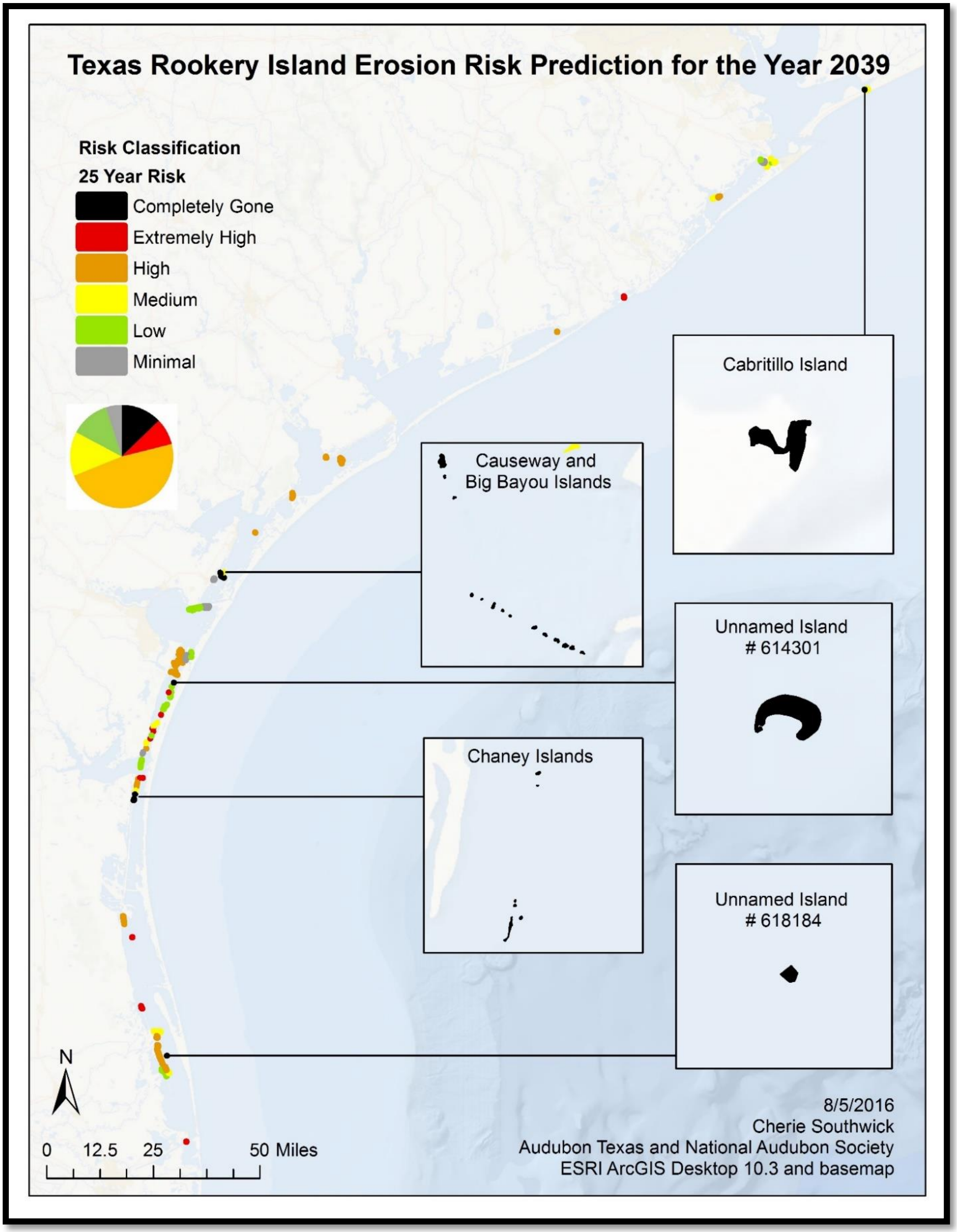

Texas Rookery Island Erosion Risk Prediction for the Year 2039
Risk Classification
25 Year Risk
Completely Gone
Extremely High
High
Medium
Low
Minimal
Cabritillo Island
Causeway and
Big Bayou Islands
Unnamed Island
614301
Chaney Islands
Unnamed Island
618184
N
0
12.5
25
50 Miles
8/5/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3 and basemap

