

SATELLITE TRACKING OF JUVENILE REDDISH EGRET (*EGRETTA*
RUFESCENS) DISPERSAL AND SITE FIDELITY

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SATELLITE TRACKING OF JUVENILE REDDISH EGRET (*EGRETTA*
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ABSTRACT

**SATELLITE TRACKING OF JUVENILE REDDISH EGRET (*EGRETTA
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Information concerning all age classes of a species is essential for a thorough understanding of population dynamics, especially in taxa such as waterbirds that exhibit delayed sexual maturity. Data on the life history of juvenile Reddish Egrets (*Egretta rufescens*) are scarce, with many aspects of its ecology lacking information completely. Information pertaining to post-fledging dispersal is integral to the development of effective conservation planning. In addition to providing this basic information about the species, knowledge of differences in movements between the two plumage morphs could illuminate additional mechanisms that influence the maintenance of plumage

dimorphism. For this thesis project, I measured the movements, dispersal and survival of juvenile Reddish Egrets using satellite telemetry. Data on 25 juveniles from the Texas coast were collected from mid-June 2010 to October 2011. Initial dispersal events were erratic and unpredictable as the birds explored their surroundings, but movements decreased as the winter of 2010 began and individuals settled on wintering grounds along the Texas coast, as well as in Florida and Tamaulipas. In general, movements were less in spring and summer 2011 relative to the previous fall and winter, as most individuals did not have a second exploratory period after their first winter. While most birds remained in the general vicinity of their natal region, the Laguna Madre, longer dispersal events also occurred as some individuals moved to Louisiana and Florida. Site fidelity (19.52%) was comparable to other juvenile waterbirds, and the survival rate of the deployed transmitters suggests that juvenile mortality may be high ($\hat{S} = 0.534$ from June 2010 – October 2011) in this population. Comparisons between the two plumage morphs, males and females, and natal colonies all yielded non-significant results, indicating that the particular circumstances of early life (initial competitive ability, inherent boldness, initial growth rate, etc.) are probably more important than plumage morph, sex, natal colony or body size in determining the dispersal habits of a particular individual. As a mostly resident species and obligate habitat specialist, Reddish Egrets are particularly vulnerable to the effects of sea level rise, coastal development, and the predicted increase in frequency and intensity of severe weather systems in the Gulf of Mexico. If foraging grounds are becoming increasingly unavailable, inexperienced juveniles may have difficulty establishing territories, leading to higher mortality due to exhaustion, starvation

or predation. This hypothesis holds implications not just for Reddish Egrets, the rarest heron in North America, but for the entire Laguna Madre ecosystem.

CHAPTER I: STUDY SPECIES



Dark and white morph Reddish Egrets in Great Inagua, Bahamas. Photo by Clay Green.

The Reddish Egret (*Egretta rufescens*) is a plumage-dimorphic, medium-sized heron species found along the coastal Gulf of Mexico and Pacific coast of Mexico in North America. Its range also extends southward into Central America and eastward to the islands of the Caribbean (Lowther and Paul 2002). Adults commonly weigh between 700-850 g and stand 70-80 cm tall (Lowther and Paul 2002). Individuals possess either all-white plumage or dark plumage consisting of a gray body with cinnamon lanceolate plumes on the neck and breast. “Pied” individuals are also known, retaining most of the appearances of the dark morph with symmetrical white primaries (Lowther and Paul

2002). The Texas population of Reddish Egrets, the largest in North America, nests primarily on coastal dredge-spoil islands from March to June amid low or dense vegetation (Lowther and Paul 2002, Tunnell Jr. and Judd 2002). Young hatch after about 28 days and leave the nest as quickly as 4 weeks later, beginning flight at about 6.5-7 weeks of age (Lowther and Paul 2002).

The Reddish Egret is North America's least studied heron, a surprising fact given its status as a species of concern and listing as threatened in several states and Mexico (Campbell 2003). Populations have increased since their decimation during the plume hunting trade of the mid-1800s, but the species is still far from common. Across its entire range, the species is estimated at < 3,000 breeding pairs, or about 7,000 individuals (Green 2006). We lack knowledge of many basic aspects of the species' life history, especially information involving survival and dispersal. In Texas, most postbreeding dispersal of adults trends northward immediately following nesting, from June to September. Southward movement predominates from October until the next nesting season (Paul 1991). Extreme dispersal events are known to occur: some banded male Reddish Egrets hatched on the Texas coast have been resighted in Central and South America (Telfair II and Swepston 1987, Green, unpubl. data). However, only about 4% of color banded Reddish Egrets in Texas have been resighted (Telfair II and Swepston 1987), so the frequency of these events is unknown.

The adaptive and ecological significance of plumage dimorphism in Reddish Egrets is of interest; especially intriguing is the clinal variation in the occurrence of plumage morphs. The ratio of dark and white morphs changes across the species' range, with no white morphs occurring in the western portion of the range (e.g. Baja California),

mostly (~90%) white morphs occurring in the Bahamas, and a more balanced ratio occurring in Texas and Tamaulipas, Mexico (Allen 1955, Bolen and Cottam 1975, Scott and Carbonell 1986, Howell and Pyle 1997, Green et al. 2011, Amy Turner, unpubl. data). Furthermore, recent molecular analyses reveals genetic differentiation across this cline as the Pacific population of Baja California, the central population of Texas and eastern Mexico, and the eastern population of Florida and the Bahamas are three genetically distinct populations (Hill et al. 2012). Potential differences between plumage morphs in their respective life histories are unclear, with some evidence for differences in foraging behavior (Green 2005, Green and Leberg 2005), but the discovery of potential differences in any additional ecological parameters could contribute to overall knowledge of intraspecific plumage-dimorphism and the evolutionary significance of its maintenance (Galeotti et al. 2003, Munday et al. 2003, Tickell 2003, Roulin 2004). Dispersal of individuals between these populations is thought to be rare, probably due to an inconsistent availability of suitable habitat between the regions (Hill et al. 2012). If this is true, the information gathered from this cohort will provide the ecological data to support the conclusions of Hill et al.'s (2012) recently acquired genetic data, which recommends the management of the species as three evolutionarily significant units (ESUs).

CHAPTER II: DISPERSAL AND MOVEMENTS

Dispersal, defined as the movement of an individual from its place of birth or a center of population density (Koford et al. 1994), is vital to the understanding of a species' ecology. Knowledge of an organism's dispersal capabilities is integral to the development of effective conservation strategies at the appropriate scales, especially in migratory birds where distances travelled may be great (Melvin et al. 1999). Some animals, however, exhibit low dispersal ability or strong site fidelity and may not be able to relocate to distant habitat when currently occupied areas face degradation (Warkentin et al. 1996). Knowledge of the dispersal of organisms at the species, population, and individual level should be a top priority to ensure that management occurs at an appropriate scale. If management is carried out incorrectly, highly mobile species could quickly leave the area under management and/or protection, largely nullifying the effort put forth; conversely, less mobile species could end up covering only a small amount of the land under observation, resulting in an over-expenditure of time, resources and effort.

Natal dispersal, defined as permanent movement away from a place of birth, may vary between sexes or age classes. Most differences in natal dispersal tendencies between groups of ecological interest concern predator or disease avoidance (Jackson et al. 1989, Brown and Brown 1992, Blakesley et al. 2006), location of new habitat due to competition (Greenwood et al. 1979), inherited exploratory tendencies (Greenwood et al. 1979, Dingemanse et al. 2002), or as a precaution against inbreeding in the future

(Greenwood 1980). One general assumption often made about bird populations is that females tend to disperse further than males, but this is not always the case (Greenwood 1980, Forero et al. 2002). In order to avoid making erroneous assumptions such as this about a relatively unknown species or population of interest, one must observe individuals directly.

Since dispersal trends vary greatly among related bird species (Melvin et al. 1999) and even among individuals of the same species (Dingemanse et al. 2003); direct observations of individuals are needed in order to obtain reliable information. Dispersal data are most commonly collected through banding programs, requiring extensive resighting effort to collect information beyond what is obtained at the time of capture. This practice has several limitations, most of which result in low rates of resighting or recapture. In the case of species that are known to travel great distances, researchers are limited in their ability to personally relocate all members of a banded study cohort. These researchers are then forced to rely on chance encounters by birders or other banders, potentially compromising the reliability of reported data (Monadjem et al. 2008). Additionally, birds of interest may travel to areas inaccessible to observers, substantially lowering the probability of their relocation. Because of these complications, telemetry has become popular among scientists interested in animal movements, especially as affordability of studies increases through continuing advances in transmitter technology.

The primary objective of this research was to examine natal dispersal in juvenile Reddish Egrets and determine the effects of sex, plumage morph, and body size on movements. Movement rate, total distance traveled and maximum dispersal distance were all measured for each bird and compared across subgroups of interest (plumage

morphs, sexes, etc.). Movement rate is of interest because it provides insight into time and energy budgets of an organism. If a nearby area that contains abundant resources becomes available, it is assumed that an individual will establish a territory there and remain stationary, conserving energy (Smith 1978, Greenwood and Harvey 1982). High levels of movement could be indicative of a dearth of quality habitat, or high levels of competition at quality habitat within which an inexperienced juvenile cannot out-compete more established adults (Greenwood et al. 1979).

METHODS

Capture, Transmitter Attachment and Data Download

Field work for this project began in May 2010. The Laguna Madre, a hypersaline lagoon comprising about 209 km of Texas coastline, served as the primary site of Reddish Egret capture. The upper Laguna Madre extends from Corpus Christi Bay to the lagoon's 32 km partition, Saltillo Flats. South of this sand flat region, the lower Laguna Madre runs southerly to Port Isabel, near the U.S./Mexico border. Boats were commonly launched from Bird Island Basin (27.473° N, 97.309° W) when exploring the upper Laguna Madre, while a public boat launch in the town of Port Mansfield, TX (26.556° N, 97.429° W) was usually used for trips to the lower Laguna Madre.

The majority of Texas Reddish Egrets breed within the Laguna Madre, and several islands at which previous Reddish Egret research has been done were revisited for this project (Holderby et al., in press). Among the common vegetation of these dredge spoil islands is saltwort (*Batis maritima*), sea oxeye daisy (*Borrchia frutescens*),

Sesuvium spp. and various species of goosefoot (Chenopodiaceae), sedge (Cyperaceae) and grasses (Poaceae). Other species found among Reddish Egrets within the waterbird colonies mostly include Tricolored Herons (*Egretta tricolor*), Brown Pelicans (*Pelecanus occidentalis*), Laughing Gulls (*Leucophaeus atricilla*), various tern species (Sternidae) and Black Skimmers (*Rynchops niger*), though other species were occasionally encountered. Islands were surveyed frequently before the capture period to assess Reddish Egret nesting status at each waterbird colony. Once young birds large enough for capture were found on an island, the boat was anchored at a suitable distance to minimize disturbance of the colony (usually ~50 m). After wading to the island, field workers approached a juvenile until it was apparent that the bird was not yet capable of strong flight. Birds were then captured on the ground using a landing net and brought back to the boat for transmitter attachment; twenty-five birds were caught using this method. Birds monitored in this study were captured from Rabbit Island (27.246° N, 97.414° W), Dubbs Island (26.721° N, 97.427° W), Rubbersnake Island (27.286° N, 97.406° W) and North Island on Long Reef (28.076° N, 96.966° W). Some of these island names are used commonly by managers working on the Texas coast, while others are used colloquially by smaller teams of researchers (Texas Colonial Waterbird Society, unpubl. data).

