Florida Field Naturalist

PUBLISHED BY THE FLORIDA ORNITHOLOGICAL SOCIETY

VOL. 47, NO. 1 MARCH 2019 PAGES 1-36

Florida Field Naturalist 47(1):1-14, 2019.

DISTRIBUTION AND POPULATION STATUS OF NESTING REDDISH EGRETS (*Egretta rufescens*) IN FLORIDA

W. ANDREW COX[1], AMY C. SCHWARZER[1], RICHARD KILTIE[1], ANN PAUL[2], MARK RACHAL[2], GINA M. KENT[3], KENNETH D. MEYER[3], AND JEROME J. LORENZ[4]

[1]*Fish and Wildlife Research Institute, Florida Fish and Wildlife Conservation Commission, Gainesville, Florida 32601*

[2]*Florida Coastal Islands Sanctuaries, Audubon Florida, Tampa, Florida 33619*

[3]*Avian Research and Conservation Institute, Gainesville, Florida 32601*

[4]*Everglades Science Center, Audubon Florida, Tavernier, Florida 33070*

Abstract.—The Reddish Egret (*Egretta rufescens*) recently received a state-listing status of Threatened in Florida because of its small population size, recent local population declines, and restricted distribution. We implemented a statewide survey of nesting Reddish Egrets during the 2016 breeding season to estimate population size as a baseline for monitoring and to identify the largest breeding colonies to help prioritize management activities in Florida. We first prioritized potential breeding sites based on historical data, then used a combination of direct counts (i.e., counts performed by walking into a colony or by slowly circling a site in a boat), flight-line surveys (i.e., counting adults flying to and from breeding sites), and nonstandardized surveys to estimate the number of breeding pairs at 305 wading-bird breeding sites throughout Florida. Fifty-eight of the 305 sites surveyed (19%) had at least one nesting pair of Reddish Egrets. Birds were fairly evenly distributed across identified core nesting areas, with 78-86 pairs in southwest Florida, 54-88 pairs in Florida Bay, 95 pairs in the lower Florida Keys, and 34-43 pairs in or near Merritt Island National Wildlife Refuge. No nesting birds were observed north of Merritt Island on the east coast or north of Cedar Key on the Gulf coast. The estimated population size after correcting for imperfect detection at sites with direct counts was 480 nesting pairs (95% CI: 375-606). Our study and past efforts differ in survey methodology, intensity, and analytical approach, which precludes a population trend analysis. Qualitatively, however, we note that our raw count (262-312 pairs) is substantially lower than that reported in past survey efforts and that we observed no colonies as large as the three largest colonies (28, 38,

and 54 pairs) documented in Florida Bay during 1977-1978. Regular monitoring to inform management and conservation actions is warranted for this rare species. The population estimate provided here should be a useful benchmark for tracking future population trends.

Keywords: abundance, *Egretta rufescens*, Florida, monitoring, population status, Reddish Egret

The Reddish Egret (*Egretta rufescens*) is North America's rarest heron. Distributed along the coasts of the Gulf of Mexico from Florida to Belize, throughout the West Indies, and near Baja California on Mexico's west coast, it has an an estimated global population of just 5,000-7,000 individuals (Green 2006). A coastal specialist that depends on shallow flats for foraging, the species was probably always relatively rare but was nearly extirpated from the United States by plume hunters in the early 1900s (Lowther and Paul 2002). In Florida, the species disappeared entirely sometime around 1908, then reappeared in Florida Bay in 1937 (Powell et al. 1989). The population then grew steadily until 1978, when researchers estimated that the Florida Bay population comprised 200-250 breeding adults (Powell et al. 1989). Nesting birds were discovered north of Florida Bay in the mid-1970s, and the population on Florida's southwest coast grew until at least 2004, when 98 nesting pairs were found in the Tampa Bay area (Hodgson and Paul 2011). The species now breeds in Florida Bay, the lower Florida Keys (Wilmers and Arnett 2004, Hill and Green 2011), in southwest Florida, from Cape Sable north to Cedar Key (Hodgson and Paul 2011, Cook 2014), and on the east coast, primarily on and near the Merritt Island National Wildlife Refuge (NWR), though isolated breeding records have been confirmed elsewhere as well (e.g., Rodgers and Schwikert 1986).

Reddish Egret nests have been monitored annually by boat and ground-based surveys in Tampa Bay for >30 years (Hodgson and Paul 2011), and monitoring began more recently in southwest Florida (Cook 2014). Monitoring has been less consistent elsewhere in the state, in part because the species' dark plumage and subcanopy nesting location make it extremely difficult to detect on aerial surveys (Rodgers et al. 2005). As such, an estimate of statewide population size that includes a measure of uncertainty has not been produced, and it is unknown whether there are large, stable colonies not currently being monitored or managed. Recent monitoring by Audubon Florida in Tampa Bay and Florida Bay suggests that both populations may now be declining (Lorenz and Paul, unpublished data), likely because of altered hydrology that reduces the quality of foraging habitat (e.g., Lorenz 2014a), human disturbance at nesting colonies (Hodgson and Paul 2011), and other anthropogenic factors such as continued coastal development and sea level rise.