Figure 5

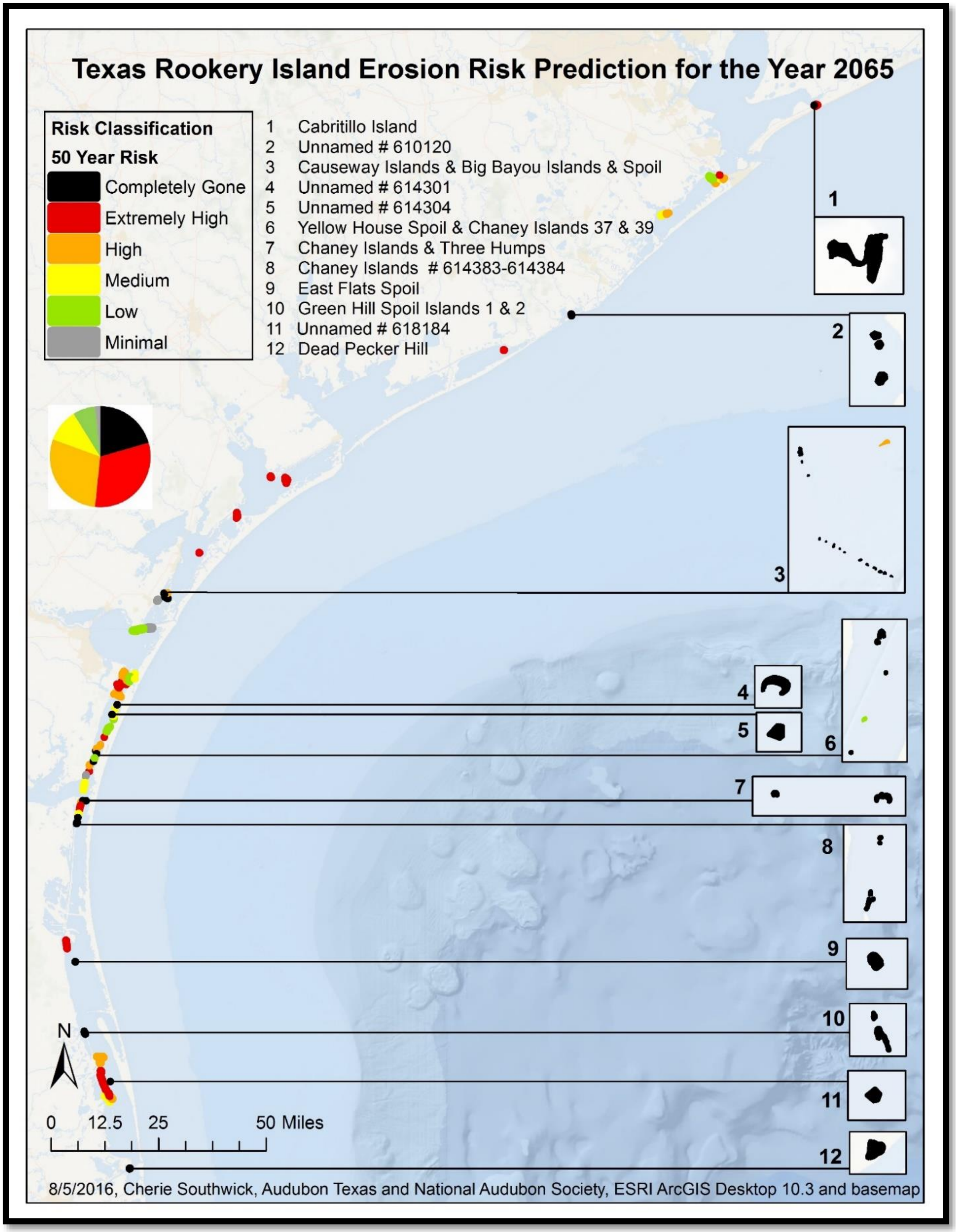

Texas Rookery Island Erosion Risk Prediction for the Year 2065
Risk Classification
50 Year Risk
Completely Gone
Extremely High
High
Medium
Low
Minimal
1 Cabritillo Island
2 Unnamed # 610120
3 Causeway Islands & Big Bayou Islands & Spoil
4 Unnamed # 614301
5 Unnamed # 614304
6 Yellow House Spoil & Chaney Islands 37 & 39
7 Chaney Islands & Three Humps
8 Chaney Islands # 614383-614384
9 East Flats Spoil
10 Green Hill Spoil Islands 1 & 2
11 Unnamed # 618184
12 Dead Pecker Hill
1
2
3
4
5
6
7
8
9
10
11
12
N
0 12.5 25 50 Miles
8/5/2016, Cherie Southwick, Audubon Texas and National Audubon Society, ESRI ArcGIS Desktop 10.3 and basemap