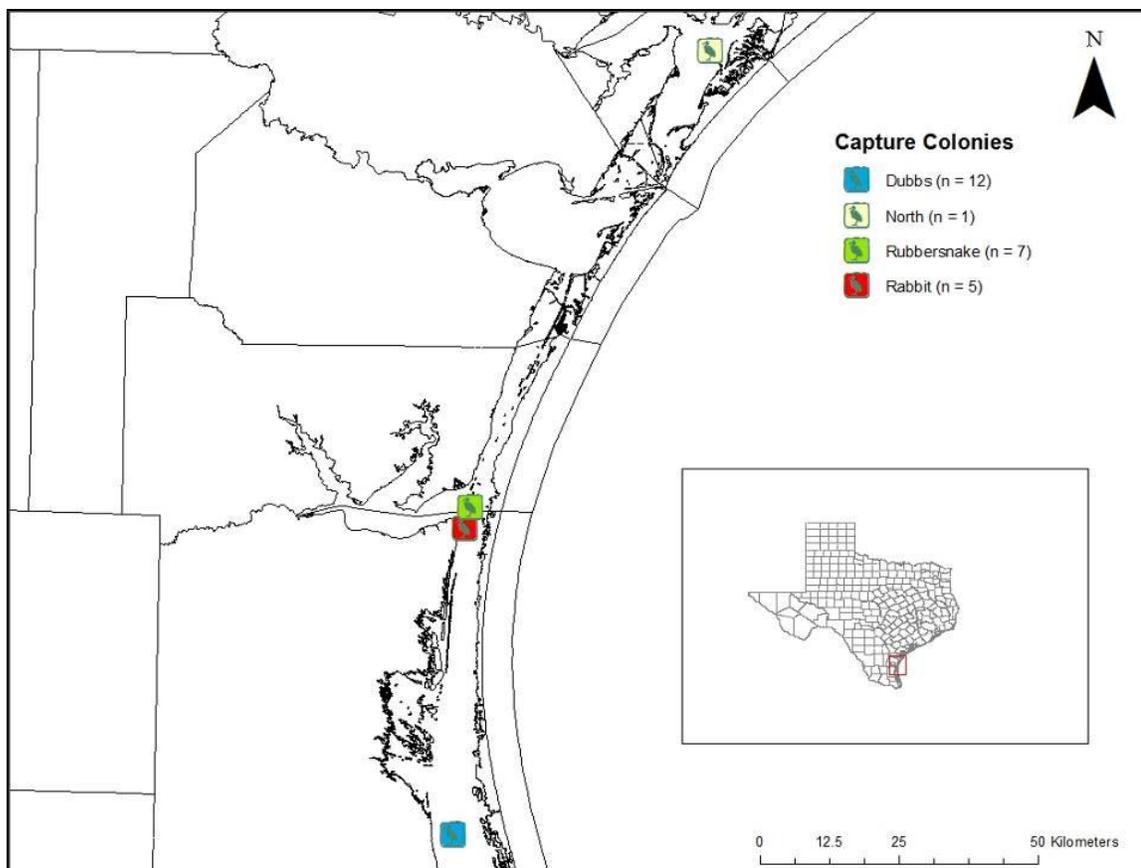


Figure 1. Capture sites for juvenile Reddish Egrets along the lower Texas coast in 2010.

Each individual was fitted with a 12g solar-powered satellite-received transmitter (PTTs; Microwave Telemetry, Columbia, Maryland) mounted on a backpack-style harness made of Teflon ribbon and fabric-surfaced rubber composite material. Enough slack was left in the harnesses to allow room for the birds to grow without interference. The full apparatus was < 4% of any bird's total weight, well within the advised requirements for telemetric studies of avian species (Caccamise and Hedin 1985). Efforts were made to minimize handling time in order to avoid unnecessary stress on the birds. No birds were held for > 40 mins, with some being released within 15 mins. After being

released, individuals were observed for a few minutes to ensure that its normal movements and activities were not obstructed by the transmitter and/or backpack.

The transmitters possess a 10 hr on/48 hr off duty cycle, producing about one high-quality (see below) location per cycle. Data were collected using the Argos data collection system (CLS America, Inc., Largo, Maryland), which uses satellites to relay data from the transmitters to ground stations. From the ground stations, datasets are sent to Argos Processing Centers and loaded onto the ArgosWeb servers for download. Though several formats are available, our data were downloaded as '.xls' files for use in Microsoft Excel. As Excel spreadsheets, information can be easily formatted into attribute tables in geographic information system (GIS) software; these tables were then used to create overlays as electronic shapefiles.

Bird locations (latitude/longitude) were reported in one of six classes, each of which was associated with an error radius. Location points that use ≥ 4 satellite messages in their calculation by Argos receive a rating from 0-3 and a corresponding error radius. Points that used ≤ 3 messages were classified as "B" or "A" and their locations were considered unreliable. Once mapped in ArcGIS, data points were sorted by these classes. The top two location classes, 3 and 2, are respectively associated with points that have 250 m and 500 m error radii. Only locations with these ratings were used in dispersal and site fidelity analyses, as all other classes of data possess error radii that are too large for their locations to be reliable, making them unsuitable for our measurements. All field protocols have been approved by the Institutional Animal Use and Care Committee at Texas State University (#0931_1015_35).

Sex Determination

One or two retrices were removed from each captured bird to be used for genetic sex determination. Reddish Egrets cannot be visually sexed in the field, so the extraction and amplification of DNA from these feathers is necessary for sexing. Approximately 1 cm of each feather's shaft was clipped from the bottom and split lengthwise. These halves were then cut twice and placed into a 1.5mL centrifuge tube containing 300 μ L of Puregene cell lysis solution. Extraction procedures from Gentra Systems' Puregene Genomic DNA Purification Kit protocol for fresh or frozen solid tissue were then followed to complete the isolation of the DNA.

Individuals were sexed using primers 2250F and 2718R as proposed by Fridolfsson & Ellegren (1999). PCR reactions followed the methods of Fridolfsson & Ellegren (1999) but quantities were adjusted to 50 μ l volumes to accommodate the BIO-RAD PTC-100 thermocycler (Hill and Green, in review). Some feather samples contained less DNA than others, so the PCR solution was occasionally modified (additional DNA added, cycles increased) to increase yield. Once PCR successfully produced a usable sample, gel electrophoresis was conducted in 2% agarose gel with Tris-EDTA buffer at 95 mV to visualize bands. Gels were stained with ethidium bromide and viewed under ultraviolet light in a Kodak Gel Logic 200 Imaging System.

Dispersal Analysis

Raw location files were imported into ArcGIS 9.3.1 and trimmed to contain only high-quality locations (classes 3 or 2). The Hawth's Analysis Tools package (Beyer 2004) was used to connect data points in chronological order using the 'Convert

Locations to Paths (points to lines)' tool in the Animal Movements toolset. These movement path lines can then be measured in ArcMap. Total movement (km) and average movement rate (km/day) were measured using these path lines, while maximum dispersal distance from natal colony (km) was measured using ArcMap's 'Measure' tool. This final measurement was calculated as the straight-line distance from the center of the natal colony to the furthest point.

Because the mechanical scale brought into the field did not possess a sufficiently high upper limit to accurately weigh all captured birds, body mass could not be used as a predictor variable in our analyses. Therefore, separate linear regressions were conducted to determine which of the structural variables showed the strongest relationship with body mass. Of tarsus, middle toe, and culmen length, tarsus showed this relationship best ($r^2 = 0.365$, $P = 0.001$) and was selected as the body size variable in subsequent analysis. Dispersal and movement measurements were then compared across sexes, plumage morphs and natal colonies, with the inclusion of tarsus length as a continuous body size variable, using analysis of covariance (ANCOVA). All statistical analyses were performed in program R version 2.13.0 (R Core Development Team 2011).

Table 1. Initial information collected on each transmitted bird.

<u>Transmitter #</u>	<u>Morph</u>	<u>Sex</u>	<u>Island Caught</u>	<u>Date Caught</u>	<u>Silver Band</u>	<u>Color Band</u>	<u>Mass (g)</u>	<u>Culmen (mm)</u>	<u>Tarsus (mm)</u>	<u>Middle Toe (mm)</u>	<u>Time Caught</u>	<u>Time Released</u>
59815	Dark	M	Dubbs	6/16/2010	1757-69859	E10	850	87.40	139.99	70.08	not recorded	not recorded
59874	Dark	M	Dubbs	6/16/2010	1757-69860	E20	920	83.95	149.90	66.19	0901	0926
59878	Dark	F	Dubbs	6/16/2010	1757-69861	E56	750	82.70	131.66	66.67	0948	1015
59828	White	F	Dubbs	6/16/2010	1757-69862	E85	360	81.16	123.90	59.87	1042	1100
59809	White	M	Dubbs	6/16/2010	1757-69863	E79	655	90.57	143.10	70.75	1148	1227
59814	White	M	Dubbs	6/16/2010	1757-69864	E36	785	84.96	139.55	74.20	1247	1309
59945	White	M	Dubbs	6/23/2010	1757-69855	E91	560	89.86	143.87	65.58	1715	1736
59937	Dark	M	Dubbs	6/23/2010	1757-69856	E16	910	89.99	141.66	70.05	1743	1821
59924	White	M	Dubbs	6/23/2010	1757-69857	E03	930	88.90	147.78	67.22	1827	1846
59944	Dark	M	Dubbs	6/23/2010	1757-69858	E83	960	82.22	142.60	67.62	1903	1921
59925	White	M	Dubbs	6/23/2010	1757-69865	E72	780	84.35	136.22	74.57	1934	1949
59911	Dark	M	Dubbs	6/23/2010	1757-69866	E89	820	87.05	136.95	65.25	1958	2013
59943	Dark	M	North Island - Long Reef	6/24/2010	1757-69867	E30	>1000	95.10	150.55	72.10	1008	not recorded
59942	Dark	M	Rubbersnake	7/8/2010	1757-69868	E06	>1000	91.10	145.65	65.12	1620	1649
59910	Dark	M	Rubbersnake	7/8/2010	1757-69869	E70	890	85.50	144.65	70.05	1710	1730
59848	White	F	Rubbersnake	7/8/2010	1757-69871	E68	730	79.86	132.15	62.45	1741	1755
59939	Dark	M	Rubbersnake	7/8/2010	1757-69872	E51	950	90.36	148.45	70.12	1805	1819
59941	White	F	Rubbersnake	7/8/2010	1757-69873	E46	900	90.00	144.45	66.75	1829	1846
59830	Dark	M	Rubbersnake	7/8/2010	1757-69874	E42	870	87.75	146.95	68.85	1856	1908
59824	Dark	M	Rabbit	7/9/2010	1757-69875	E26	670	73.52	125.52	65.40	0915	0930
59891	White	M	Rabbit	7/9/2010	1757-69876	E48	790	86.80	132.05	63.25	0936	0953
59950	White	M	Rabbit	7/9/2010	1757-69877	E12	770	74.40	125.05	64.95	1008	1020
59857	Dark	M	Rabbit	7/9/2010	1757-69878	E39	800	84.45	132.62	65.25	1027	1049
59977	White	M	Rabbit	7/9/2010	1757-69879	E92	870	88.55	146.25	69.92	1102	1117
59953	Dark	M	Rubbersnake	8/12/2010	1797-39365	E32	790	91.45	140.40	71.75	0915	0940

RESULTS

We captured and placed transmitters on 14 dark morph and 11 white morph birds. Twenty-one of the birds were male and 4 were female. Excluding one transmitter that failed almost immediately (#59891), transmitters produced an average of 364 (± 67) unique class 2 or 3 locations over the course of the 69-week observation period. Total distance traveled through the entire period averaged 916.62 km (SE: ± 132.90 km), or 2.97 km/day (± 0.468 km/day). The birds' maximum distances traveled from their natal colonies averaged 204.83 km (± 54.65 km), with 18 of the 24 maximum distances occurring before the end of 2010.

Most of the furthest movement records occurred south of an individual's natal colony and were predominately composed of visits or permanent relocations to Tamaulipas, Mexico. The five birds that remained in Mexico after arriving there were all dark-morph males from various colonies. Other long-distance movements included a northeast movement to eastern Louisiana, made by the dark-morph male (#59943) captured on North Island. This bird's transmitter failed on September 12, 2010 in the town of Luling, Louisiana and it is unknown if the bird perished there or continued to move eastward after transmitter failure. Finally, the longest movement, also northeast of its natal colony, was made by a dark-morph male (#59874) from Dubbs Island that settled on Little Saint George Island off the northern Florida Gulf Coast. Transmissions from the island began on November 19, 2010, and continued until this transmitter's failure or possible death of the individual on July 3, 2011.

Overall, movements were most common for the first 6 months of observation, after the birds were able to leave the natal colony for extended periods of time. Fourteen of the 23 birds did not return again to the vicinity of their natal colony during the total period of observation once they initially dispersed (see Chapter 2). Most departures from the natal colony occurred in late July-early August, with some exceptions. This immediate period of post-fledging dispersal was characterized by frequent relocations as the birds explored the coastal areas surrounding their natal areas. Beginning around early January, 2011, though, movements ceased almost entirely, and the birds appeared to settle down into wintering areas. Notable movements decreased during this period from 1.28 km/day during the ‘exploration’ period (7/10/10-12/31/10) to 0.15 km/day during winter and into spring (1/1/11-4/30/11). Movements appeared to increase as the birds’ second summer approached, but activity levels never reached the levels of the initial 6 months post-fledging.

Out of the entire cohort of 25 birds, 17 provided location transmissions that were sufficient to determine their general wintering grounds. Most of the birds wintered on the Texas coast or in Tamaulipas, Mexico, at an average distance of 122.94 km (\pm 20.48 km) from their natal colony. As previously mentioned, one bird settled in Florida and continued providing locations into the wintering period.

Comparisons between groups of interest yielded mostly non-significant results. No differences were found between groups for total distance traveled (Morph: $F_{1,17} = 1.18$, $P = 0.292$; Sex: $F_{1,17} = 2.60$, $P = 0.125$; Colony: $F_{2,17} = 1.53$, $P = 0.244$; Tarsus: $t = 1.30$, $P = 0.213$, Figure 3), maximum distance traveled (Morph: $F_{1,17} = 0.69$, $P = 0.417$; Sex: $F_{1,17} = 0.03$, $P = 0.874$; Colony: $F_{2,17} = 1.52$, $P = 0.248$; Tarsus: $t = 2.11$, $P =$

0.050, Figure 4) or movement rate (Morph: $F_{1,17} = 1.14$, $P = 0.300$; Sex: $F_{1,17} = 1.21$, $P = 0.287$; Colony: $F_{2,17} = 0.99$, $P = 0.392$; Tarsus: $t = 1.51$, $P = 0.149$, Figure 5).