The Florida Fish and Wildlife Conservation Commission (FWC) determined that the Reddish Egret met the criteria for listing as State Threatened (FWC 2016) because of its small population size, recent local declines, and restricted distribution (FWC 2013). The State also finalized a Species Action Plan for the Reddish Egret and other wading birds that called for the identification and monitoring of the most important breeding colonies across the state. We implemented a statewide survey of Reddish Egrets during the 2016 breeding season using a standardized protocol to provide a baseline population estimate for future population monitoring and to identify the largest breeding colonies to inform the prioritization of management activities in Florida.

Methods

Data collection.—We searched for breeding Reddish Egrets from November 2015 through June 2016 throughout coastal Florida. The earliest surveys were done in Florida Bay and the lower Florida Keys, where the breeding season starts earlier and extends longer than elsewhere in the state (Lowther and Paul 2002). The extent of Florida's coastline (~2,200 km), the logistical challenges associated with surveying coastal islands (e.g., weather, tides, cost), and the sparse, clumped distribution of Reddish Egrets precluded a stratified and/or randomized survey design. Instead, we focused our efforts on known colonial wading bird nesting sites with current or historical records of breeding Reddish Egrets, as well as places where suitable Reddish Egret nesting and foraging habitat occurred in proximity to each other. Sites included natural and dredge-spoil islands in estuarine, marine, and freshwater systems that were typically dominated by red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), and Brazilian pepper (*Schinus terebinthifolius*). Sites occurred primarily in each of four distinct core nesting areas: lower Florida Keys, Florida Bay, Merritt Island NWR, and Pinellas County south to Marco Island (hereafter, Southwest Florida; Fig. 1). Large stretches of Florida's coast have few or no recently documented records of nesting Reddish Egrets (e.g., the eastern Panhandle and Big Bend south to Cedar Key, Jacksonville south to Merritt Island, and Merritt Island south to Biscayne Bay), but to ensure that we were not missing breeding birds we worked with land managers, NGO staff, and other local experts to identify potential survey sites. We recognized that large mixed-species colonies of wading birds existed in the coastal habitats of Everglades National Park between Cape Sable (Florida Bay) and Marco Island that likely include Reddish Egret nesting. But these colonies are inaccessible by boat and are surveyed only from the air, precluding, as mentioned, documentation of Reddish Egret nesting numbers. Therefore, this area was not included in our estimates. We also reviewed records on eBird (ebird.org) for locations of adult birds during the breeding season and surveyed nearby potential breeding sites.

We developed the statewide survey framework for monitoring Reddish Egrets based on Cox et al. (2017). There we recommended that the survey method used at a particular site be chosen based on a site-prioritization process as well as more fundamental logistical constraints. The prioritization process arose from our effort to balance the trade-off between sampling extent (i.e., we wanted to visit undersampled sites and make sure we could identify range expansions and contractions) and intensity of effort (we wanted to sample a subset of sites twice so we could estimate variances). We prioritized sites using the following criteria: high, a site with high relative abundance and/or consistent

occupancy across recent years; medium, a site with infrequent or historical rather than recent nest records; and low, a site outside a core nesting area or with suspected low-quality nesting and/or nearby foraging habitat (i.e., few or no shallow flats; Lowther and Paul 2002) where nesting birds had not been previously documented. We surveyed high- and medium-priority sites at least twice within a short time period (i.e., usually within a week) when possible to allow for estimation of count variances. Low-priority sites were surveyed opportunistically and were rarely surveyed twice.

We could not adopt one survey protocol that suited all sites regardless of their prioritization rating because colonies occurred on properties owned and managed by federal, state, local, and private entities that allowed various degrees of access. In addition, nesting birds occupied habitat of varying structure (e.g., canopy height, vegetation density) on islands of variable size, and in some cases entry into a colony on foot would have caused undue disturbance to nesting birds. We therefore relied on two primary survey protocols for high- and medium-priority sites: direct counts (i.e., counts performed by walking into a colony or by slowly circling a small colony from a boat ~30 m offshore) and flight-line surveys (in which two to four observers station themselves on opposite sides of a site approximately 100 m from a colony and recorded all incoming and outgoing Reddish Egret flights for 2 h starting 1 h after sunrise). Most sites were surveyed twice within a week to estimate count variance. Detailed descriptions and assessments of direct counts and flight-line surveys may be found in Cox et al. (2017).

Unlike other sites, those in Florida Bay were usually surveyed >2 times over the course of the breeding season because we performed our surveys concurrent with a long-term Roseate Spoonbill (*Platalea ajaja*) monitoring program with repeated colony visits. The protocol for the Florida Bay sites is outlined in detail in Lorenz (2014b), but, briefly, we visited current and historic Roseate Spoonbill and Reddish Egret nesting colonies a minimum of three times per season, with early-season visits made every three weeks for sites known to have had nesting activity during the previous five years. We marked each active nest with a uniquely numbered 16- × 8-cm waterproof colored (red or blue) card attached with a spring-loaded clip to a tree near the nest, and revisited active colonies every 7-10 days until all nests failed or chicks became branchlings. Color tags have been used to mark nests in Florida Bay for >30 years and no evidence to date suggests that individual predators or predator populations have associated the tags with nests (J. Lorenz, pers. obs).