Figure 6

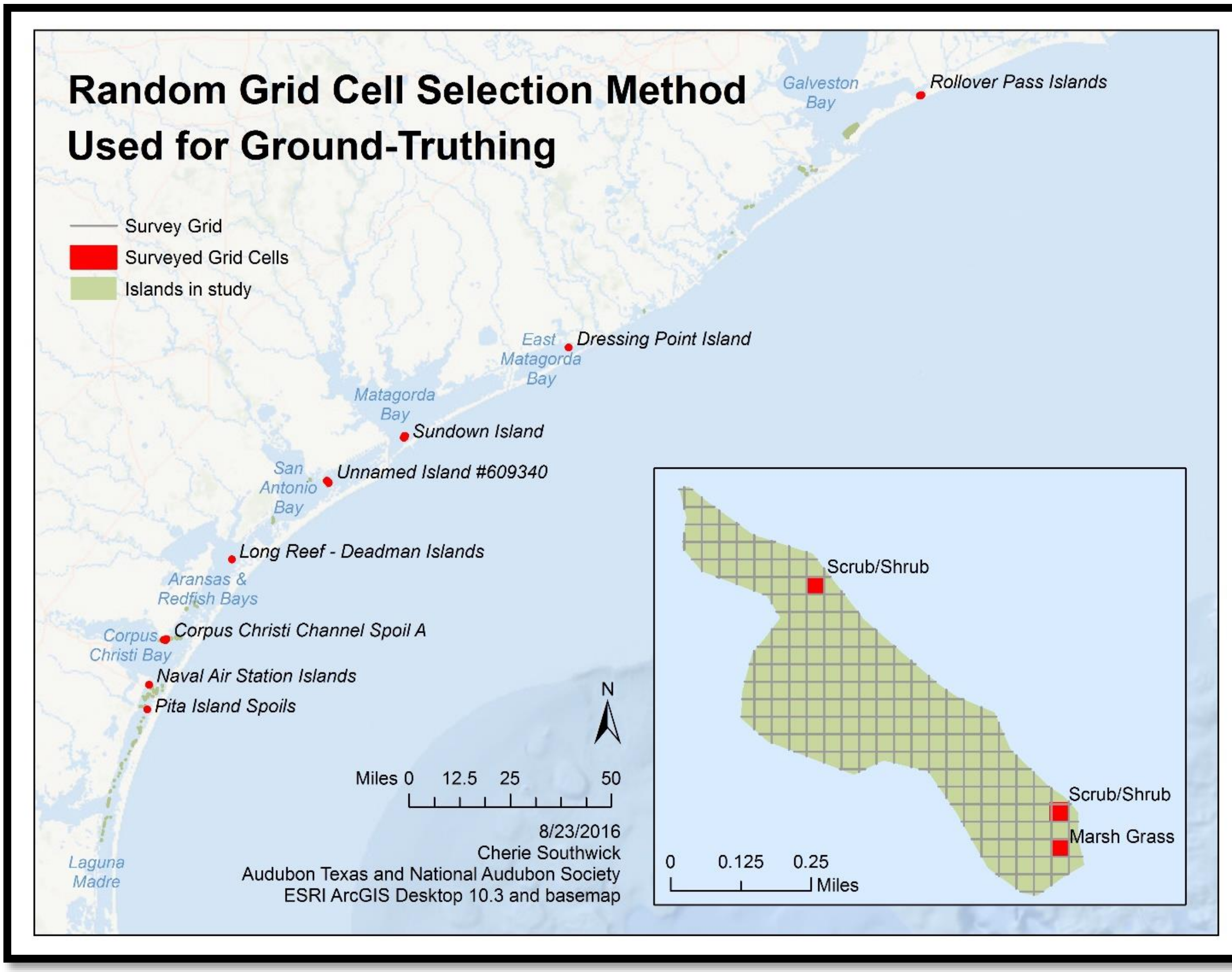
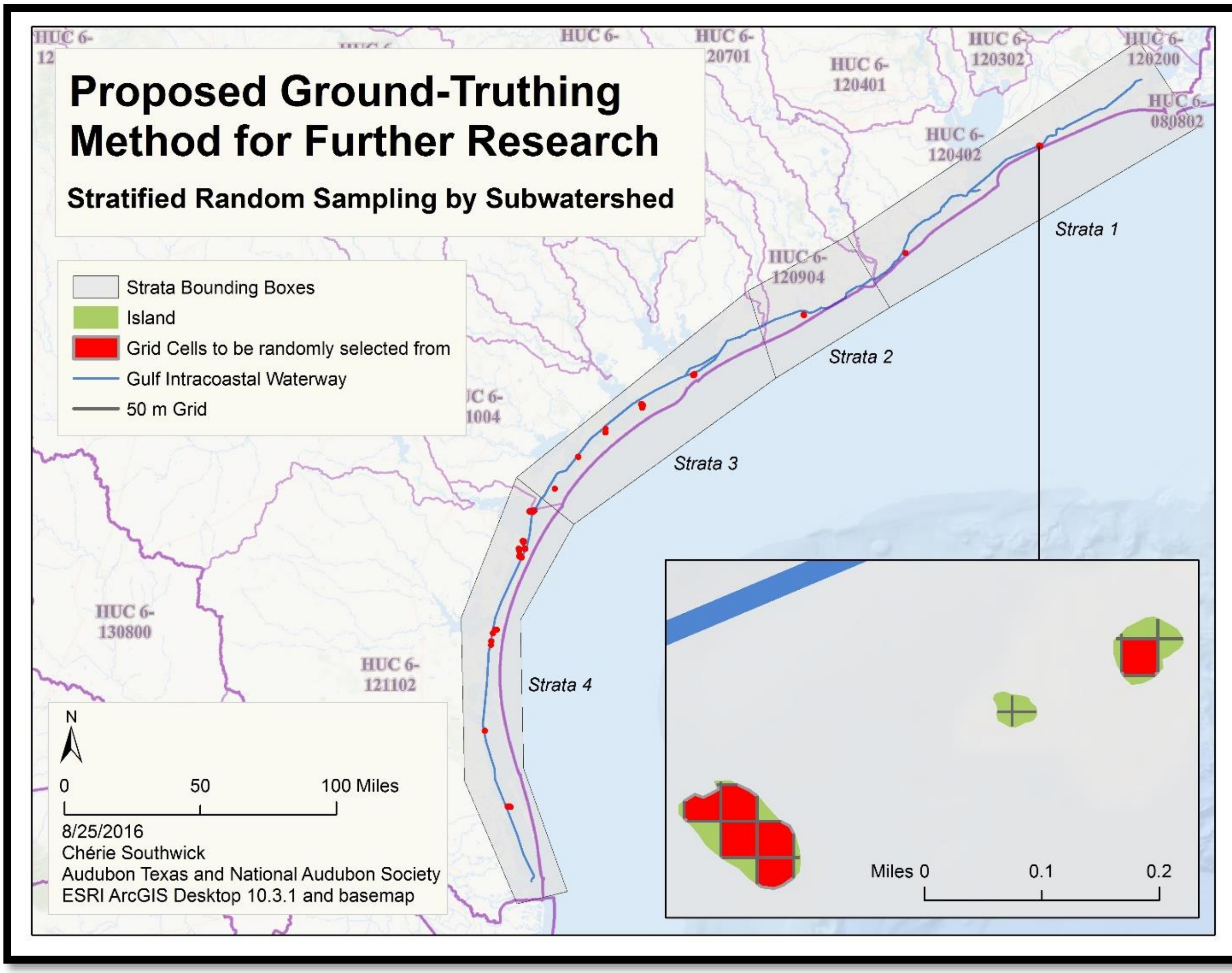
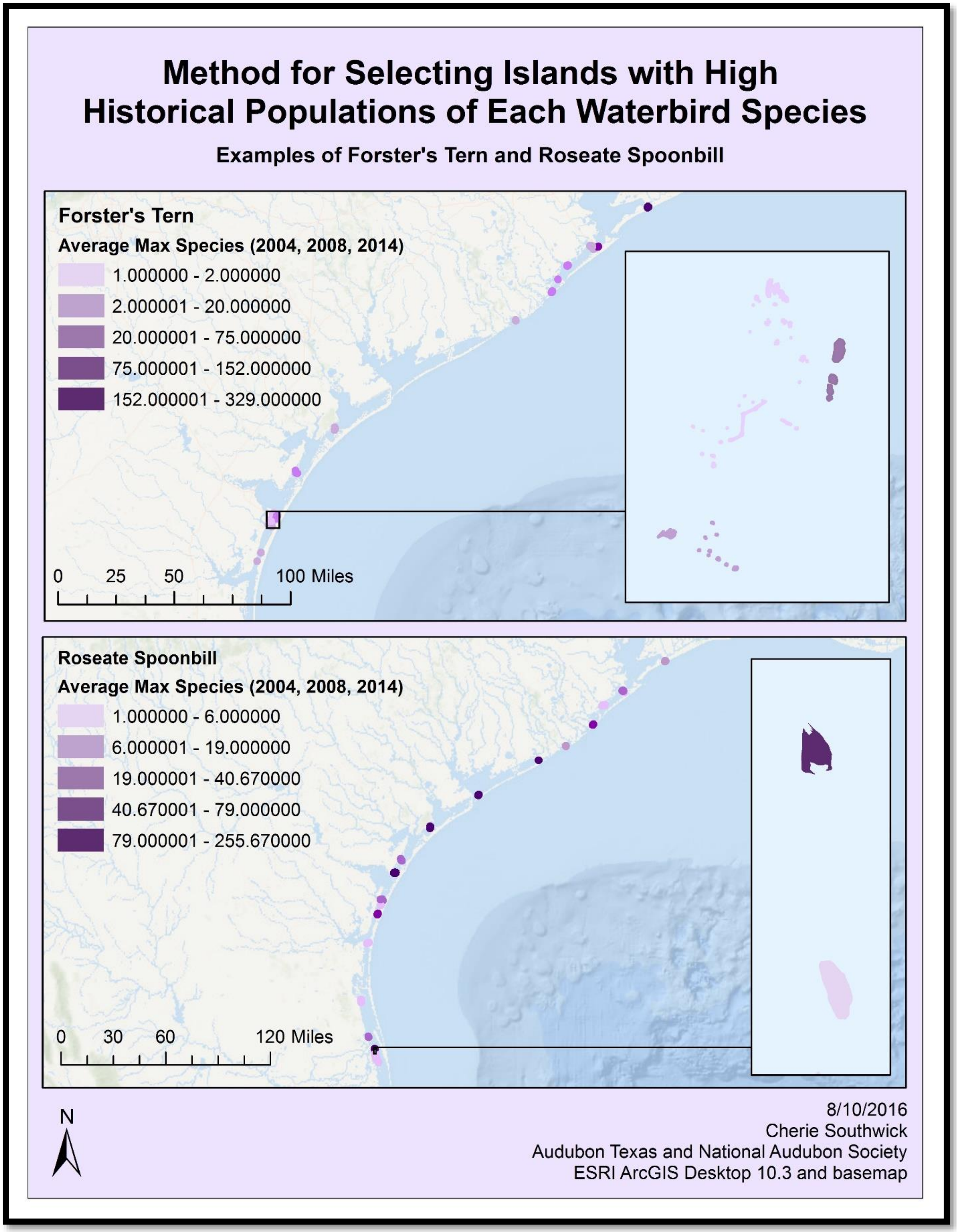