Table 2. Movement and dispersal measurements for individual marked birds.

<u>Transmitter #</u>	<u>Morph</u>	<u>Sex</u>	<u>Natal Colony</u>	<u>Maximum Dispersal from Natal Colony(km)</u>	<u>Total Distance Traveled (km)</u>	<u>Movement Rate (km/day)</u>
59809	W	M	Dubbs	214	553.00	1.18
59814	W	M	Dubbs	131	365.00	2.01
59815	D	M	Dubbs	194	1417.94	2.99
59824	D	M	Rabbit	203	746.73	1.67
59828	W	F	Dubbs	112	1948.39	4.09
59830	D	M	Rubbersnake	51	237.06	0.84
59848	W	F	Rubbersnake	130	276.51	1.72
59857	D	M	Rabbit	55	463.78	1.04
59874	D	M	Dubbs	1262	2145.62	5.66
59878	D	F	Dubbs	220	1123.00	2.42
59891	W	M	Rabbit	n/a	n/a	n/a
59910	D	M	Rubbersnake	11	33.20	4.15
59911	D	M	Dubbs	244	1483.78	3.17
59924	W	M	Dubbs	324	609.86	2.48
59925	W	M	Dubbs	75	524.66	1.12
59937	D	M	Dubbs	84	849.32	1.81
59939	D	M	Rubbersnake	190	1692.83	3.74
59941	W	F	Rubbersnake	98	1687.69	3.73
59942	D	M	Rubbersnake	170	2088.74	4.61
59943	D	M	North	735	960.88	12.01
59944	D	M	Dubbs	85	914.03	1.96
59945	W	M	Dubbs	132	1103.19	2.36
59950	W	M	Rabbit	8	49.02	1.40
59953	D	M	Rubbersnake	53	292.39	2.56
59977	W	M	Rabbit	135	432.33	2.59
			<i>Mean</i>	204.83	916.62	2.97
			<i>Std. Error</i>	54.65	132.90	0.47