We adopted an unstandardized approach for surveying low-priority sites that allowed us to cover substantial ground in a relatively short time, survey at any time of day, and take advantage of the efforts of other research and monitoring groups in the state. These survey efforts were made in areas with confirmed but older nesting records, areas with verified records in public databases (e.g, eBird sightings) of the presence but not documented nesting of Reddish Egrets, and at sites proximate to adult Reddish Egrets whose flight lines suggested they were nesting. We included these surveys in our overall data set if the surveyor was confident that the survey was reliable. Some unstandardized surveys were performed via a slow, close pass in a kayak or outboard motor boat. In others, one person visited an island to search for nesting birds while a second watched the canopy for perching Reddish Egrets. In some cases we performed a 1- to 2-h flight-line survey in late morning or early afternoon to look for nesting birds. We returned to a site when possible to perform a standardized survey if we suspected or had confirmed that Reddish Egrets were breeding there.

Analysis.—For each site, one of four count types was used: 1) direct count, performed once or twice within a short time period (i.e., usually within a week); 2) flight-line survey, performed once or twice within a similarly short time period; 3) low-priority-site survey, performed once; and 4) direct count, repeated throughout the breeding season (Florida Bay), resulting in peak and total nest counts for each site rather than a snapshot estimate. We limited estimation of detection rates to sites with one or two direct

counts because the other data types were either amenable to estimating variances but not detectability or, as in the low-priority-site surveys, were not designed to estimate variances. Furthermore, we used detection rates to correct the raw counts only for those sites at which direct counts revealed nesting reddish egrets. This approach assumes that all zero counts were true zeros, which may be untrue to some extent. However, many of the sites had nesting wading birds but were clearly unsuitable for reddish egrets (e.g., limited vegetation that lacked their preferred understory). Furthermore, some sites did not appear to have any nesting wading birds, and a retrospective review of our data showed that reddish egrets rarely nested in the absence of other species (n=1 site). As such, applying corrections for detectability to the many sites where reddish egrets were not detected would have resulted in a gross overestimate of the state's Reddish Egret population size.

We estimated detection rates for the sites with direct counts using the double-observer model via generalized multinomial N-mixtures (Nichols et al. 2000, Royle 2004) with the *gmultmix* function from the *unmarked* library (Fiske and Chandler 2011) for the R statistical environment (R Core Team 2016). Data frames were first assembled with the *unmarkedFrameGMM* unmarked function with type = double and numPrimary = 1, hence availability was not estimated. Default limits of integration (K = max observed count + 100) were assumed, and the stability of model results against larger K (500) was confirmed. Four models were compared that differed only in the conditional distributions (Poisson or negative binomial) and in whether detection probability was assumed to be constant or region-specific (southwest Florida vs. Florida Keys), because we had different crews and general site characteristics in each region. Latent abundance (i.e., inferred abundance including individuals not detected) was assumed to be constant. We assessed goodness of fit by unmarked's *parboot* parametric bootstrap function of the sum of squared errors from the best model, with 250 simulations (Fiske and Chandler 2011). Confidence intervals for abundance and detection probability point estimates from the best double-observer model were obtained by parametric bootstrap with 1,000 simulations.

To obtain a population-size point estimate from the four data types, we summed the following: the point estimate from the best double-observer model for the direct count data, the mean value flight-line count from sites that received two surveys, the mean value of the peak and maximum counts from Florida Bay, and the counts from low-priority sites or sites that received a single flight-line survey. We then used a parametric bootstrapping to obtain a confidence interval around the resulting population size. One thousand parametric bootstrap simulations of the best double-observer model from the direct counts were performed to estimate the sum of the mean best unbiased predictors (unmarked function *bup*) of the posterior empirical Bayes estimates (unmarked function *ranef*) of latent site abundances. For each simulated total from double-observer models, the numbers of nests estimated by flight-line, low-priority surveys, and Florida Bay were added. For Florida Bay sites and for sites assessed by flight-line surveys where two estimates were made, one from each pair of site counts was excluded by 50-50 chance for each simulation, so that the uncertainty implied by differences in pairs of counts at each site was included in the uncertainty estimate for the grand estimated sum.