Random Grid Cell Selection Method Used for Ground-Truthing
Survey Grid
Surveyed Grid Cells
Islands in study
Galveston Bay
Rollover Pass Islands
East Matagorda Bay
Dressing Point Island
Matagorda Bay
Sundown Island
San Antonio Bay
Unnamed Island #609340
Long Reef - Deadman Islands
Aransas & Redfish Bays
Corpus Christi Bay
Corpus Christi Channel Spoil A
Naval Air Station Islands
Pita Island Spoils
Laguna Madre
N
Miles 0 12.5 25 50
8/23/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3 and basemap
Scrub/Shrub
Scrub/Shrub
Marsh Grass
0 0.125 0.25 Miles

Figure 7



Proposed Ground-Truthing Method for Further Research
Stratified Random Sampling by Subwatershed
Strata Bounding Boxes
Island
Grid Cells to be randomly selected from
Gulf Intracoastal Waterway
50 m Grid
HUC 6-20701
HUC 6-120401
HUC 6-120302
HUC 6-120200
HUC 6-080802
HUC 6-120402
HUC 6-120904
HUC 6-130800
HUC 6-121102
Strata 1
Strata 2
Strata 3
Strata 4
N
0
50
100 Miles
8/25/2016
Chérie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3.1 and basemap
Miles 0
0.1
0.2

Figure 8



Method for Selecting Islands with High Historical Populations of Each Waterbird Species
Examples of Forster's Tern and Roseate Spoonbill
Forster's Tern
Average Max Species (2004, 2008, 2014)
1.000000 - 2.000000
2.000001 - 20.000000
20.000001 - 75.000000
75.000001 - 152.000000
152.000001 - 329.000000
0 25 50 100 Miles
Roseate Spoonbill
Average Max Species (2004, 2008, 2014)
1.000000 - 6.000000
6.000001 - 19.000000
19.000001 - 40.670000
40.670001 - 79.000000
79.000001 - 255.670000
0 30 60 120 Miles
N
8/10/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3 and basemap