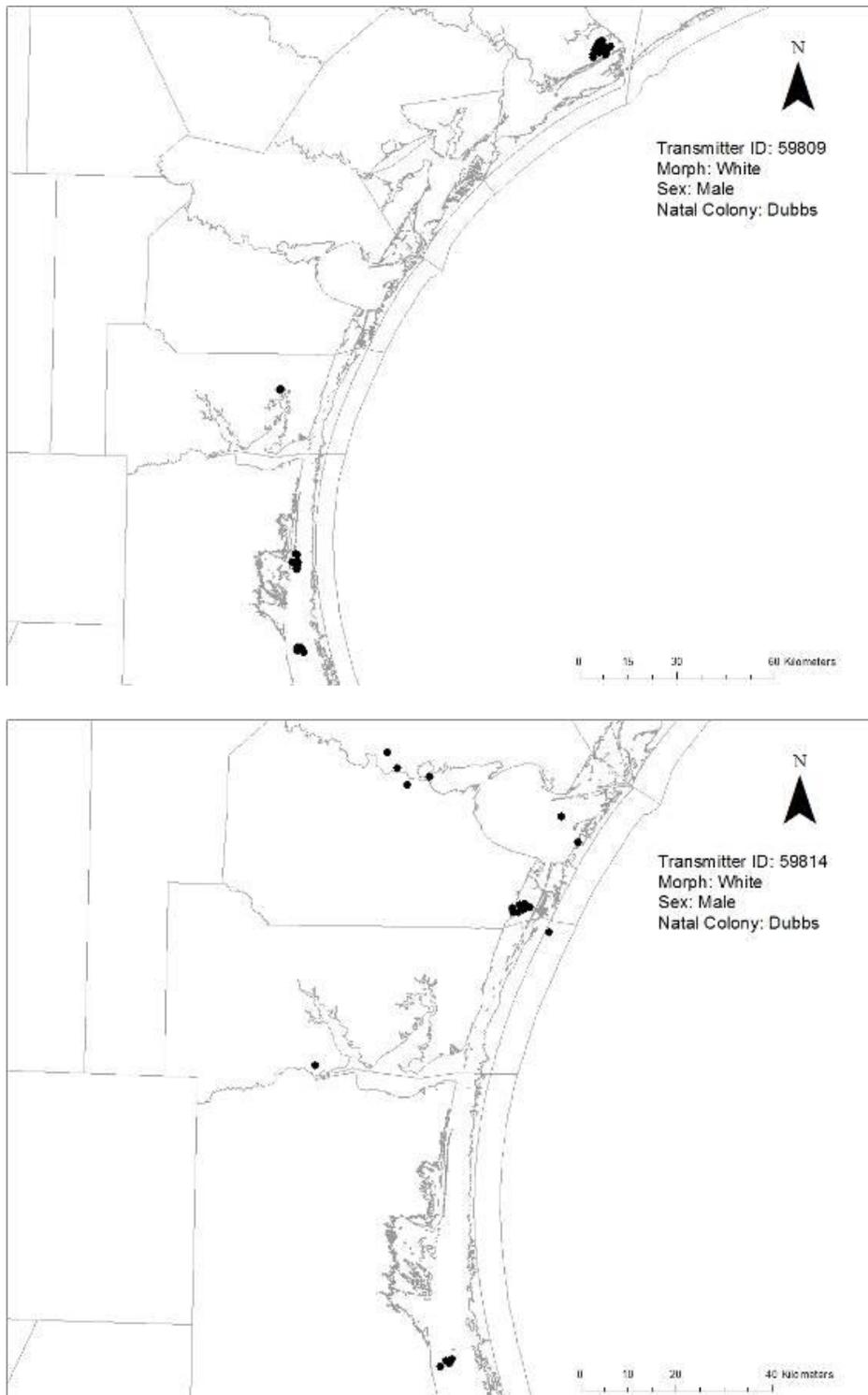


Figure 2. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

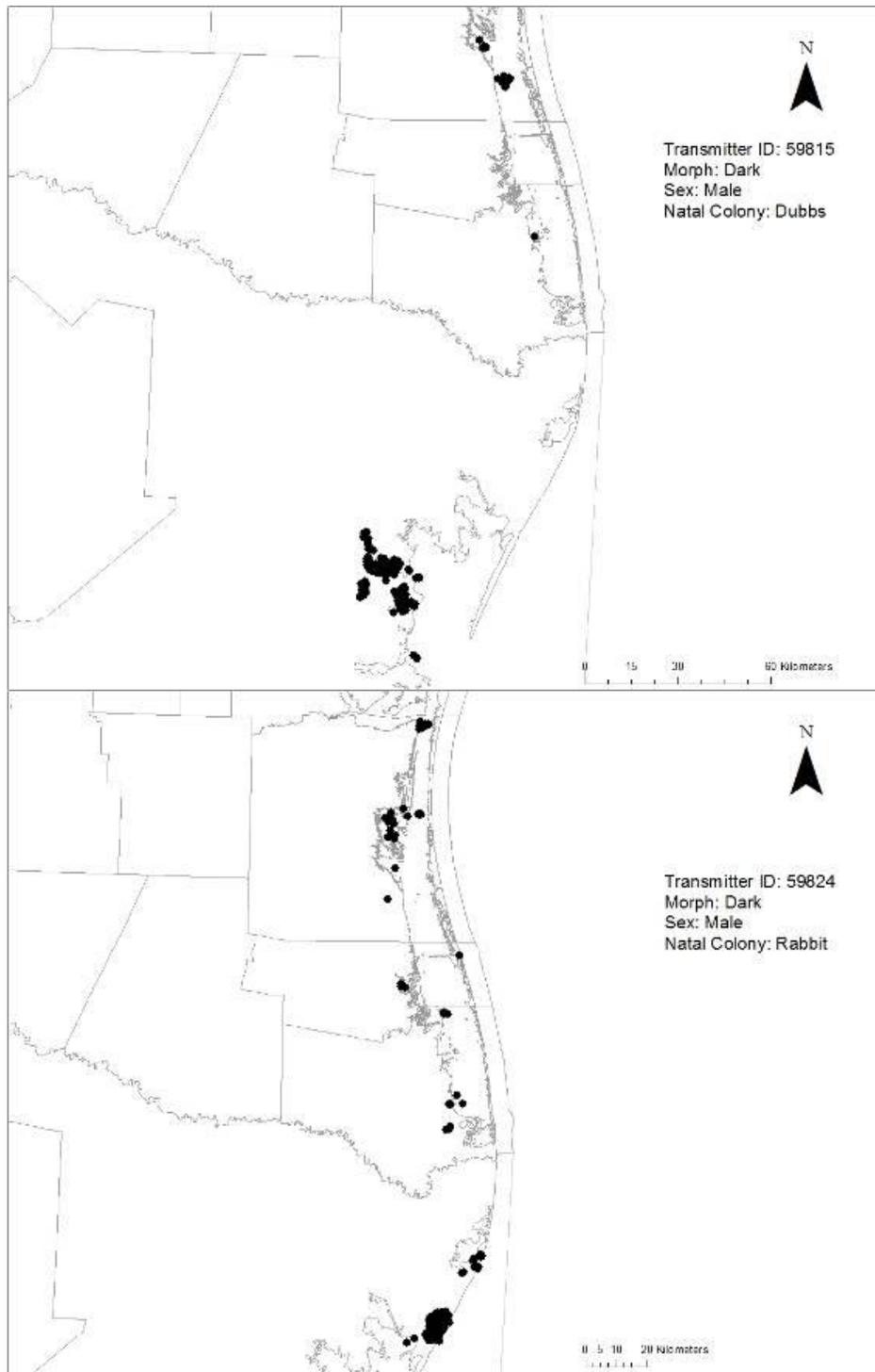


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

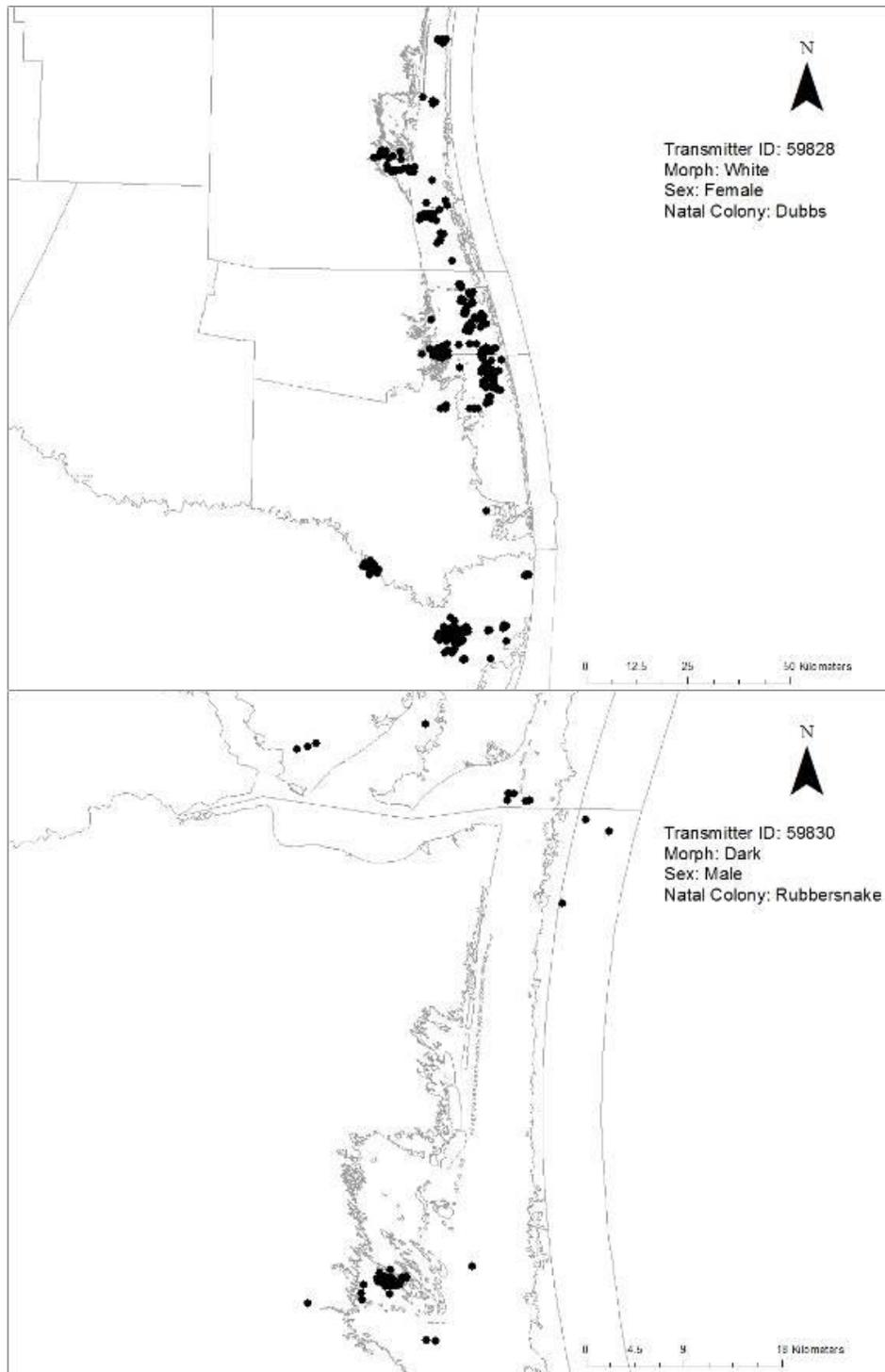


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

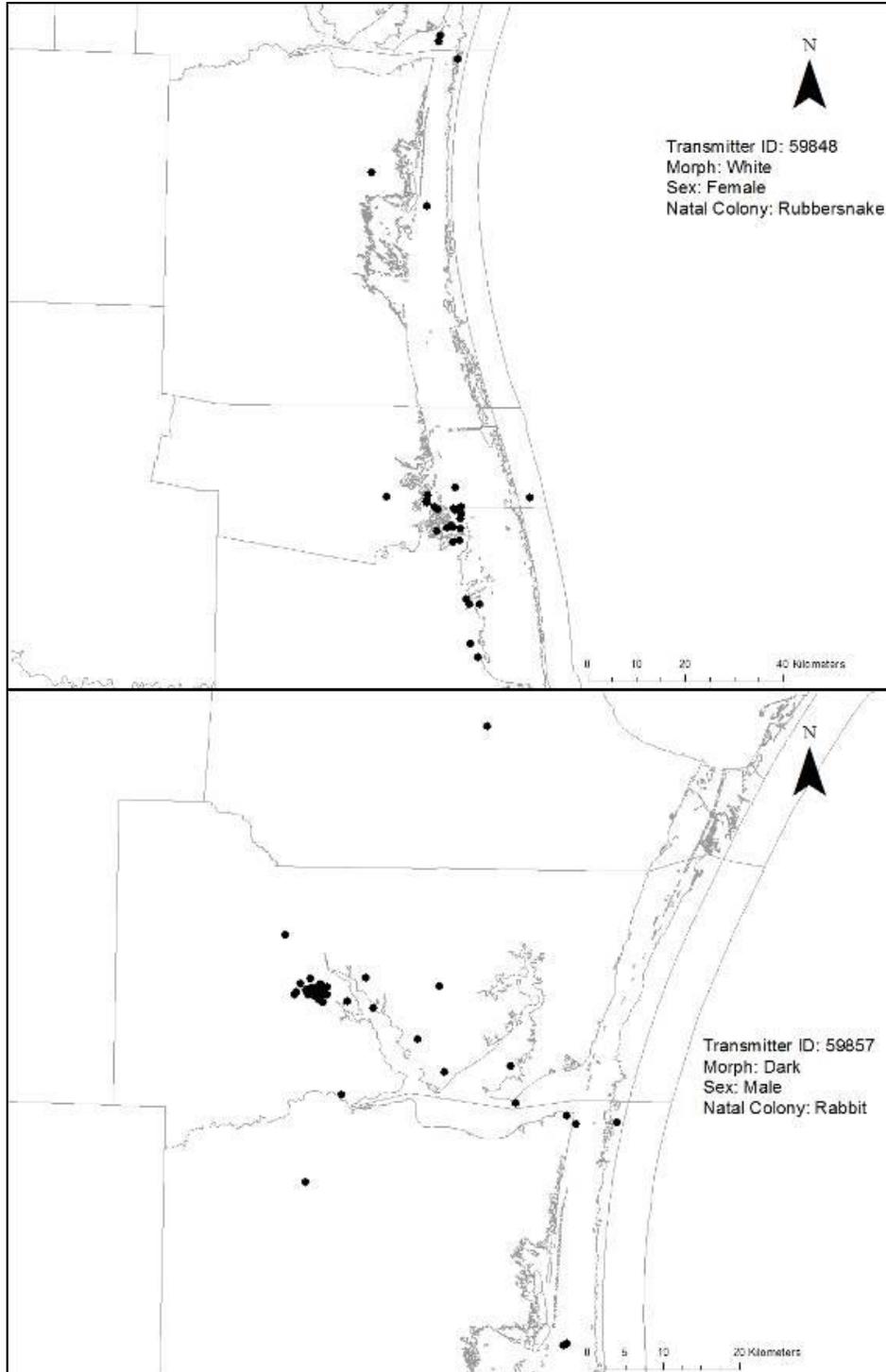


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

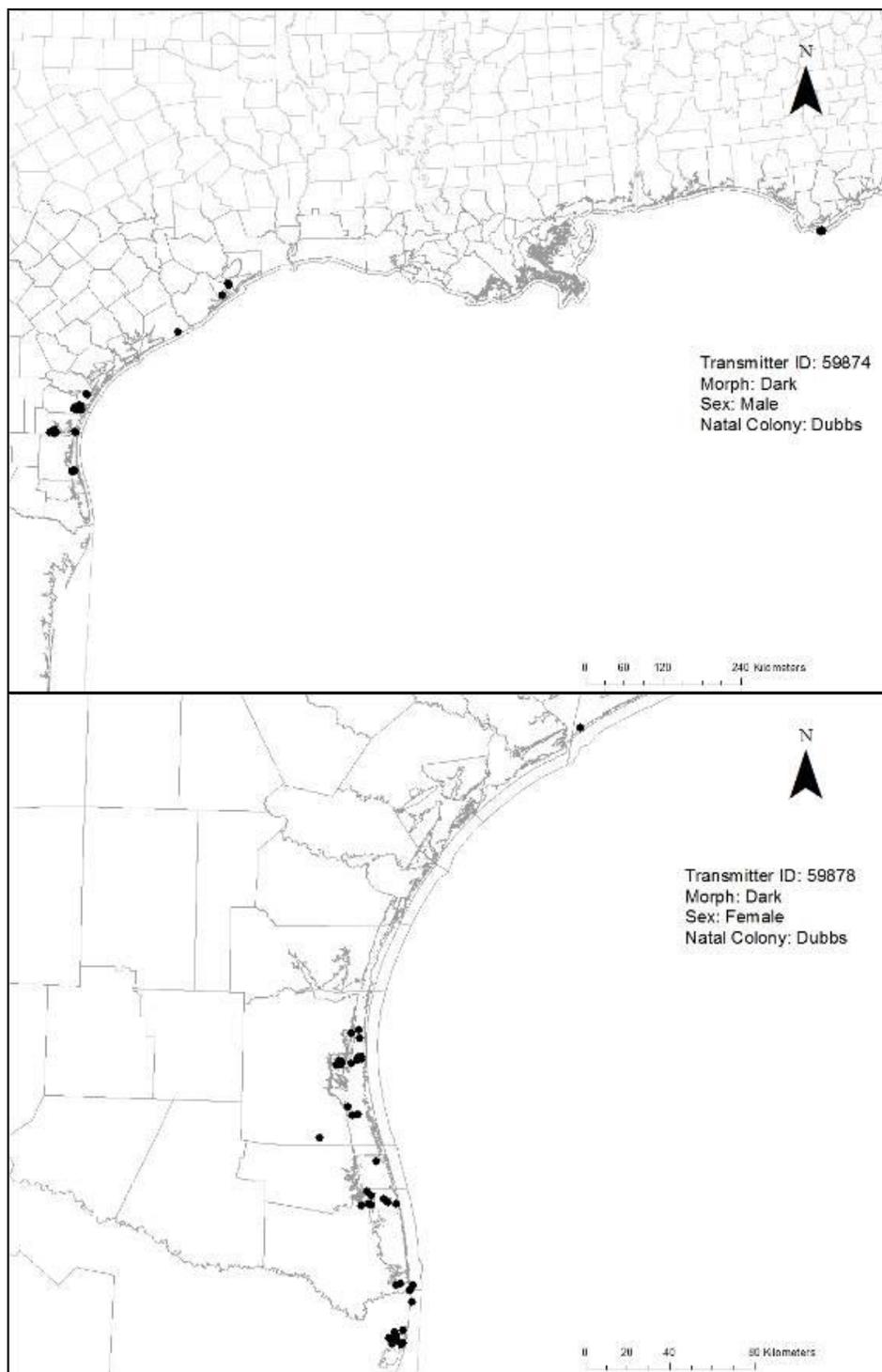