Results

We surveyed 305 sites throughout Florida for nesting Reddish Egrets (Fig. 1). Twelve sites were surveyed via flight-line survey, 9 (75%) of which were surveyed twice. One hundred thirty-three sites were surveyed via direct count, 28 (21%) of which were surveyed twice. Fifty-six sites were surveyed in Florida Bay, and

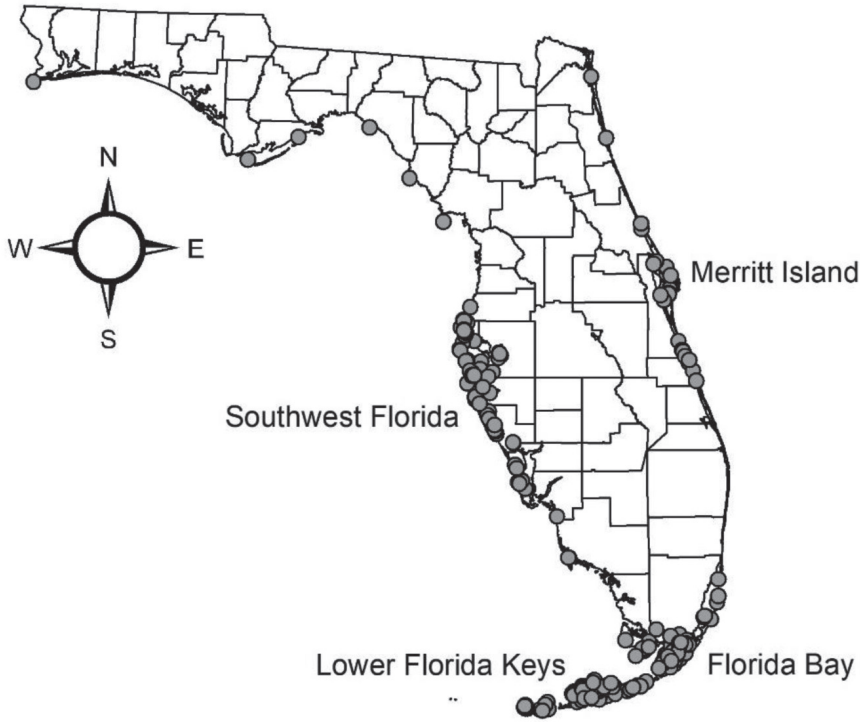

Figure 1. Locations of the 305 sites surveyed for nesting Reddish Egrets during the 2016 breeding season.

104 sites were surveyed by our team and external partners using unstandardized methods. Fifty-eight of the 305 sites (19%) had at least one nesting pair of Reddish Egrets (Table 1). Before accounting for detectability, 262-312 pairs were detected overall, with the range of values reflecting variability from sites that were surveyed twice via flight-line counts and from peak versus total nest counts from Florida Bay. The two largest colonies each had 23 pairs of nesting birds, but 29 sites (50%) had three or fewer pairs. Birds were fairly evenly distributed across the core nesting areas, with 78–86 pairs in southwest Florida, 54-88 pairs in Florida Bay, 95 pairs in the lower Florida Keys, and 34-43 pairs in or near Merritt Island National Wildlife Refuge (Fig. 2). No nesting birds were observed north of Merritt Island on the Atlantic coast or north of Cedar Key on the Gulf coast.

The best of the four double-observer models was one assuming a negative binomial conditional distribution and region-specific detection probabilities. The Akaike information criterion weight for this model

Table 1. Maximum number of nesting pairs (not corrected for detectability) and managing entities for sites with nesting Reddish Egrets during the 2016 breeding season. Table is sorted by Florida Fish and Wildlife Conservation Commission Management Region.

FWC Region	Site	Latitude	Longitude	Max. # of Pairs	Managing entities
North central	Snake Key	29.0964	−83.0309	2	Cedar Keys National Wildlife Refuge
Northeast	Mullethead Island	28.7262	−80.7701	23	Merritt Island National Wildlfe Refuge
	Banana North #1	28.5146	−80.6062	12	Merritt Island National Wildlfe Refuge
	Banana South #4	28.4875	−80.6209	4	Merritt Island National Wildlfe Refuge
	Tank Island	28.7031	−80.7979	3	Merritt Island National Wildlfe Refuge
	Big Island	28.6089	−80.6601	1	Merritt Island National Wildlfe Refuge
South	Little Saddlebunch #5	24.6045	−81.6210	23	The Nature Conservancy/Great White Heron National Wildlfe Refuge[a]
	Brews Key	25.0437	−80.7122	20	Everglades National Park
	Duck Key	25.1801	−80.4894	14	Everglades National Park
	Palm Key	25.1173	−80.8809	13	Everglades National Park
	Marco ABCs “B” middle	25.9566	−81.7040	10	Rookery Bay National Estuarine Research Reserve
	Picnic Key Mangrove SE	24.6336	−81.3931	9	Privately owned[b]
	Water Key Mangrove (cluster) 3	24.7469	−81.3458	9	Great White Heron National Wildlife Refuge[a]
	Arsenicker Key	25.3966	−80.2866	9	Biscayne Bay National Park
	Sandy Key	25.0347	−81.0140	9	Everglades National Park
	Central Jimmie	25.0493	−80.6471	8	Everglades National Park
	Upper Sugarloaf Sound	24.6426	−81.5460	7	Great White Heron National Wildlife Refuge[a]
	Coupon Bite Mangrove	24.6556	−81.3473	6	National Key Deer Refuge[a]
	Cudjoe Key Mangrove	24.6986	−81.4961	5	Great White Heron National Wildlife Refuge[a]

[a]Ownership not defined, so most geographically proximate managing entities are listed.
[b]Landowner information available at qPublic.net for Monroe County.
[c]Landowner information available at hcpafl.org for Hillsborough County.