Figure 9

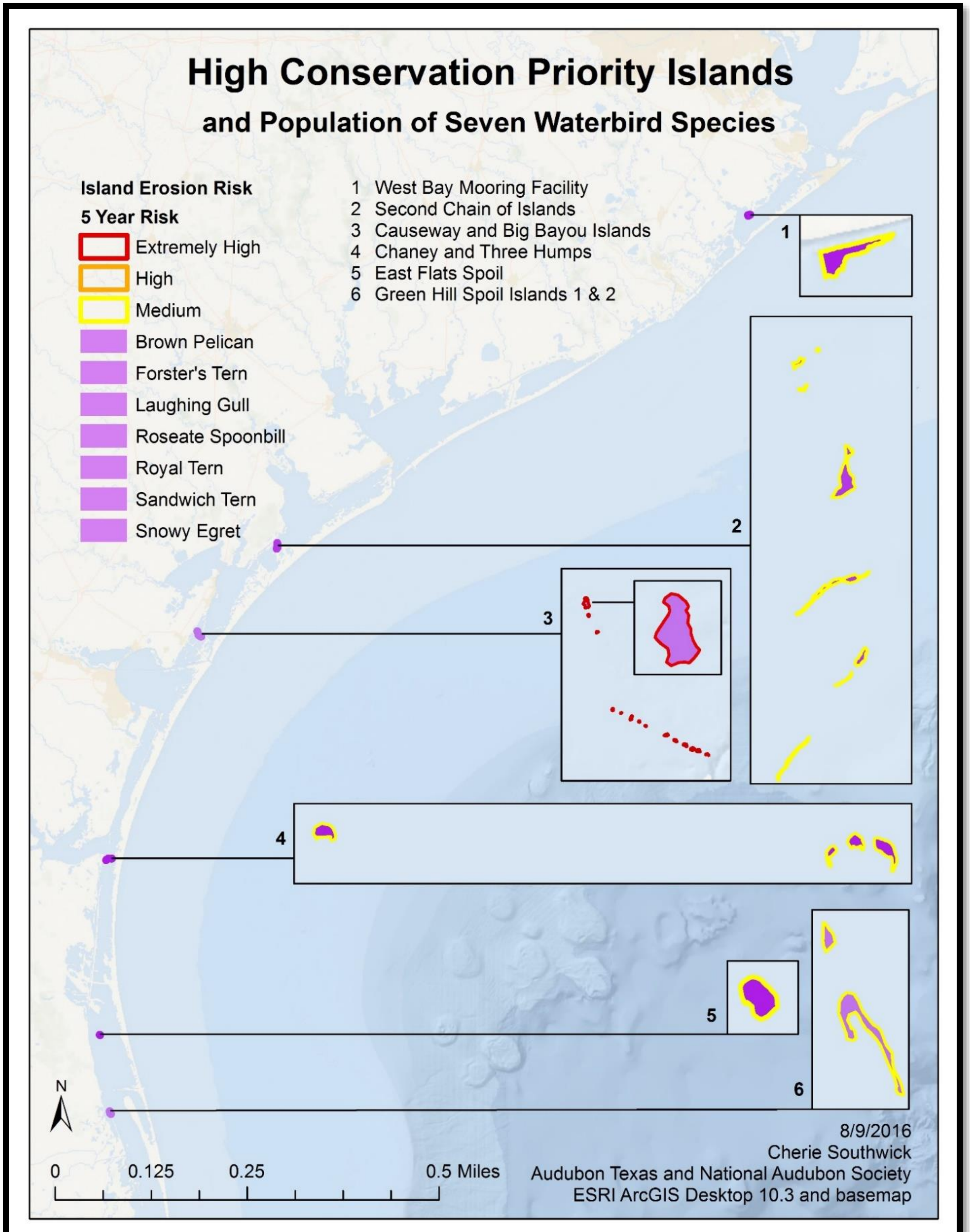

High Conservation Priority Islands
and Population of Seven Waterbird Species
Island Erosion Risk
5 Year Risk
Extremely High
High
Medium
Brown Pelican
Forster's Tern
Laughing Gull
Roseate Spoonbill
Royal Tern
Sandwich Tern
Snowy Egret
1 West Bay Mooring Facility
2 Second Chain of Islands
3 Causeway and Big Bayou Islands
4 Chaney and Three Humps
5 East Flats Spoil
6 Green Hill Spoil Islands 1 & 2
1
2
3
4
5
6
N
0 0.125 0.25 0.5 Miles
8/9/2016
Cherie Southwick
Audubon Texas and National Audubon Society
ESRI ArcGIS Desktop 10.3 and basemap

Figure 10

Table 1

Island-Risk Categorization

Risk Level	Percentage of Island Area Lost Over Term
Completely Gone	Site has lost 100%
Extremely High	Greater than 75%
High	50-75%
Medium	25-50%
Low	5-25%
Minimal	Less than 5%

Table 2

NAIP Generated Island Areas (in square meters) Grouped by TCWS ID

TCWS ID	2004 Total Area	2004 Vegeta-tion	2004 Open Ground	2008 Total Area	2008 Vegeta-tion	2008 Open Ground	2014 Total Area	2014 Vegeta-tion	2014 Open Ground
600300	31111.18	30375.1	736.076	30890.66	29901.1	989.563	30323.8	630.995	29692.8
600302	21252.62	19621	1631.62	23065.89	20443.5	2622.39	3331.23	-	3331.23
600415	1048.837	756.708	292.129	1346.183	12.5027	1333.68	25502.32	5172.52	20329.8
600416	672.342	163.582	508.76	895.6564	1.31939	894.337	399.608	-	399.608
600422	63323.6	50291.3	13032.3	67108.1	42503.2	24604.9	66069.8	44061.5	22008.3
600423	12531.48	3597.5	8933.98	12211.61	1949.41	10262.2	10481.05	842.905	9638.14
600424	623612.5	565951	57661.5	667643.1	600446	67197.1	655387.1	566966	88421.1
600426	337443.3	321116	16327.3	329549.8	313519	16030.8	332883.8	293334	39549.8
600451	9281.69	3523.51	5758.18	10484.48	16.9827	10467.5	8270.628	581.928	7688.7
600500	3357.323	8.34284	3348.98	10094.43	323.185	9771.24	2835.39	-	2835.39
600552	147132.4	87111.4	60021	141548.2	90404	51144.2	36893.14	844.335	36048.8
600564	2664.862	212.882	2451.98	-	-	-	-	-	-
609320	146475.4	137052	9423.44	116857.2	109779	7078.17	125145.3	105181	19964.3
609340	436454.5	356026	80428.5	412756.4	373936	38820.4	409651.4	363074	46577.4
609341	3205.326	140.236	3065.09	2487.183	335.453	2151.73	2756.074	411.114	2344.96
609342	6134.27	1390.82	4743.45	5274.83	2359.62	2915.21	5328.09	1921.44	3406.65
609422	35704.1	29466	6238.098	30402.28	23788.14	6614.14	29709.68	22236.8	7472.88
609501	9379.44	4086.55	5292.89	9459.703	125.523	9334.18	8461.661	434.021	8027.64
610120	20443.62	19270.5	1173.12	16802.57	15992.9	809.67	14626.76	12822.4	1804.36
610160	43747.72	42852.1	895.621	42316.41	35522.5	6793.91	36556.34	33960.4	2595.94
614100	236442.2	46035.2	190407	-	-	-	248856.6	180629	68227.6
614121	20608.43	13106.4	7502.03	-	-	-	36505.8	18989.9	17515.9
614122	4498.29	4478.83	19.4597	-	-	-	5141.956	616.706	4525.25
614184	1253517	1053560	199957	16.4349	-	16.4349	1344864	762624	582240
614185	1648273	1130810	517463	-	-	-	1717654	1000500	717154
614221	289399.4	213997	75402.4	197479.4	121907	75572.4	183156.3	74636.3	108520