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

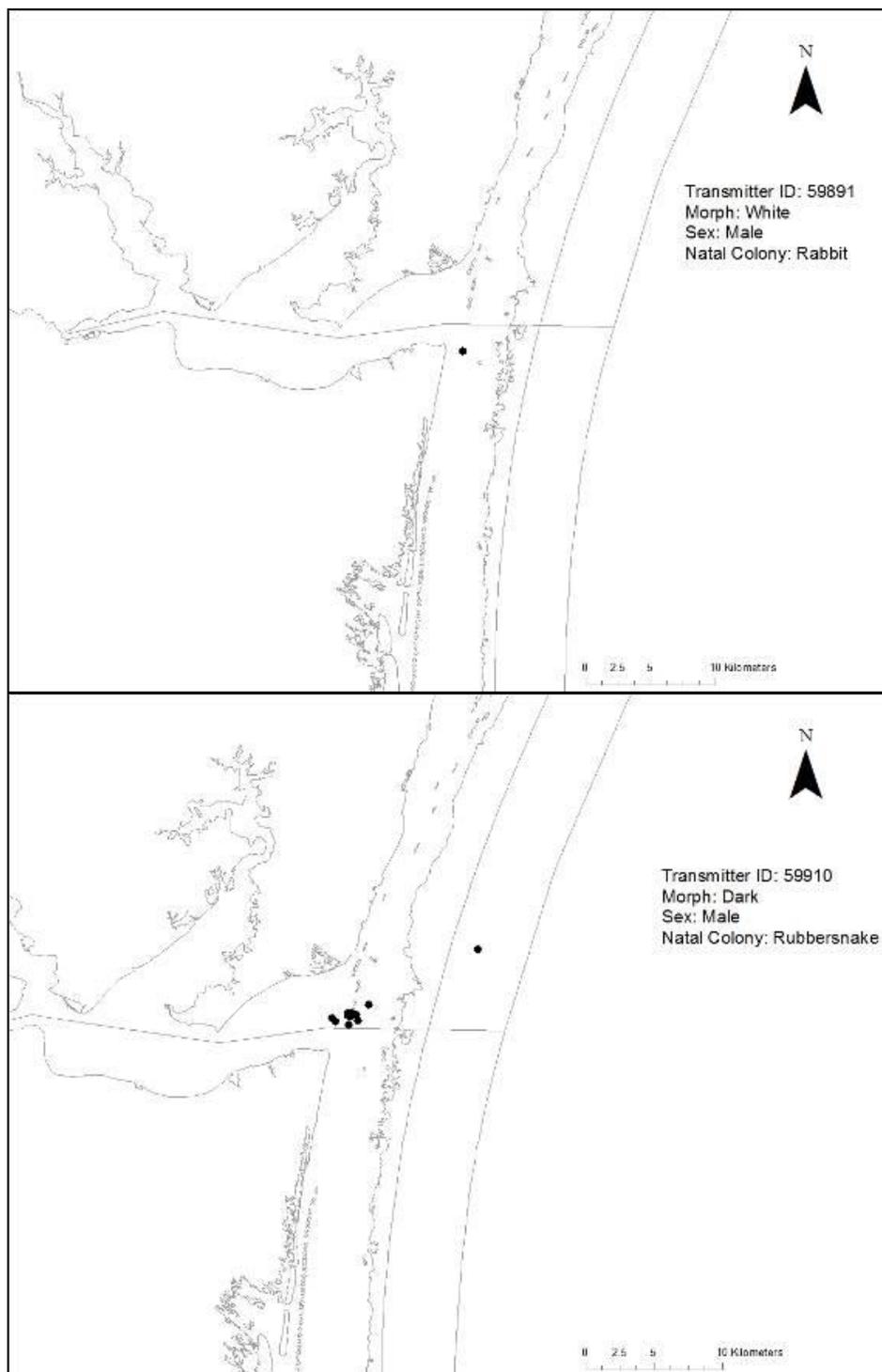


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

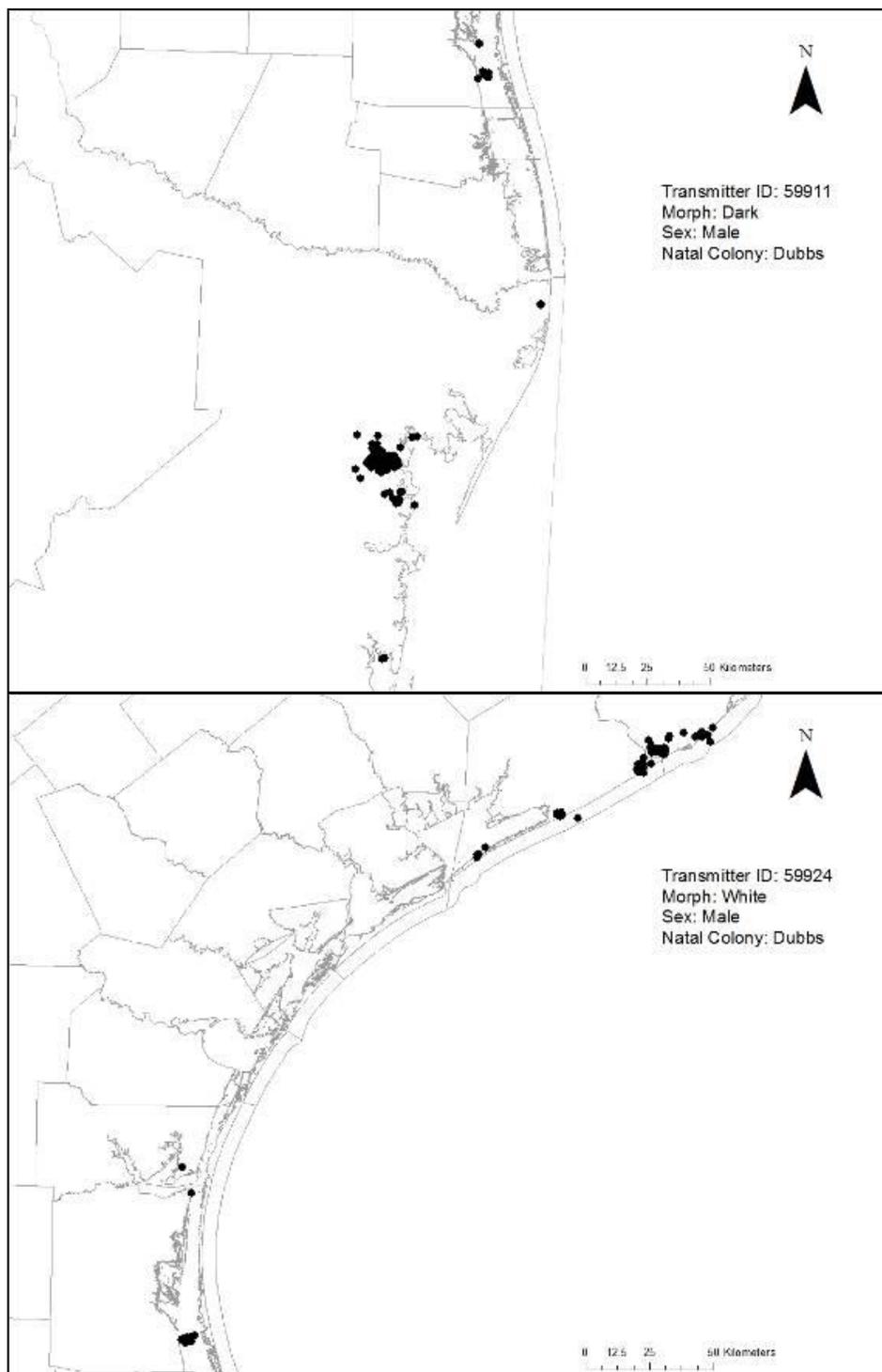


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

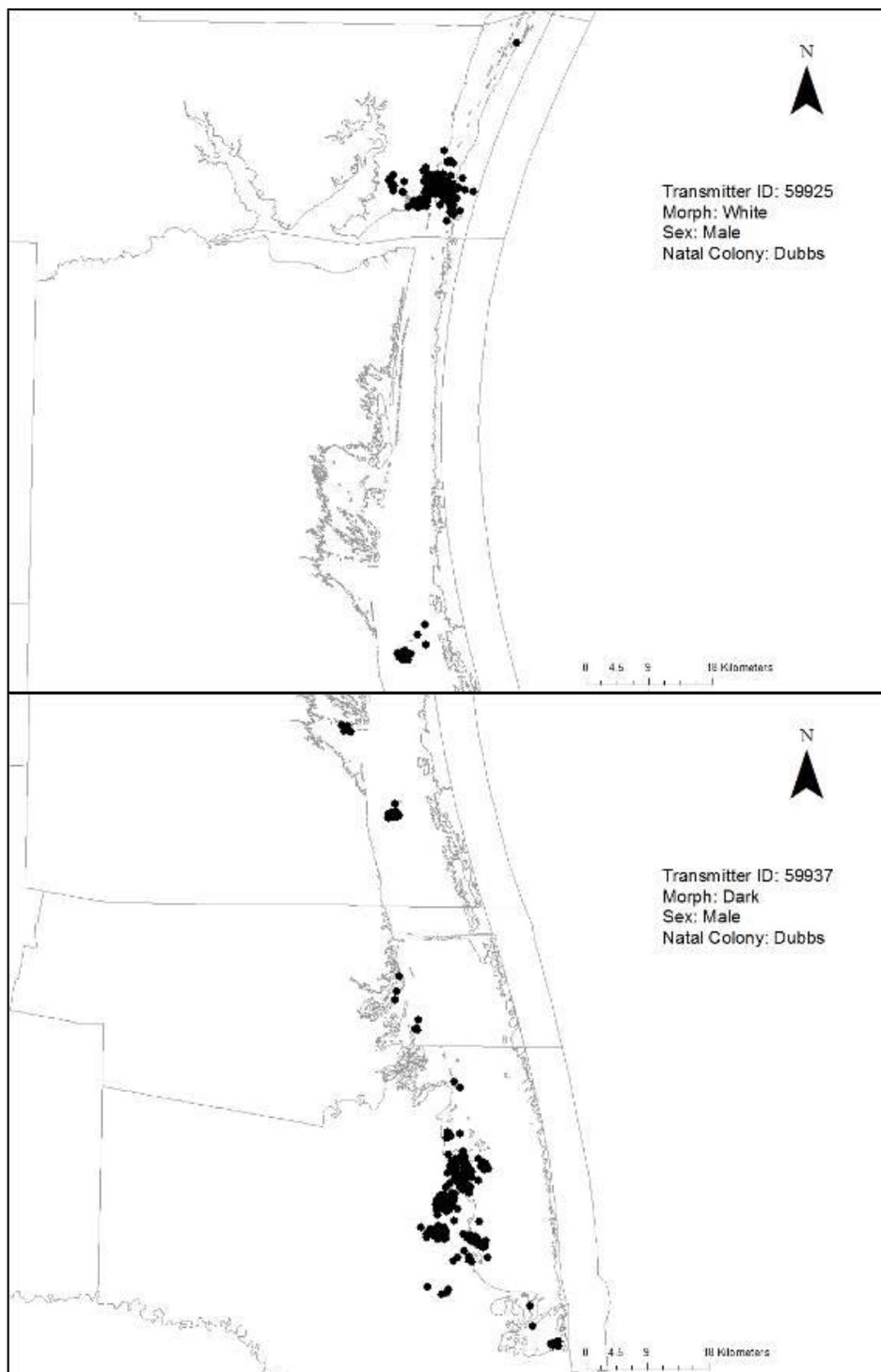


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

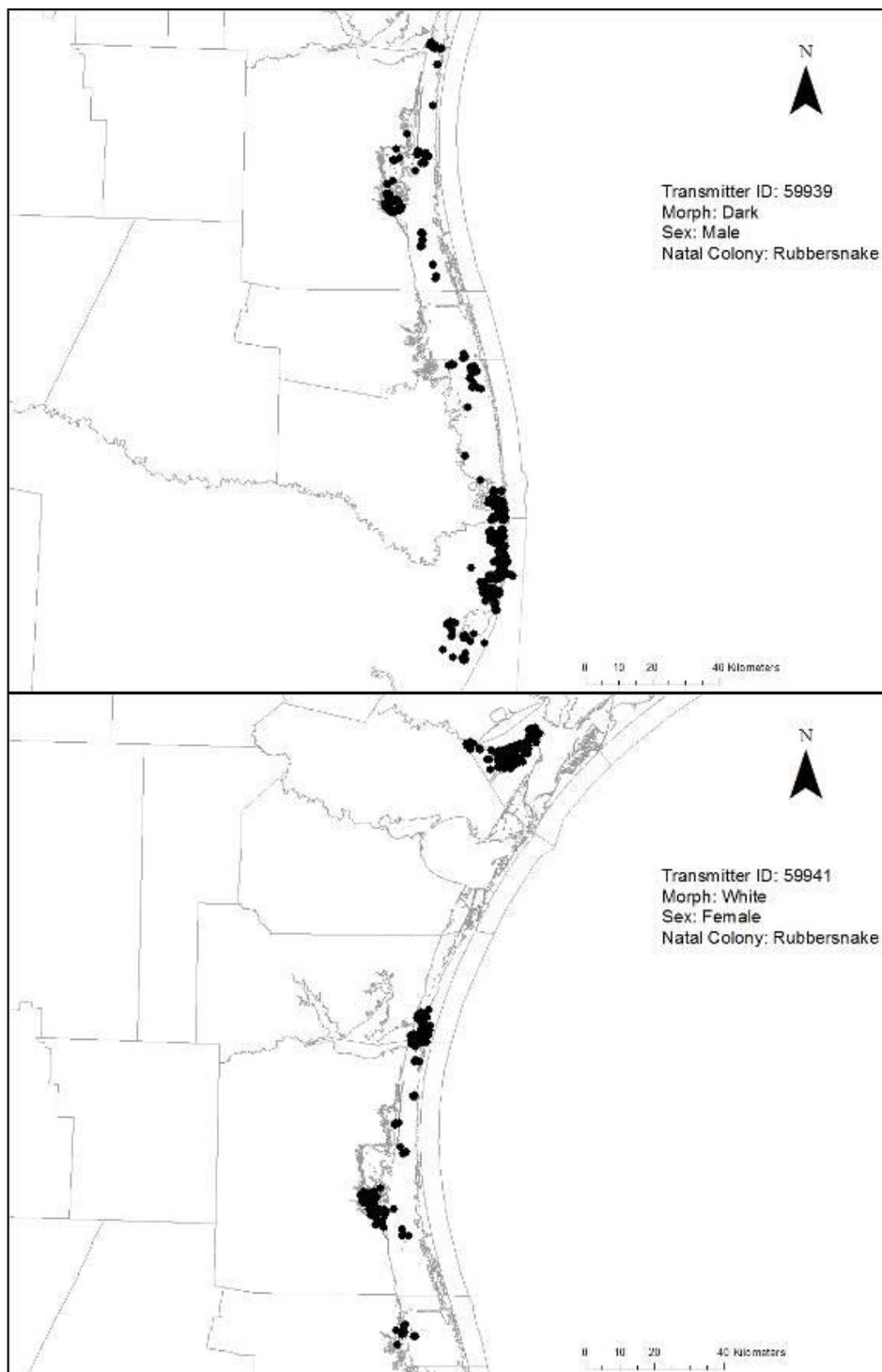


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

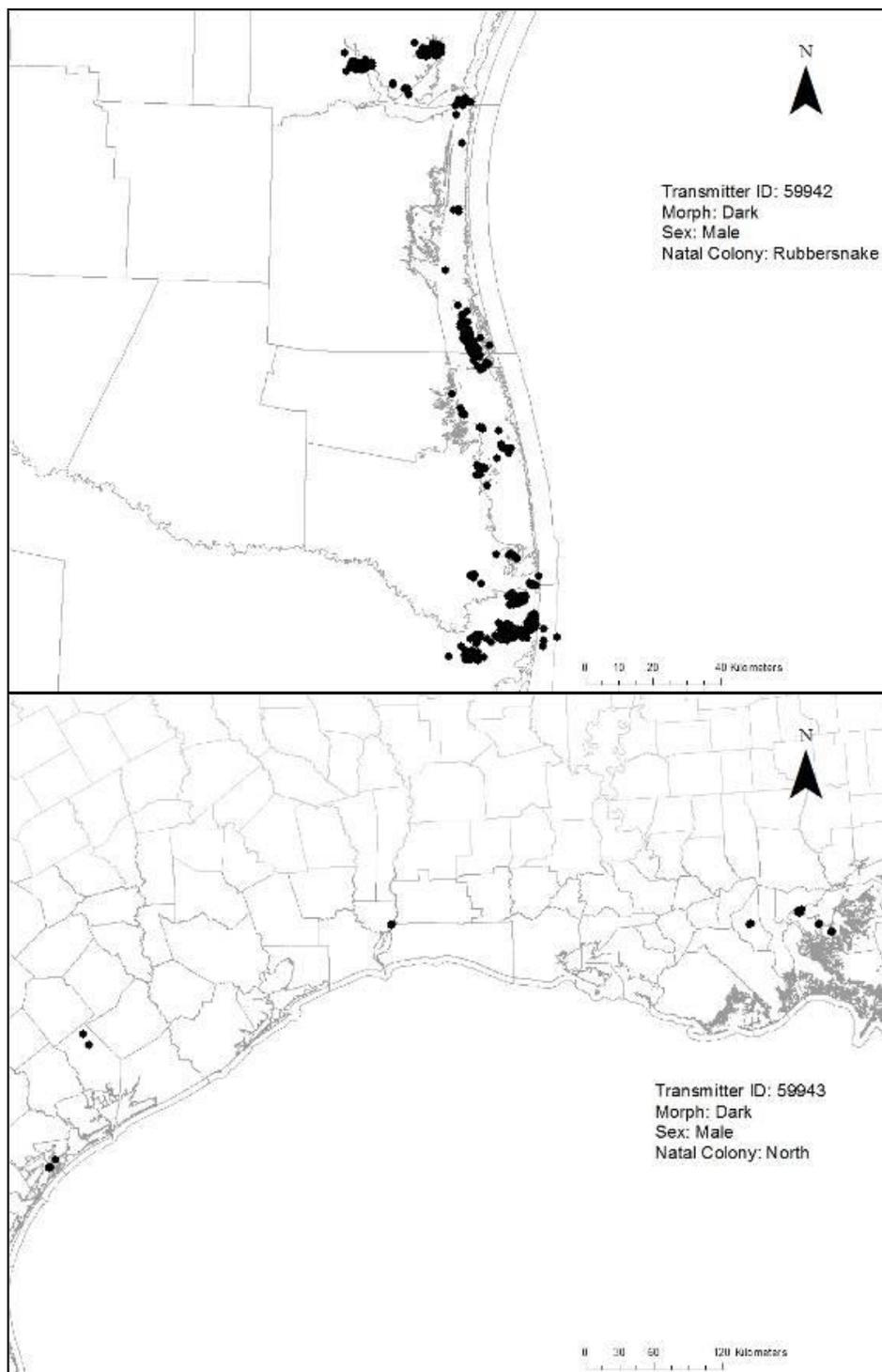