Table 1. (Continued) Maximum number of nesting pairs (not corrected for detectability) and managing entities for sites with nesting Reddish Egrets during the 2016 breeding season. Table is sorted by Florida Fish and Wildlife Conservation Commission Management Region.

FWC Region	Site	Latitude	Longitude	Max. # of Pairs	Managing entities
North central	Snake Key	29.0964	–83.0309	2	Cedar Keys National Wildlife Refuge
	Pine Channel Mangrove SE	24.7072	–81.3977	5	National Key Deer Refuge[a]
	Green Heron Mangroves	24.7317	–81.5073	5	Great White Heron National Wildlife Refuge[a]
	Stake Key	25.0594	–80.5861	5	Everglades National Park
	Marco ABCs "A" west	25.9580	–81.7059	4	Rookery Bay National Estuarine Research Reserve
	Niles Channel Mangrove	24.7114	–81.4472	4	National Key Deer Refuge[a]
	Happy Jack	24.6857	–81.5686	3	Great White Heron National Wildlife Refuge/Monroe County[a]
	Howell Key Mangrove	24.6699	–81.4296	3	National Key Deer Refuge/Monroe County[a]
	Little Money Key	24.6855	–81.2267	3	Privately owned[b]
	Lil 1st Mate	25.0268	–80.6469	3	Everglades National Park
	Eagle Key	25.1680	–80.5963	3	Everglades National Park
	Marco ABCs "C" east	25.9555	–81.7012	2	Rookery Bay National Estuarine Research Reserve
	Boca Grande	24.5368	–82.0052	2	Key West National Wildlife Refuge
	Lower Sugarloaf Sound	24.6243	–81.5723	2	Florida Keys Wildlife and Environmental Area[a]
	Torch Key Mangrove N	24.7413	–81.4702	2	Great White Heron National Wildlife Refuge[a]
	Torch Key Mangrove SW	24.7332	–81.4730	2	Great White Heron National Wildlife Refuge[a]
	Budd NW	24.7211	–81.5122	1	Great White Heron National Wildlife Refuge[a]
	Johnston Key Mangroves SE mini	24.7097	–81.5785	1	Great White Heron National Wildlife Refuge[a]
	Galdin 3	24.7005	–81.5955	1	Great White Heron National Wildlife Refuge[a]
	Happy Jack Kiss	24.6854	–81.5758	1	Great White Heron National Wildlife Refuge[a]

[a]Ownership not defined, so most geographically proximate managing entities are listed.
[b]Landowner information available at qPublic.net for Monroe County.
[c]Landowner information available at hcpafl.org for Hillsborough County.

Table 1. (Continued) Maximum number of nesting pairs (not corrected for detectability) and managing entities for sites with nesting Reddish Egrets during the 2016 breeding season. Table is sorted by Florida Fish and Wildlife Conservation Commission Management Region.

FWC Region	Site	Latitude	Longitude	Max. # of Pairs	Managing entities
North central	Snake Key	29.0964	–83.0309	2	Cedar Keys National Wildlife Refuge
	Crane Key (Lower Keys)	24.7546	–81.5132	1	Great White Heron National Wildlife Refuge[a]
	Mangrove Key	25.3945	–80.3160	1	Biscayne Bay National Park
	Central Bob Allen Key	25.0319	–80.6784	1	Everglades National Park
	North Nest Key	25.1501	–80.5092	1	Everglades National Park
	Porjoe Key	25.1378	–80.4730	1	Everglades National Park
Southwest	White Pelican Island	26.7905	–82.2463	11	Navigational district, Audubon
	Useppa Broken Island North	26.6755	–82.1942	10	Florida
	Three Rooker Bar State Park	28.1106	–82.8370	9	Florida
	Richard T. Paul Alafia Bank	27.8470	–82.4176	7	Mosaic Fertilizer LCC, Port Tampa Bay, Audubon
	Cortez Key Bird Sanctuary	27.4622	–82.6828	5	Audubon
	Roberts Bay Bird Islands	27.2946	–82.5445	5	Florida, Audubon
	Clearwater Harbor I-25 Bird Island	27.9660	–82.8147	5	City of Clearwater, Audubon
	Coffeepot Bayou	27.7915	–82.6241	4	Bird Island Trust
	Manbirtee Key	27.6359	–82.5740	2	Port Manatee, Audubon
	Bonita Bay North Island	26.3431	–81.8239	2	Bonita Bay Home Owner's Association
	Alligator Lake Bird Island	27.9811	–82.6989	2	City of Safety Harbor
	Lost River	27.6916	–82.4977	2	Privately owned[c]
	St. Joseph Sound Marker 26	28.0755	–82.7999	2	Florida, Pinellas Aquatic Preserve, Audubon
	Belleair Beach	27.9132	–82.8422	1	Town of Belleair Beach
	Miguel Bay	27.5710	–82.5993	1	Florida, Terra Ceia Aquatic Preserve, Audubon

[a]Ownership not defined, so most geographically proximate managing entities are listed.
[b]Landowner information available at qPublic.net for Monroe County.
[c]Landowner information available at hcpafl.org for Hillsborough County.