614222	129833.3	80911	48922.3	91113.7	50047.6	41066.1	63220.4	19336.9	43883.5
614240	478905	241427	237478	423772	243901	179871	422368	164043	258325
614241	16319.4	13472.1	2847.3	13491.62	11653.6	1838.02	15756.27	8504.34	7251.93
614300	147474.6	106403	41071.6	131976.8	62860.1	69116.7	108965.2	58037.9	50927.3
614301	2450.645	985.525	1465.12	1048.719	924.246	124.473	754.818	192.837	561.981
614302	11888.03	11679	209.025	12703.91	12365.4	338.512	12354.44	8655.99	3698.45
614304	4528.79	1461.85	3066.94	3356.55	1850.17	1506.38	2686.537	433.617	2252.92
614305	255876	108159	147717	237532.9	178016	59516.9	211677.1	66992.1	144685
614306	76068.4	65216.9	10851.5	73803.22	64573.7	9229.52	70724	41414.4	29309.6
614340	106319.2	69565.4	36753.8	87097.3	74431	12666.3	92310.1	59360.8	32949.3
614341	350867	211594	139273	299567.2	267594	31973.2	308186	145166	163020
614342	4015.635	590.865	3424.77	2666.61	1134.05	1532.56	3657.375	123.325	3534.05
614343	7979.04	5760.25	2218.79	8624.63	6963.74	1660.89	7610.42	2619.54	4990.88
614344	17193.82	6803.72	10390.1	14963.34	11179.8	3783.54	6947.9	1721.69	5226.21
614345	18825.03	9666.59	9158.44	16146.83	9811.64	6335.19	19070.99	1997.39	17073.6
614346	516.8179	33.2639	483.554	211.1285	58.8435	152.285	23.34992	2.63122	20.7187
614347	272.5235	90.3435	182.18	364.467	106.67	257.797	177.1629	17.5939	159.569
614348	2639.421	0.871284	2638.55	9407.35	4472.66	4934.69	8465.233	400.353	8064.88
614360	10728.1	3682.01	7046.09	6162.28	3752.76	2409.52	6116.3	1655.59	4460.71
614361	370985	246678	124307	-	-	-	305482	189248	116234
614362	11064.55	6030.37	5034.18	14090.48	2044.18	12046.3	18230.92	8415.21	9815.71
614363	32932.36	25344.6	7587.76	32714.46	26210	6504.46	35921.6	13663.6	22258
614364	30231.1	18723.7	11507.4	24988.79	21685.2	3303.59	26564.21	8008.91	18555.3
614380	23731.22	7526.82	16204.4	14451.31	8180.62	6270.69	9076.07	7721.58	1354.49
614382	21434.77	9570.37	11864.4	13299.42	11808.9	1490.52	12550.48	11992.3	558.18
614383	1268.29	308.986	959.304	-	-	-	385.5218	81.8768	303.645
614384	33819.44	8182.64	25636.8	17370.23	988.325	16381.9	10616.92	6763.41	3853.51
618100	203869.8	83911.8	119958	141603.2	95039.2	46564	119484.2	65730.7	53753.5
618120	-	-	-	22939.12	9886.62	13052.5	16315.33	4524.83	11790.5
618143	78154	40887.8	37266.2	77246.74	69143.6	8103.14	50134.8	19353.7	30781.1
618160	24293.4	5763	18530.4	15692.51	2649.21	13043.3	11522.43	1347.43	10175
618161	284808.3	197966	86842.3	265257.3	204354	60903.3	249568.4	189207	60361.4
618180	1790908	424488	1366420	1779436	539676	1239760	1071135	282960	788175
618182	1536529	518429	1018100	1583699	552739	1030960	1401782	556355	845427
618183	662524	305124	357400	622726	407708	215018	613930	418451	195479
618184	-	-	-	4825.42	1449.91	3375.51	3069.68	225.83	2843.85
618240	83488.1	42754.1	40734	64250.2	37347.2	26903	60160.1	36916.8	23243.3

Table 3

Results of DSAS Analysis on TCWS ID Island groups

TCWS ID	Possible shoreline retreat per year (m)	2014 Area (square meters)	Possible shoreline retreat (m) by 2019	Possible shoreline retreat (m) by 2024	Possible shoreline retreat (m) by 2039	Possible shoreline retreat (m) by 2064	% area lost by 2019	% area lost by 2024	% area lost by 2039	% area lost by 2064
600300	-0.28	30,368.50	-1.382	-2.764	-6.910	-13.8194	-15.99%	-26.51%	-49.80%	-75.42%
600302	-0.77	3,334.10	-3.835	-7.670	-	-	-49.80%	-79.70%	-100.00%	-100.00%
600415	-0.03	26,688.70	-0.138	-0.276	-0.689	-1.37887	-2.54%	-4.98%	-11.51%	-19.75%
600416	0.06	399.61	0.305	0.611	1.526	3.052632	-11.01%	-21.32%	-47.23%	-77.24%
600422	-0.15	70,506.10	-0.749	-1.499	-3.747	-7.49313	-7.72%	-13.72%	-28.35%	-44.88%
600423	0.03	11,614.90	0.173	0.345	0.863	1.725166	-3.52%	-6.77%	-15.56%	-28.80%
600424	-0.06	693,336.00	-0.311	-0.623	-1.557	-3.11319	-1.04%	-1.84%	-3.70%	-6.12%
600426	-0.88	335,713.00	-4.404	-8.808	-22.021	-44.0418	-8.97%	-15.51%	-33.54%	-58.16%
600451	-0.08	8,270.68	-0.382	-0.765	-1.912	-3.82456	-11.19%	-20.45%	-43.96%	-73.33%
600500	-0.05	28,958.60	-0.232	-0.463	-1.158	-2.31507	-7.87%	-14.20%	-27.65%	-40.97%
600552	-0.39	38,360.50	-1.949	-3.898	-9.745	-19.4892	-25.60%	-38.93%	-57.85%	-74.40%
609320	-0.79	135,116.00	-3.945	-7.890	-19.724	-39.4485	-24.82%	-37.51%	-59.36%	-85.09%
609340	-0.57	443,036.00	-2.857	-5.715	-14.286	-28.5725	-24.23%	-38.92%	-65.26%	-87.49%
609422	-0.22	33,290.60	-1.103	-2.206	-5.516	-11.0316	-26.93%	-43.41%	-68.22%	-84.56%
609501	-0.25	8,513.51	-1.268	-2.535	-6.339	-12.6771	-14.29%	-27.85%	-59.89%	-85.94%
610120	-0.86	20,245.80	-4.281	-8.562	-21.406	-	-24.69%	-43.62%	-84.70%	-100.00%
610160	-0.92	36,556.30	-4.610	-9.220	-23.050	-46.0991	-13.03%	-24.91%	-53.56%	-84.31%
614100	-0.02	248,873.00	-0.109	-0.218	-0.544	-1.08781	-0.80%	-1.47%	-2.84%	-4.24%
614121	0.00	1,753.43	-0.003	-0.005	-	-	-93.44%	-99.88%	-100.00%	-100.00%
614122	-0.13	5,142.62	-0.630	-1.259	-3.148	-6.29688	-8.55%	-15.92%	-36.18%	-58.55%
614184	-0.03	1,347,880.00	-0.167	-0.334	-0.835	-1.66953	-0.27%	-0.51%	-1.11%	-1.94%
614185	-0.39	2,056,770.00	-1.959	-3.919	-9.797	-19.5947	-1.93%	-3.33%	-7.06%	-12.83%
614221	-0.41	245,208.00	-2.057	-4.114	-10.285	-20.5694	-18.34%	-29.86%	-51.03%	-74.59%
614222	-0.32	91,901.40	-1.598	-3.195	-7.989	-15.9773	-15.63%	-28.97%	-59.25%	-84.09%
614240	-0.05	450,860.00	-0.236	-0.472	-1.181	-2.36191	-0.88%	-1.66%	-3.58%	-6.26%
614241	0.03	15,753.20	0.161	0.323	0.807	1.61435	-3.07%	-6.06%	-14.50%	-26.58%
614300	-0.51	116,012.00	-2.531	-5.061	-12.654	-25.3072	-18.39%	-29.59%	-52.01%	-71.26%
614301	-0.50	1,370.43	-2.520	-5.039	-	-	-45.57%	-79.66%	-100.00%	-100.00%
614302	0.12	12,917.90	0.612	1.225	3.062	6.123188	-4.91%	-8.27%	-16.63%	-28.68%
614304	-0.71	3,249.11	-3.565	-7.130	-17.826	-	-35.28%	-57.28%	-96.20%	-100.00%
614305	-0.36	218,040.00	-1.783	-3.566	-8.916	-17.8323	-5.86%	-9.64%	-18.88%	-32.53%
614306	-0.08	71,507.40	-0.403	-0.805	-2.013	-4.02542	-2.21%	-4.04%	-8.44%	-14.37%
614340	-0.10	118,625.00	-0.482	-0.964	-2.409	-4.81897	-1.45%	-2.62%	-5.78%	-10.49%
614341	-0.15	310,294.00	-0.760	-1.521	-3.802	-7.60345	-2.11%	-3.72%	-7.83%	-13.86%
614342	-0.18	3,857.48	-0.908	-1.815	-4.538	-9.07692	-22.94%	-42.37%	-80.29%	-98.52%
614343	-0.18	9,025.57	-0.915	-1.830	-4.575	-9.15	-9.71%	-18.32%	-40.69%	-71.15%
614344	-0.39	16,603.60	-1.966	-3.933	-9.832	-19.6645	-12.49%	-20.82%	-41.28%	-65.26%
614345	-0.15	20,871.90	-0.735	-1.471	-3.676	-7.35256	-3.42%	-5.96%	-12.87%	-23.61%
614346	0.12	167.53	0.600	1.200	3.000	-	-35.89%	-57.79%	-93.30%	-100.00%
614347	0.18	435.21	0.910	1.819	4.548	-	-24.33%	-44.50%	-87.34%	-100.00%
614348	-0.37	11,225.80	-1.843	-3.686	-9.214	-	-46.39%	-71.20%	-97.68%	-100.00%
614360	-0.47	13,816.30	-2.340	-4.679	-11.698	-23.3955	-25.45%	-40.65%	-70.34%	-95.47%
614361	-0.15	328,154.00	-0.767	-1.534	-3.836	-7.67239	-6.63%	-9.68%	-16.31%	-25.19%
614362	0.63	20,691.60	3.150	6.301	15.751	-	-29.33%	-46.59%	-79.26%	-100.00%
614363	0.34	36,931.80	1.715	3.430	8.574	17.14789	-12.67%	-20.29%	-38.38%	-57.67%
614364	0.01	27,559.90	0.039	0.078	0.194	0.388235	-0.54%	-1.06%	-2.50%	-4.54%
614380	-0.21	17,355.00	-1.052	-2.104	-5.261	-10.5224	-15.29%	-27.06%	-55.05%	-82.92%
614382	-0.11	17,335.20	-0.558	-1.115	-2.788	-5.57616	-9.00%	-14.50%	-27.09%	-41.35%
614383	0.30	581.29	1.514	3.028	-	-	-44.31%	-76.49%	-100.00%	-100.00%
614384	-0.70	15,431.50	-3.515	-7.030	-	-	-51.86%	-76.97%	-100.00%	-100.00%
618100	-0.83	143,397.00	-4.169	-8.339	-20.847	-41.6949	-19.26%	-34.38%	-68.61%	-97.11%