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

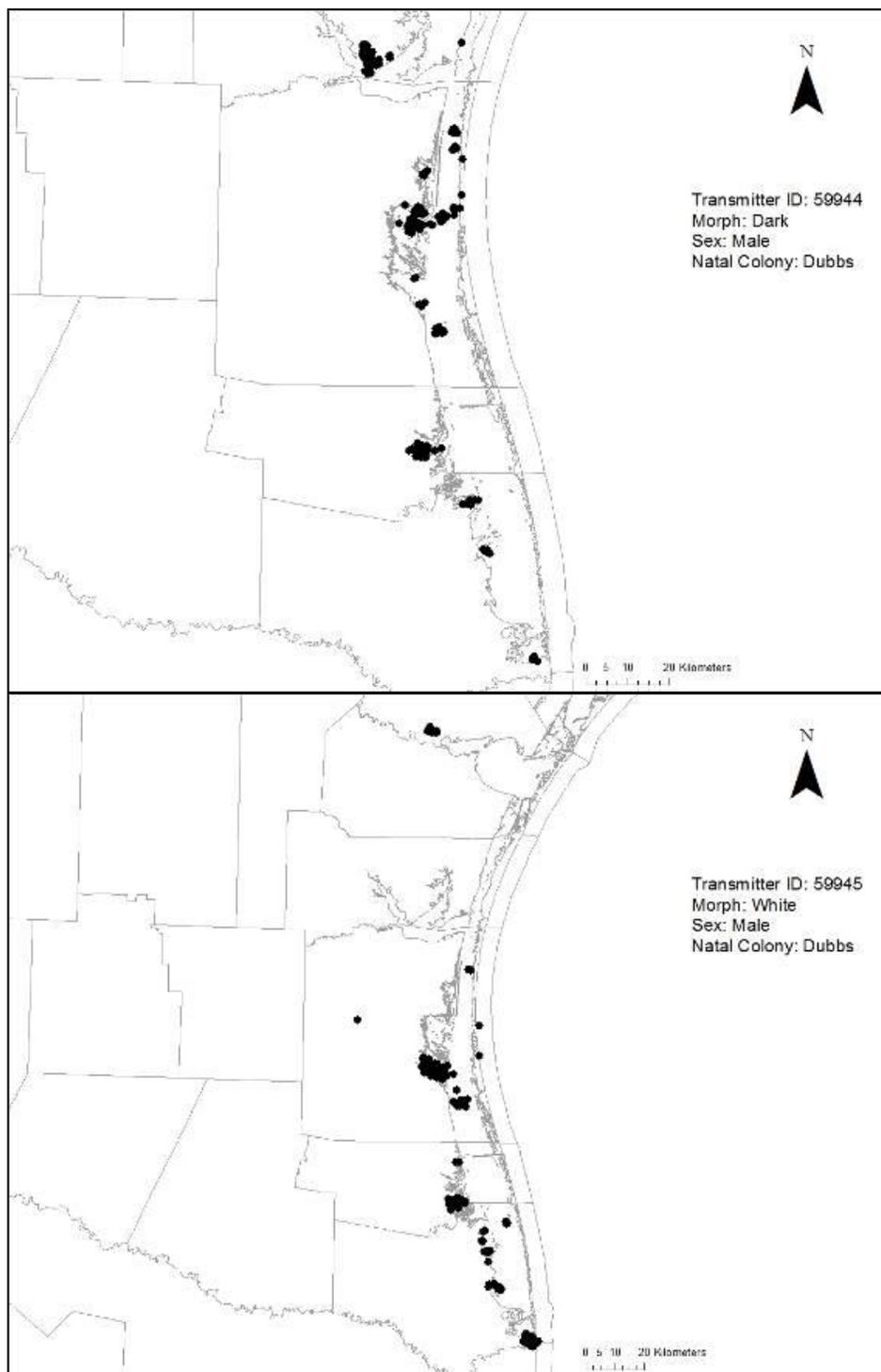


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

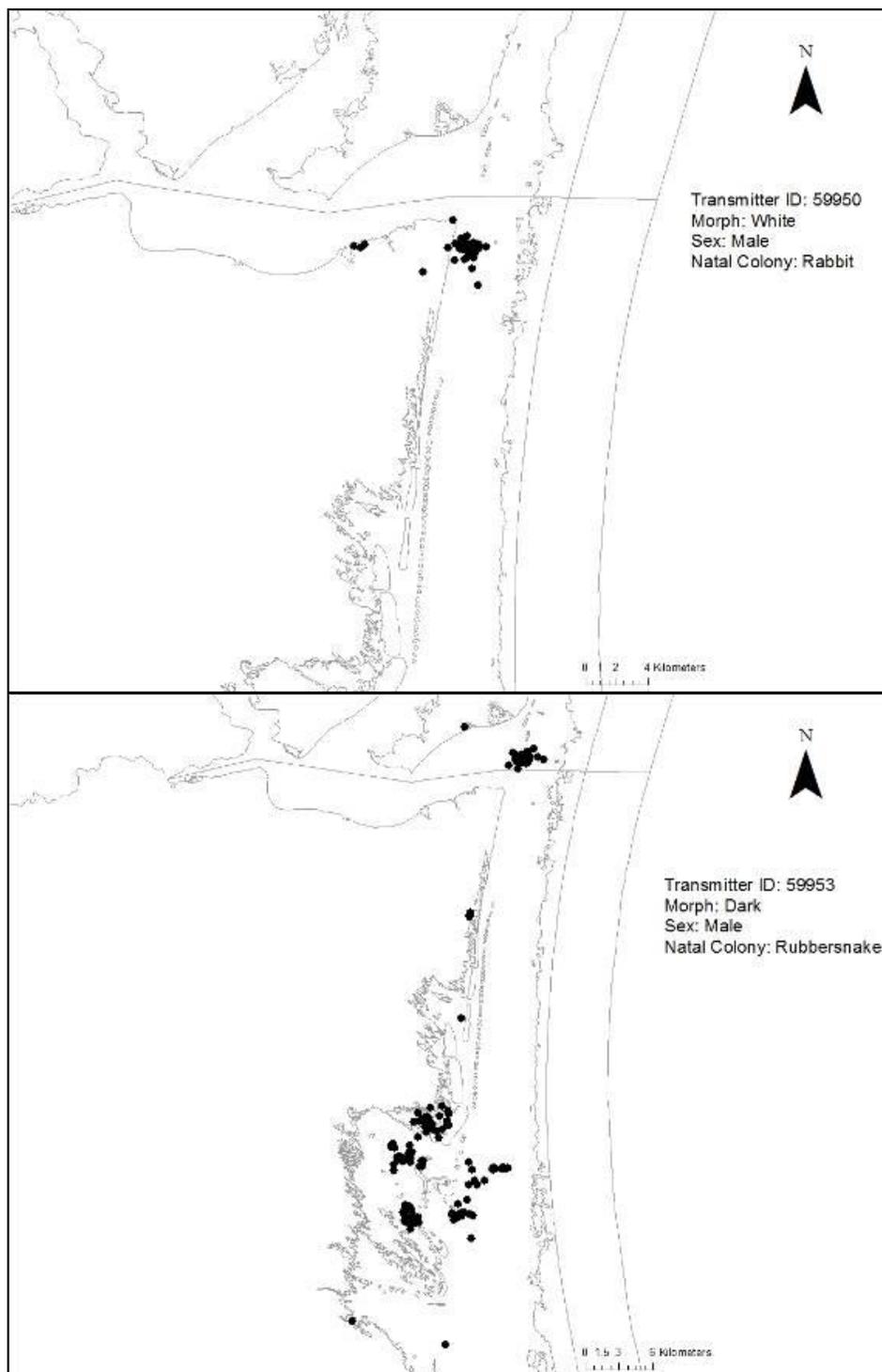


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

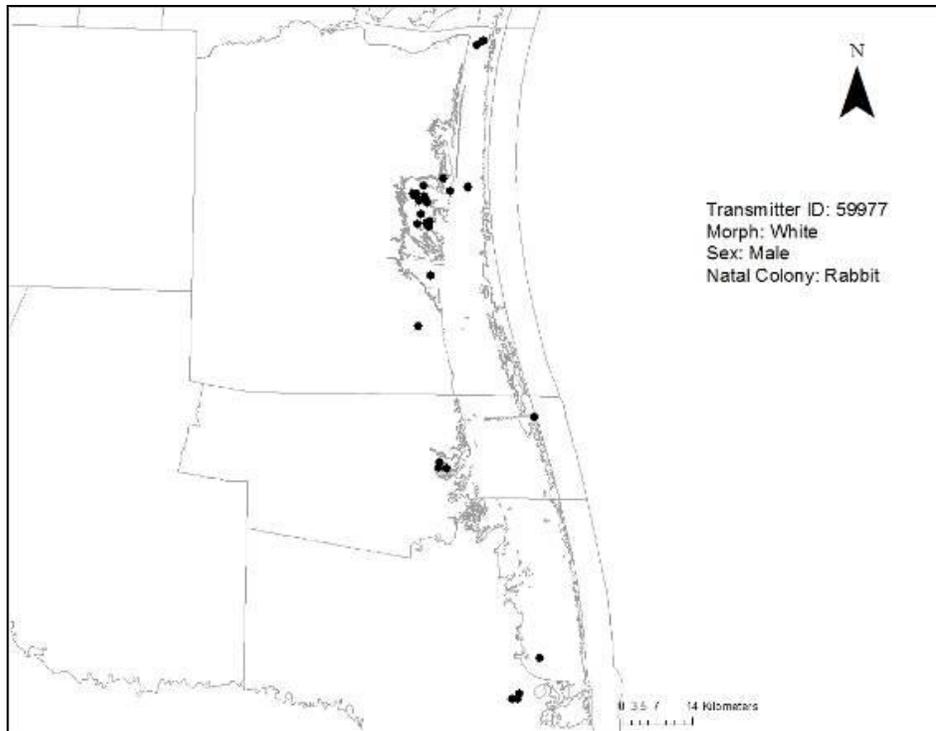


Figure 2-continued. All locations (June 2010 – October 2011) of juvenile Reddish Egrets marked with satellite transmitters along the lower Texas coast in June-July 2010.