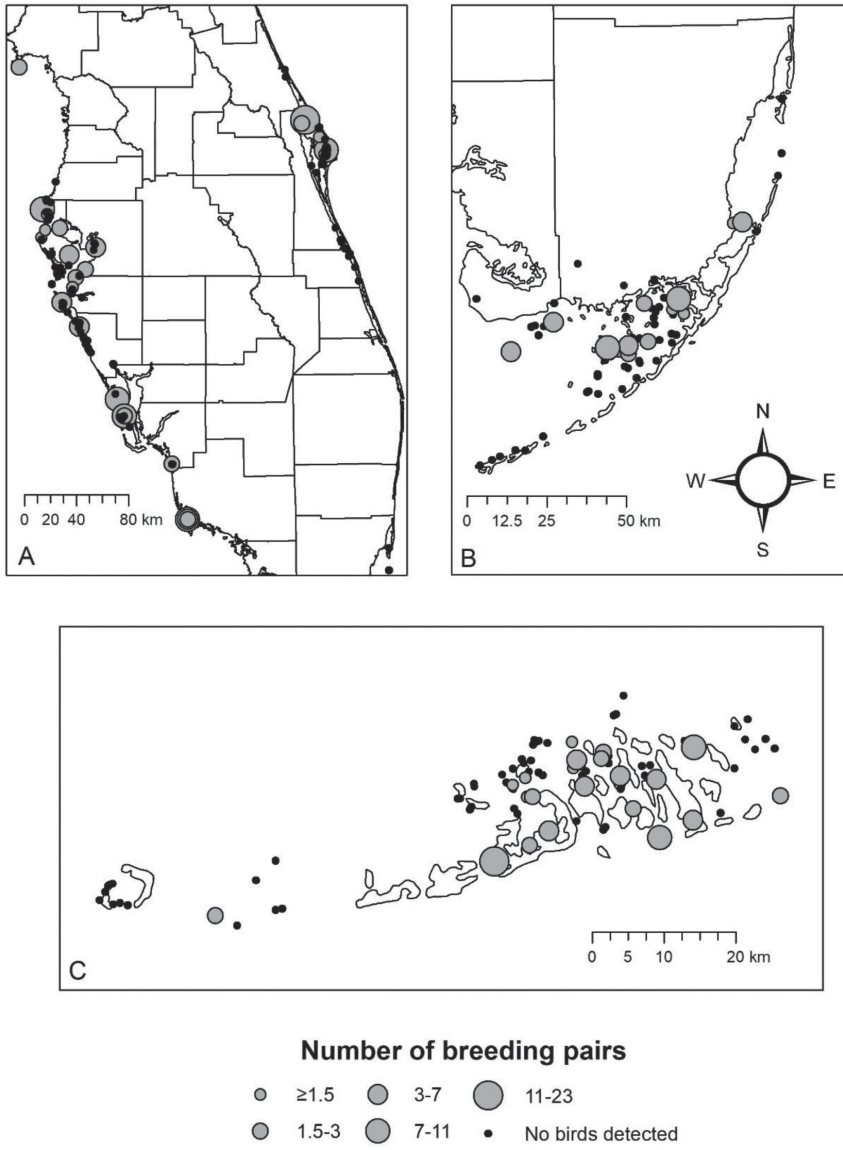

Figure 2. Locations and counts of nesting Reddish Egrets during the 2016 breeding season in (A) southwest Florida and Merritt Island NWR, (B) Florida Bay, and (C) the lower Florida Keys.

was 0.99, and goodness of fit was excellent (p = 0.59). After back-transformation, latent abundance was estimated to be 10.54 (95% CI: 7.26-14.82) for the sites counted by double-observer protocol, and

p(detection) = 0.77 (0.70–0.82) for the Florida Keys sites and 0.47 (0.27-0.61) for the southwest Florida sites. The bootstrapped point estimate of the sum for all sites was 480 (95% CI: 375-606).

Discussion

The subcanopy nesting location, the variability in nesting habitats and site-access permissions, and the extent of nesting habitat make the Reddish Egret an especially challenging bird to survey. The snapshot nature of our survey (i.e., sites outside of Florida Bay were often visited during just one week of the breeding season) likely missed birds that nested outside our survey window, and our effort cannot be considered truly comprehensive because it was simply not possible to visit all the nesting habitat along Florida's ~2,200 km of coastline. In particular, we failed to survey the region in southwest Florida between Cape Sable in Marco Island, where large mixed colonies exist that probably include Reddish Egrets but are inaccessible because they are so remote. Nevertheless, our approach, which prioritized sites based on known Reddish Egret occupancy and allowed for different count types performed by biologists from numerous organizations, produced a statewide estimate of nesting Reddish Egrets that incorporated detectability and other count variances to the extent possible and that was consistent with prior knowledge about the status of the species in Florida.