618120	-1.88	18,118.20	-9.403	-18.805	-47.013	-	-32.62%	-56.30%	-99.77%	-100.00%
618140	0.00	2,700.04	0.000	0.000	0.000	0	0.00%	0.00%	0.00%	0.00%
618143	-1.29	52,185.00	-6.426	-12.851	-32.129	-	-41.14%	-66.36%	-95.51%	-100.00%
618160	-0.28	42,046.60	-1.398	-2.797	-6.991	-13.9825	-11.93%	-19.48%	-38.55%	-63.62%
618161	-1.48	258,113.00	-7.391	-14.782	-36.956	-73.9123	-23.39%	-31.77%	-51.55%	-74.54%
618180	-1.31	1,125,620.00	-6.562	-13.124	-32.810	-65.6204	-19.78%	-31.87%	-58.16%	-83.68%
618182	-0.47	1,438,070.00	-2.345	-4.691	-11.727	-23.4547	-5.25%	-8.37%	-15.52%	-25.12%
618183	-1.28	613,525.00	-6.392	-12.783	-31.958	-63.9151	-15.13%	-25.28%	-49.30%	-74.86%
618184	-2.14	3,178.24	-10.723	-21.446	-	-	-72.64%	-99.90%	-100.00%	-100.00%
618240	-2.33	60,169.20	-11.653	-23.305	-58.264	-	-26.70%	-45.85%	-86.11%	-100.00%