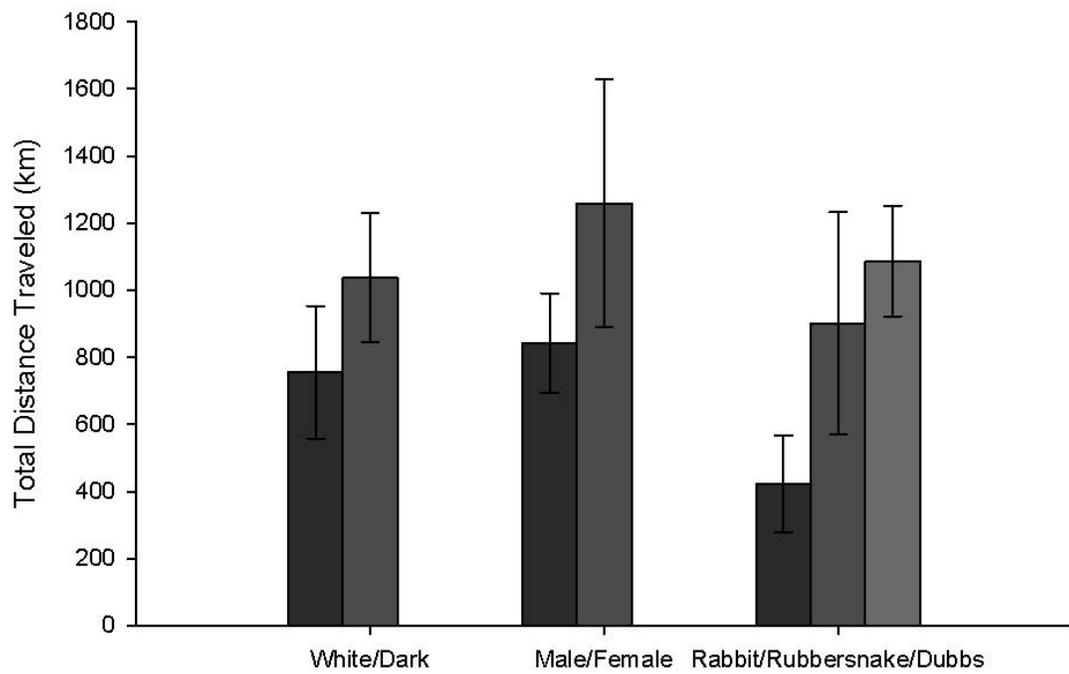


Figure 3. Total linear distance between all points traveled by marked Reddish Egrets, by plumage morph, sex, and natal colony. Error bars represent standard error.

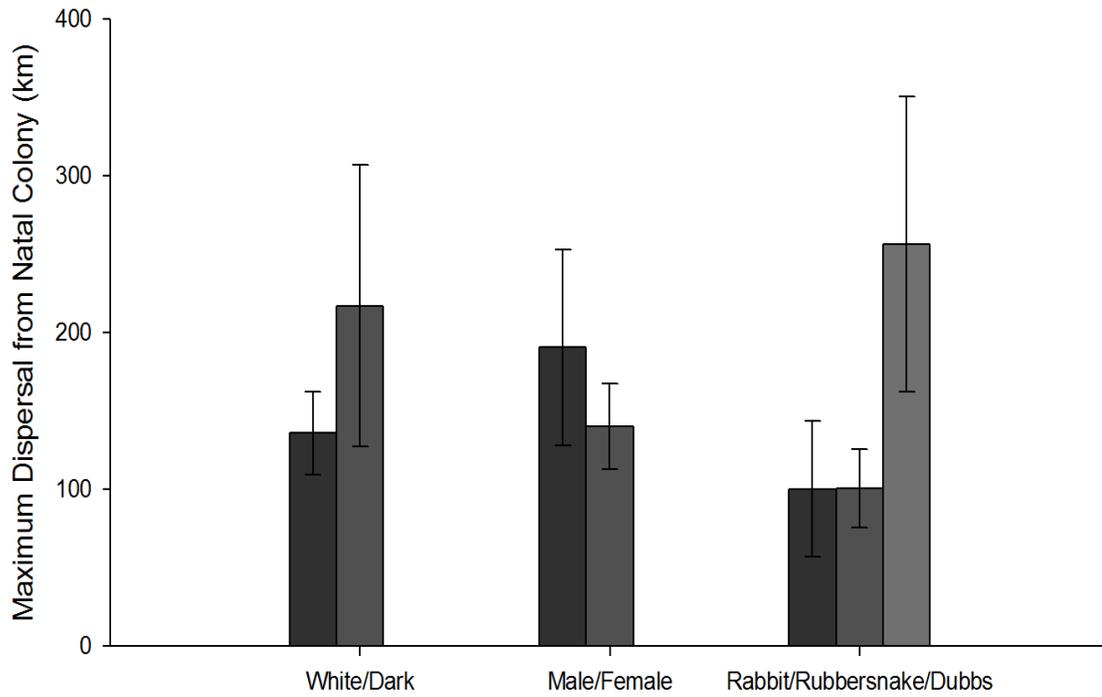


Figure 4. Maximum linear distance traveled from natal colony by marked Reddish Egrets, by plumage morph, sex, and natal colony. Error bars represent standard error.

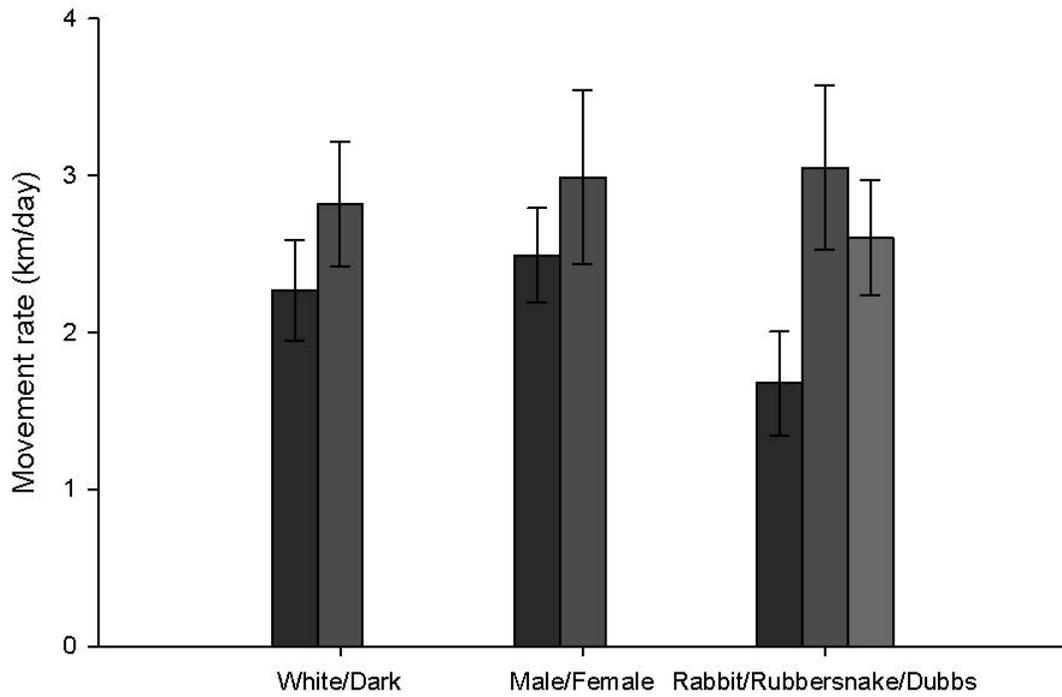


Figure 5. Average movement rate (distance traveled per day) of marked Reddish Egrets, by plumage morph, sex, and natal colony. Error bars represent standard error.

DISCUSSION

The movements of juvenile Reddish Egrets largely correspond to the writings of Rydzewski (1956), who wrote of Grey Herons (*Ardea cinerea*): “just after leaving the nest, young and adult birds disperse from the natal heronry keeping no steady direction of flight. Only later the movements of the birds become directed southwestward and in this direction most of their winter haunts are reached.” Rydzewski then goes on to classify these two periods of activity as the “nomadic period” and “migration period”, respectively. This pattern has been consistently noted in the literature (Dusi 1967, Cezilly 1997, Ganey et al. 1998, Stahl and Sagar 2006). Though the landscape is a bit dissimilar to the Gulf coast, this cohort of Reddish Egrets also appeared to disperse mostly southward after their initial bout of exploration. From here, they settled in areas that have been previously identified as key wintering areas for adult Reddish Egrets (Mikuska et al. 1998). Though not a surprising result, this study appears to be the first to confirm that juveniles use these same areas as well.

Though no comparisons between groups of interest yielded statistically significant ($P < 0.05$) results, it appears that a bird’s body size (as represented by tarsus length) has some effect on the maximum distance it travels ($t = 2.11, p = 0.050$). This suggests that structurally larger birds could disperse farther than others due to superior body condition (e.g. higher body fat content). It is also interesting that the two furthest migrations were both performed by males, but on average females traveled a greater total distance. This cohort did not consist of a sufficient amount of females to allow for the discovery of any statistically significant differences in dispersal or movement behaviors between sexes.

Increased sample size through additional transmittered birds coupled with long-term banding will also increase the probability of more balanced sex ratios in future cohorts, as well as allow further examination of potential differences in movement due to body size or condition.

Overall, variation in dispersal and movement measurements exists mostly among individual birds. This could be the result of random events occurring in the travels of some birds such as chance discovery of unoccupied quality habitat patches or birds being consistently out-competed in areas of high Reddish Egret density, but it may also be a real function of differences in individual bird behavior. The existence of personality in animals has been increasingly acknowledged in ecology and probably warrants more consideration than commonly given (Wilson et al. 1993, Wilson et al. 1994, Wilson 1998, Bolnick et al. 2003, Dall et al. 2004, Roshier et al. 2008, Opper et al. 2009). In birds, many unusual movements formerly considered to be arbitrary are now thought to be more indicative of the personality of the individual, with some individuals being more bold or exploratory than others (Roshier et al. 2008). If this is the case in this cohort, it would appear that most young Reddish Egrets are less willing to travel long distances in their search for wintering areas. This is important in that local bird densities at individual habitat patches may increase to an unsustainable level as habitat disappears. This degradation of the Texas coast is an acknowledged phenomenon (Cendrero and Fischer 1997, Leu et al. 2008), indicating that conservation efforts for Reddish Egrets should focus on preservation of habitat to manage this mostly resident population of birds.

CHAPTER III: SITE FIDELITY

Site fidelity, or the frequency with which individuals return to a defined area or relocate annually (Greenwood 1980), is another critical component to the understanding of a population's dynamics. Individuals often reuse breeding sites if they have experienced high reproductive success in years past, and, conversely, tend to relocate when fecundity is low (Haas 1998, Robinson 1985). The degree of site fidelity in a species can also influence genetic variability among populations (Lande and Barrowclough 1987). Along with knowledge of overall dispersal behavior in a species of interest, understanding of site fidelity within a population leads to effective conservation and management.

Previous studies of site fidelity in waterbird populations have shown very weak loyalty to natal areas. Melvin et al. (1999) measured the natal site fidelity of seven waterbird species from a data set spanning from 1914 to 1994. In their study, the White Ibis (*Eudocimus albus*), usually considered a "nomadic" species (Kushlan and Bildstein 1992), exhibited the highest level of natal site fidelity (24%). This number decreased in the other six species, ranging as low as 7.9-18% in the three *Egretta* species observed (Little Blue Heron, *Egretta caerulea*; Snowy Egret, *Egretta thula*; and Tricolored Heron, *Egretta tricolor*). These estimates of low site fidelity suggest that members of the genus *Egretta* show an even stronger degree of nomadism. It would be reasonable to assume

that the Reddish Egret would fall somewhere in the range of its congeners in this regard, but this hypothesis has not been directly tested. New avenues for data collection, such as telemetry, enable researchers to test this hypothesis and other questions about movement and survival.

The primary objective of this research was to examine site fidelity in Reddish Egrets and to determine the effects of sex, plumage morph and body size on site fidelity. Reddish Egrets are seen annually breeding along the Texas coast, but it is mostly unknown how faithful individuals are to particular breeding colonies. There is no knowledge of how often juveniles return to their natal colony after dispersing, whether they return to their place of birth upon achieving sexual maturity, or if their site fidelity is similar to those of adults. Sexes have been shown to differ in their site fidelity in other bird species (Lemon et al. 1996, Konczey et al. 1997), but no studies to my knowledge have examined fidelity differences within a dimorphic species. Differences in site fidelity between dark and white morph Reddish Egrets could be related to availability of habitat advantageous to each morph. If habitat across a coastal region (or within one breeding site) is composed in such a way as to maximize a certain ratio of morphs' ability to raise young (i.e. ease of foraging, Green 2005, Green and Leberg 2005), site fidelity may reflect that ratio, maintaining the ratio of plumage morphs seen in this population. Higher site fidelity at certain colonies may be indicative of their overall quality. Finally, an effect of body size on fidelity may be due to the tendency of competitively dominant birds to reclaim their breeding territories annually, forcing less physically fit birds to relocate more often to nest or forage.