Our population estimate of 480 breeding pairs is greater than the last published estimate of 250-300 pairs (Green 2006), which was considered a best guess because of spatial and/or temporal gaps in survey coverage. It is also greater than a 1990 estimate of 400 pairs at 40 sites (R. T. Paul, as reported in Robertson and Woolfenden 1992). Qualitatively, however, we note that our raw count (262-312 pairs) is substantially lower than that reported in Robertson and Woolfenden (1992), that the number of pairs (100-125) estimated by Powell et al. (1989) in Florida Bay in 1977-1979 is greater than our estimate of 54-88 pairs. In addition, although we found birds nesting on five sites not documented by Powell et al. (1989), only six of 18 (33%) nesting sites active in 1977-1979 were still active in 2015-2016. Furthermore, our raw counts for Tampa Bay and southwest Florida in 2016 are substantially lower than those from the early 2000s (Hodgson and Paul 2011). Taken together, these facts suggest that regular monitoring of nesting Reddish Egrets is warranted until we can determine a statewide population trend with confidence. It will also allow managers to track regional populations to identify emergent issues within any of the core nesting areas.

Our survey effort was limited north of Cedar Key on the Gulf coast and north of Merritt Island on the Atlantic coast because eBird records and communications with land managers and other partners indicated

that few, if any, adult Reddish Egrets are found there during the breeding season. It is not entirely clear why that is so. Active colonies of wading birds exist in those areas, and, although Reddish Egrets require a specific foraging habitat (Lowther and Paul 2002, Bates et al. 2016), the presence of juveniles in northeast Florida and the Panhandle during the breeding season (W. A. Cox, unpublished data) and of adults in the Big Bend during the winter (W. A. Cox, pers. obs.) suggests that foraging habitat is available in some of those areas. It may be that prey availability is sufficient for self-maintenance but insufficient to raise young. Alternatively, nesting habitat may be a limiting factor, at least on the Big Bend and Panhandle coasts. Nevertheless, further northward expansion may be just a matter of time, as the species has moved steadily northward in Florida since recovering from extirpation in the early 1900s, only recently began breeding in the Cedar Keys National Wildlife Refuge (the northernmost location on Florida's Gulf coast), and has nested as far north on the Atlantic coast as South Carolina (Ferguson 2005). Any observed northward shift and/or range extension may be in response to climate change, as has been observed or projected for numerous other bird species (Zuckerberg et al. 2009, Wu et al. 2018). Regular monitoring of Reddish Egrets should allow for early detection of changes in the distribution of the species and provide an opportunity for climate resilient conservation planning and management. The degree to which climate change and concomitant sea-level rise will disrupt linkages between Reddish Egret foraging and breeding habitat is an open question that may also be informed by monitoring efforts.

Continued monitoring of Reddish Egret nesting sites across Florida will identify high priority breeding sites and is a necessary precursor to implementation of management actions that will benefit the species. For example, the substantial number of nesting birds in Florida Bay further reinforces the need to restore historical freshwater inputs from the Everglades to historic salinity levels to restore prey bases for nesting wading birds (Lorenz 2014a). Protecting colony sites in waterways popular with recreational boaters and fishermen by posting the perimeter of the colony and/or including a no-entry buffer area should prove beneficial as nesting Reddish Egrets appear to be particularly sensitive to disturbance by humans (A. Paul, pers. obs.). Finally, numerous sites in Tampa Bay that were historically occupied by Reddish Egrets and other wading birds have been abandoned in recent years because of the presence of predators such as raccoons (*Procyon lotor*). Targeted predator removal prior to the breeding seasons at these sites and additional active colonies may be warranted and should benefit Reddish Egrets. Reddish Egrets tend to be found in greater abundance in large colonies with greater species diversities (Cox et al. 2019), so management at the most important Reddish Egret colonies will also benefit numerous other wading birds.

Acknowledgments

Funding for this study was provided through the Florida State Wildlife Grants program (grant ID#FL-T-F15AF00394) in cooperation with the U.S. Fish and Wildlife Service, Wildlife and Sport Fish Restoration Program. Additional funding was provided by Florida's Non-game Wildlife Trust Fund. Housing and logistical support was provided by the Merritt Island National Wildlife Refuge, Biscayne Bay National Park, and the Florida Keys National Wildlife Refuge Complex. Additional in-kind support was provided by Avian Research and Conservation Institute and Audubon Florida. We thank Carol Cassels, Carolyn Enloe, Peter Frezza, Saskia Janes, Ed Kwater, Katie Malachowski, Amanda Powell, Carol Rizkalla, Suzy Roebling, and Ricardo Zambrano for their help in the field. We thank Anne Macias for her dedication to reddish egrets and for the use of her excellent photos. She will be missed. Janell Brush, Carol Rizkalla, and Mark Cook provided comments that improved earlier versions of this manuscript.