Table 4

Island-risk Statistical Predictions for 5, 10, 25 and 50 years from 2014

TCWS ID	% area lost by 2019	5 Year Risk	% area lost by 2024	10 Year Risk	% area lost by 2039	25 Year Risk	% area lost by 2064	50 Year Risk
614121	93.44	Extremely High	99.88	Extremely High	100.00	Completely Gone	100.00	Completely Gone
618184	72.64	High	99.90	Extremely High	100.00	Completely Gone	100.00	Completely Gone
614384	51.86	High	76.97	Extremely High	100.00	Completely Gone	100.00	Completely Gone
600302	49.80	Medium	79.70	Extremely High	100.00	Completely Gone	100.00	Completely Gone
614348	46.39	Medium	71.20	High	97.68	Extremely High	100.00	Completely Gone
614301	45.57	Medium	79.66	Extremely High	100.00	Completely Gone	100.00	Completely Gone
614383	44.31	Medium	76.49	Extremely High	100.00	Completely Gone	100.00	Completely Gone
618143	41.14	Medium	66.36	High	95.51	Extremely High	100.00	Completely Gone
614346	35.89	Medium	57.79	High	93.30	Extremely High	100.00	Completely Gone
614304	35.28	Medium	57.28	High	96.20	Extremely High	100.00	Completely Gone
618120	32.62	Medium	56.30	High	99.77	Extremely High	100.00	Completely Gone
614362	29.33	Medium	46.59	Medium	79.26	Extremely High	100.00	Completely Gone
609422	26.93	Medium	43.41	Medium	68.22	High	84.56	Extremely High
618240	26.70	Medium	45.85	Medium	86.11	Extremely High	100.00	Completely Gone
600552	25.60	Medium	38.93	Medium	57.85	High	74.40	High
614360	25.45	Medium	40.65	Medium	70.34	High	95.47	Extremely High
609320	24.82	Low	37.51	Medium	59.36	High	85.09	Extremely High
610120	24.69	Low	43.62	Medium	84.70	Extremely High	100.00	Completely Gone
614347	24.33	Low	44.50	Medium	87.34	Extremely High	100.00	Completely Gone
609340	24.23	Low	38.92	Medium	65.26	High	87.49	Extremely High
618161	23.39	Low	31.77	Medium	51.55	High	74.54	High
614342	22.94	Low	42.37	Medium	80.29	Extremely High	98.52	Extremely High
618180	19.78	Low	31.87	Medium	58.16	High	83.68	Extremely High
618100	19.26	Low	34.38	Medium	68.61	High	97.11	Extremely High
614300	18.39	Low	29.59	Medium	52.01	High	71.26	High
614221	18.34	Low	29.86	Medium	51.03	High	74.59	High
600300	15.99	Low	26.51	Medium	49.80	Medium	75.42	Extremely High
614222	15.63	Low	28.97	Medium	59.25	High	84.09	Extremely High
614380	15.29	Low	27.06	Medium	55.05	High	82.92	Extremely High
618183	15.13	Low	25.28	Medium	49.30	Medium	74.86	High
609501	14.29	Low	27.85	Medium	59.89	High	85.94	Extremely High
610160	13.03	Low	24.91	Low	53.56	High	84.31	Extremely High
614363	12.67	Low	20.29	Low	38.38	Medium	57.67	High
614344	12.49	Low	20.82	Low	41.28	Medium	65.26	High
618160	11.93	Low	19.48	Low	38.55	Medium	63.62	High

600451	11.19	Low	20.45	Low	43.96	Medium	73.33	High
600416	11.01	Low	21.32	Low	47.23	Medium	77.24	Extremely High
614343	9.71	Low	18.32	Low	40.69	Medium	71.15	High
614382	9.00	Low	14.50	Low	27.09	Medium	41.35	Medium
600426	8.97	Low	15.51	Low	33.54	Medium	58.16	High
614122	8.55	Low	15.92	Low	36.18	Medium	58.55	High
600500	7.87	Low	14.20	Low	27.65	Medium	40.97	Medium
600422	7.72	Low	13.72	Low	28.35	Medium	44.88	Medium
614361	6.63	Low	9.68	Low	16.31	Low	25.19	Medium
614305	5.86	Low	9.64	Low	18.88	Low	32.53	Medium
618182	5.25	Low	8.37	Low	15.52	Low	25.12	Medium
614302	4.91	Minimal	8.27	Low	16.63	Low	28.68	Medium
600423	3.52	Minimal	6.77	Low	15.56	Low	28.80	Medium
614345	3.42	Minimal	5.96	Low	12.87	Low	23.61	Low
614241	3.07	Minimal	6.06	Low	14.50	Low	26.58	Medium
600415	2.54	Minimal	4.98	Minimal	11.51	Low	19.75	Low
614306	2.21	Minimal	4.04	Minimal	8.44	Low	14.37	Low
614341	2.11	Minimal	3.72	Minimal	7.83	Low	13.86	Low
614185	1.93	Minimal	3.33	Minimal	7.06	Low	12.83	Low
614340	1.45	Minimal	2.62	Minimal	5.78	Low	10.49	Low
600424	1.04	Minimal	1.84	Minimal	3.70	Minimal	6.12	Low
614240	0.88	Minimal	1.66	Minimal	3.58	Minimal	6.26	Low
614100	0.80	Minimal	1.47	Minimal	2.84	Minimal	4.24	Minimal
614364	0.54	Minimal	1.06	Minimal	2.50	Minimal	4.54	Minimal
614184	0.27	Minimal	0.51	Minimal	1.11	Minimal	1.94	Minimal

Table 5

High Conservation Priority Islands for Seven Bird Species
(Note: HCPI stands for High Conservation Priority Islands)

Species (and population count used)	Total HCPI	HCPI	Island Names	Avg Max Species	Island Risk
brown pelican (> 285)	0	0	N/A	N/A	N/A
Forster's tern (> 20)	15	1	West Bay Mooring Facility	75	Medium
		3	Causeway Island and Causeway Island Platforms	30	Extremely High
		11	Big Bayou 1B - 1L	30	Extremely High
laughing gull (> 735.5)	2	1	East Flats Spoil	943.67	Medium
		1	West Bay Mooring Facility	2165.5	Medium
roseate spoonbill (> 19)	14	3	Causeway Island and Causeway Island Platforms	20	Extremely High
		11	Big Bayou 1B - 1L	25	Extremely High
royal tern (> 36.4)		1	East Flats Spoil	270.97	Medium
	5	3	Three Humps 614-362F	101.85	Medium
		1	Chaney 614-362C	101.85	Medium
sandwich tern (> 61.5)	5	1	East Flats Spoil	209.77	Medium
		3	Three Humps 614-362F	121.1	Medium
		1	Chaney 614-362C	121.1	Medium
snowy egret (> 20.33)	13	8	Second Chain of Islands	42.5	Medium
		3	Three Humps 614-362F	65	Medium
		1	Chaney 614-362C	65	Medium
		1	West Bay Mooring Facility	88	Medium

Table 6

Improved Ground-Truthing Method for Further Research

Strata	Islands within strata	Grid cells within strata	Grid cells to be randomly selected from each strata (if 20% of all grid cells within each strata are sampled)	Weight to assign to each strata's results (rounded to nearest hundredth)
1	19	8	8 x .2 = 1.6 ≈ **2**	8/320 = 0.025 = 2.50%
2	2	15	15 x .2 = **3**	15/320 = 0.046875 = 4.69%
3	32	191	191 x .2 = 38.2 ≈ **38**	191/320 = 0.596875 = 59.69%
4	133	106	106 x .2 = 21.2 ≈ **21**	106/320 = 0.33125 = 33.13%

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