Literature Cited

Bates, E. M., L. M. Koczur, A. Krainyk, B. M. Ballard, and A. C. Kasner. 2016. Spatial and temporal dynamics of foraging habitat availability for Reddish Egrets in the Laguna Madre, Texas. International Journal of Biodiversity and Conservation 8:251-258.

Cook, M. I. 2014. South Florida Wading Bird Report. South Florida Water Management District, West Palm Beach.

Cox, W. A., A. Schwarzer, R. Kiltie, A. Paul, M. Rachal, G. M. Kent, K. D. Meyer, J. J. Lorenz, P. E. Frezza, H. Rafferty, and S. Roebling. 2017. Development of a survey protocol for monitoring Reddish Egrets (*Egretta rufescens*) in Florida, USA. Waterbirds 40:334-343.

Cox, W. A., B. Bankovich, K. Malachowski, A. C. Schwarzer, A. Paul, M. Rachal, J. J. Lorenz, K. D. Meyer, and G. M. Kent. 2019. Nest site selection by Reddish Egrets in Florida. Journal of Wildlife Management. 83:184-191.

Ferguson, L. M., P. G. Jodice, W. Post, and F. I. Sanders. 2005. Reddish Egret extends its breeding range along the North American Atlantic coast into South Carolina. Waterbirds 28:525-526.

Fiske, I., and R. B. Chandler. (2011). unmarked: An R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43:1-23.

FWC [Florida Fish and Wildlife Conservation Commission]. 2013. A Species Action Plan for Six Imperiled Wading Birds: Little Blue Heron, Reddish Egret, Roseate Spoonbill, Snowy Egret, Tricolored Heron, and White Ibis. Tallahassee.

FWC [Florida Fish and Wildlife Conservation Commission]. 2016. Florida's Imperiled Species Management Plan. Tallahassee.

Green, M. C. 2006. Status Report and Survey Recommendations on the Reddish Egret (*Egretta rufescens*). U.S. Fish and Wildlife Service, Atlanta, Georgia.

Hill, A., and C. Green. (2011). Reddish Egret (*Egretta rufescens*) in the lower Florida Keys. Journal of Heron Conservation 1:2-5.

Hodgson, A. B., and A. F. Paul. 2011. The Status of Reddish Egrets in Tampa Bay, Florida, USA 1974-2008. Audubon of Florida Coastal Islands Sanctuaries, Tampa. Challenge Cost Share Agreement #401818G564, Migratory Bird Program, U.S. Fish and Wildlife Service, Atlanta, Georgia.

Lorenz, J. J. 2014a. A review of the effects of altered hydrology and salinity on vertebrate fauna and their habitats in northeastern Florida Bay. Wetlands 34:189-200.

Lorenz, J. J. 2014b. The relationship between water level, prey availability and reproductive success of Roseate Spoonbills foraging in a seasonally flooded wetland while nesting in Florida Bay. Wetlands 34:201-211.

Lowther, P. E., and R. T. Paul. 2002. Reddish Egret (*Egretta rufescens*). The Birds of North America Online (A. Poole, Editor). Cornell Lab of Ornithology, Ithaca, New York. <https://doi.org/10.2173/bna.633>.

Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117:393-408.

Powell, G. V. N., R. D. Bjork, J. C. Ogden, R. T. Paul, A. H. Powell, and W. B. Robertson. 1989. Population trends in some Florida Bay wading birds. Wilson Bulletin 101:436-457.

R Core Team. 2016. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

Robertson, W. B., Jr., and G. Woolfenden. 1992. Florida Bird Species: An Annotated List. Florida Ornithological Society Special Publication No. 6, Gainesville.

Rodgers, J. A., Jr., P. S. Kubilis, and S. A. Nesbitt. 2005. Accuracy of aerial surveys of waterbird colonies. Waterbirds 28:230-237.

Rodgers, J. A., Jr., and S. T. Schwikert. 1986. Recolonization of Pelican Island by Reddish Egrets. Florida Field Naturalist 14:76-77.

Royle, J. A. 2004. Generalized estimators of avian abundance from count survey data. Animal Biodiversity and Conservation 27:375-386.

Wilmers, T., and J. Arnett. 2004. A Survey of Reddish Egrets in the Lower Florida Keys. Florida Keys National Wildlife Refuges, Big Pine Key, Florida.

Wu, J. X., C. B. Wilsey, L. Taylor, and G. W. Schuurman. 2018. Projected avifaunal responses to climate change across the U.S. National Park system. PLoS ONE 13:e0190557.

Zuckerberg, B., A. M. Woods, and W. F. Porter. 2009. Poleward shifts in breeding bird distributions in New York State. Global Change Biology 15:1866-1883.