METHODS

Birds were captured and data were collected as detailed in Chapter 1. I defined site fidelity as the frequency with which individuals could be located within a buffer of latitude and longitude of their natal colony, a scale used previously in waterbird site fidelity analyses (Mikuska et al. 1998, Melvin et al. 1999). The four colonies from which Reddish Egrets were captured were plotted in ArcMap and 5-minute-radius (9.265 km) buffers were created around them. In addition to its previous use, this radius is also biologically meaningful in that adult Reddish Egrets make foraging flights of about this length during the breeding season (Reed et al., unpubl. data), so instances in which juveniles follow adults to local foraging sites will not be erroneously identified as emigration events from the natal area. The number of records for each bird that occurred within the buffer of its corresponding natal colony was then calculated as a percentage of the total number of records reported by that bird. In addition to comparing fidelity measures between sexes, plumage morphs and natal colonies, variation due to individual bird body size was considered using analysis of covariance (ANCOVA). The individual wearing transmitter #59891 was removed from all analyses due to its almost immediate failure.

RESULTS

Most departures from the natal area occurred between July and August 2010, not long after transmitter attachment. After their first departure, many birds abandoned the

natal colony for the duration of the study period, with 14 of 23 departing birds not returning during the 69-week observation period. Some birds, however, returned often, making as many as six return visits through autumn. No birds with functioning transmitters were visiting their natal colonies by December 9, 2010. The entire cohort of Reddish Egrets had an average of 19.52% (SE: $\pm 5.25\%$) fidelity to their natal colony. No differences were found between sexes ($F_{1,17} = 0.79$, $P = 0.386$), plumage morphs ($F_{1,17} = 0.17$, $P = 0.689$), colonies ($F_{2,17} = 1.43$, $p = 0.267$) or tarsus length ($t = -1.51$, $P = 0.149$, Figure 6).

Table 3. Site fidelity measurements for individual birds. Birds marked #59891 (failed) and #59943 (sole representative of North Island) removed from comparisons.

<i>Transmitter #</i>	<i>Morph</i>	<i>Sex</i>	<i>Natal Colony</i>	<i>Records within Natal Area (5-minute-radius buffer)</i>	<i>Total Records</i>	<i>Natal Site Fidelity (%)</i>
59809	W	M	Dubbs	193	3017	6.40
59814	W	M	Dubbs	26	148	17.57
59815	D	M	Dubbs	453	5859	7.73
59824	D	M	Rabbit	538	3969	13.56
59828	W	F	Dubbs	496	4472	11.09
59830	D	M	Rubbersnake	55	333	16.52
59848	W	F	Rubbersnake	16	188	8.51
59857	D	M	Rabbit	25	343	7.29
59874	D	M	Dubbs	83	683	12.15
59878	D	F	Dubbs	24	316	7.59
59910	D	M	Rubbersnake	97	102	95.10
59911	D	M	Dubbs	366	3970	9.22
59924	W	M	Dubbs	127	599	21.20
59925	W	M	Dubbs	535	2667	20.06
59937	D	M	Dubbs	507	4566	11.10
59939	D	M	Rubbersnake	525	6431	8.16
59941	W	F	Rubbersnake	1119	6156	18.18
59942	D	M	Rubbersnake	318	4835	6.58
59944	D	M	Dubbs	356	3414	10.43
59945	W	M	Dubbs	127	1590	7.99
59950	W	M	Rabbit	326	326	100.00
59953	D	M	Rubbersnake	421	1713	24.58
59977	W	M	Rabbit	17	213	7.98
					<i>Mean</i>	19.52
					<i>Std. Error</i>	5.25

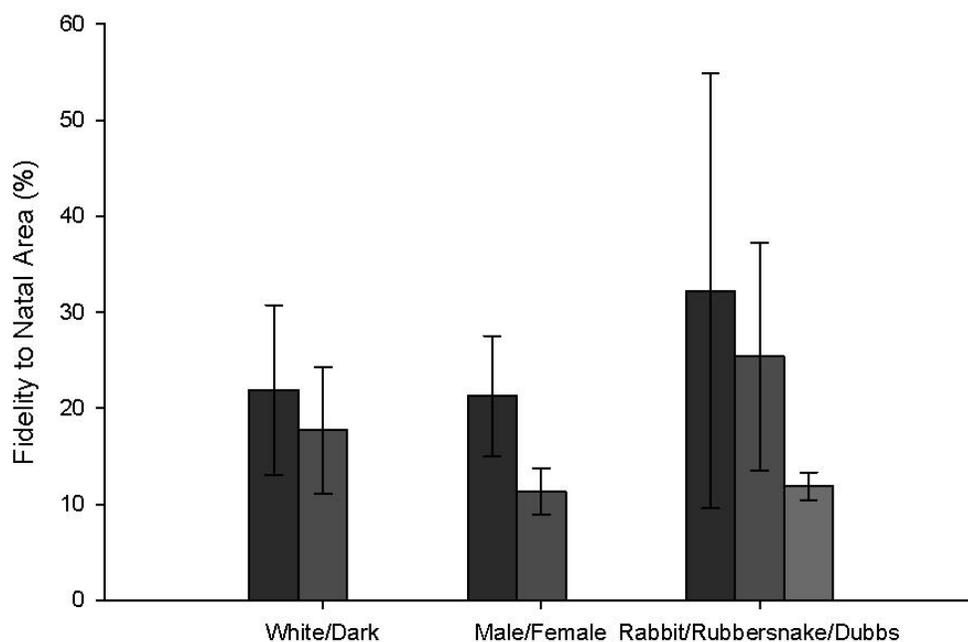


Figure 6. Site fidelity comparisons (June 2010 – October 2011) for marked Reddish Egrets, by plumage morph, sex, and natal colony. Error bars represent standard error.

DISCUSSION

My measurements of site fidelity in juvenile Reddish Egrets indicate similarity with other waterbirds (Telfair II et al. 2000, Melvin et al. 1999). This supports the classification of the Reddish Egret as a "nomadic" species that can occupy large areas over relatively short periods of time. It may be that areas other than the natal colony offer greater opportunities for newly-independent young to establish territories, especially since the breeding colony is initially still dense with other birds.

The fidelity of juvenile Reddish Egrets to their natal colony after reaching sexual maturity is potentially important to the conservation of the species, as high breeding site

fidelity could influence the readiness with which an individual would leave a breeding site of poor quality. Being overly faithful to a degraded breeding colony could impact fecundity, impeding population growth. Reddish Egrets commonly do not breed until 3 or 4 years of age (Lowther and Paul 2002), so observations of this cohort's fidelity would obviously require considerably more time. With satellite data, relationships between distance dispersed over an individual's lifetime and that individual's site fidelity could be examined. If the majority of these birds establish territories at a great enough distance from the Laguna Madre, they may not need to return when the breeding season arrives. With nearly half of our transmitters no longer providing data, though, it is uncertain whether any members of this cohort will be transmitting locations when they become sexually mature. If no birds continue sending data for a long enough period of time, future cohorts will have to be fitted with new transmitters, hopefully ones that last longer, as this and many other ecological variables of interest would benefit greatly from transmitter manufacturers addressing this need (Oppel et al. 2009).

Information concerning natal site fidelity for mature Reddish Egrets could probably be gained through the use of color banding. With a comprehensive effort made toward marking a large number of juveniles, surveys could follow that observe where these birds nest, regardless of their activities between breeding seasons. Though this would limit the ability of researchers to attribute low fidelity to high mortality when many birds go unaccounted, it would allow the collection of much larger quantities of data from year to year. Some combination of banding and satellite telemetry would probably be the ideal experimental design, so as to achieve a larger sample size and some balance of detailed data and reasonable costs.

CHAPTER IV: SURVIVAL

Understanding the stage at which populations suffer the greatest degree of mortality is important in conservation planning, as members of different age classes can potentially experience different threats to their survival. Nesting success rates in Reddish Egret colonies appear to be quite high (> 85%) in the absence of complete colony failure (Holderby et al., in press), but survival of juveniles and adults remains unknown. Through a combination of their newfound mobility and inexperience relative to older birds, juveniles may be more likely to interact naively with predators or venture into less suitable habitat. In their search for suitable foraging territory, juveniles may also expend too much energy if such habitat is not found quickly and perish due to exhaustion and/or malnourishment. Compounding this problem is the low efficiency and high energetic cost of the Reddish Egret's active foraging strategies relative to other egret species (Rodgers 1983, Green 2005). Juvenile foraging success is even lower compared to adult Reddish Egrets, and most do not develop as wide a repertoire of hunting tactics until maturation, as foraging behaviors are not taught by parents (Rodgers 1983). This would suggest that many juveniles may not develop sufficiently variable hunting skills quickly enough to survive in a challenging habitat.

If mortalities related to starvation are too common, insufficient numbers of birds will survive to reach sexual maturity. Low rates of survival could even lead to decreases in total population numbers despite any amount of quality habitat at or around the nesting

grounds. Using the ARGOS dataset comprised of recently fledged birds, an attempt was made to estimate survival in this Reddish Egret cohort. Survival rates can then be compared to nestlings and adults to discern at what age survival is lowest in the population.

Comparisons between survival rates of sexes are also of great interest within the juvenile cohort, regardless of overall cohort survival. Differences in juvenile survival between sexes could have impacts on the generation's total future reproduction, as unequal numbers of each sex entering the breeding population (especially more males than females) would result in many individuals being unable to join a mating pair. Sex ratios at birth are approximately 1:1 (Hill and Green, in press), so any unequal sex ratios seen in adult populations would be a result of differential survival rates among males and females at an earlier life stage.

There are currently no estimates of yearly survival for Reddish Egret populations anywhere throughout the species' range. Adults are known to live up to ~12 years (Lowther and Paul 2002), but this is based on one banded bird so it is unclear if this is their normal length of longevity. Observational studies of other *Egretta* species have shown annual variation in survival rates (Hafner et al. 1998), probably because of fluctuating water levels' effects on chick survival in the coastal regions where many of these birds breed. Mortality rates are often high for immature birds (Keedwell 2002), and this may be a major limiting factor in this species' recovery, as hatchling survival rates seem high (Holderby et al, in press).

Differences in survival of juvenile Reddish Egrets between dark and white morphs is obviously worthy of examination, as any differences between plumages would

contribute to the understanding of the maintenance of the species' dimorphism. This is especially interesting in the Texas population, where the ratio of dark to white birds most closely approaches 1:1 (Amy Turner, unpubl. data). If survival rates are comparable to the ratio of plumage morphs observed in the population, it would be extremely interesting to seek out potential increases or decreases in survival pressures across a longitudinal gradient. This approach could potentially identify environmental mechanisms maintaining plumage morph ratios elsewhere throughout the species' range (Allen 1955, Bolen and Cottam 1975, Scott and Carbonell 1986, Howell and Pyle 1997, Green et al. 2011).

METHODS

Birds were captured and data were collected as detailed in Chapter 1. Analysis of juvenile Reddish Egret survival was complicated by a lack of mortality sensors on the transmitters, as concerns about apparatus weight precluded the use of many add-ons offered by Microwave Telemetry. Because of this, it is impossible to determine the fates of many birds after transmitter failure due to occasionally large error radii on last known locations as well as movement to areas that are inaccessible for various reasons. Though probably an overestimation of mortality, consideration of all transmitter failures as mortalities, as done by Millsap et al. (2004) still allows for reasonable comparisons of survival between different groups of interest (morphs, sexes, etc.).

The nonparametric Kaplan-Meier estimator (Kaplan and Meier 1958), using Pollock et al.'s (1989) modification for staggered entry of subjects, was used to derive

survival estimates. Individuals whose signals were lost and did not return through the end of the study were marked as mortalities from the week of their last transmission. Since the Kaplan-Meier estimator does not consider predictors of survival on its own, the log-rank test (Savage 1956, Kalbfleisch and Prentice 1980, Cox and Oakes 1984) using Cox and Oakes' (1984) variance calculations, was used to make pairwise comparisons between curves for sexes, morphs, and natal colonies, as recommended by Pollock *et al.* (1989). Analysis of the bird with transmitter #59943, the only bird captured at North Island at Long Reef, was included in sex and morph comparisons but was removed from comparisons between natal colonies.

RESULTS

At the end of the 69-week observation period, 14 of the original 25 transmitters were still reporting location data, resulting in an overall survival estimate of 0.534 ± 0.191 (Figure 7). Comparisons between morphs (Dark: 0.629 ± 0.250 (SE), White: 0.417 ± 0.279 ; $\chi^2 = 0.83$, $P = 0.362$, Figure 8), sexes (Male: 0.494 ± 0.208 , Female: 0.750 ± 0.424 ; $\chi^2 = 0.59$, $P = 0.442$, Figure 9), and colonies (Dubbs: 0.750 ± 0.245 , Rabbit: 0.500 ± 0.49 , Rubbersnake: 0.400 ± 0.351 ; Dubbs vs Rabbit: $\chi^2 = 1.60$, $P = 0.206$, Rabbit vs Rubbersnake: $\chi^2 = < 0.01$, $P = 0.984$, Dubbs vs Rubbersnake: $\chi^2 = 2.98$, $p = 0.084$, Figure 10) detected no significant differences in survival between subgroups.

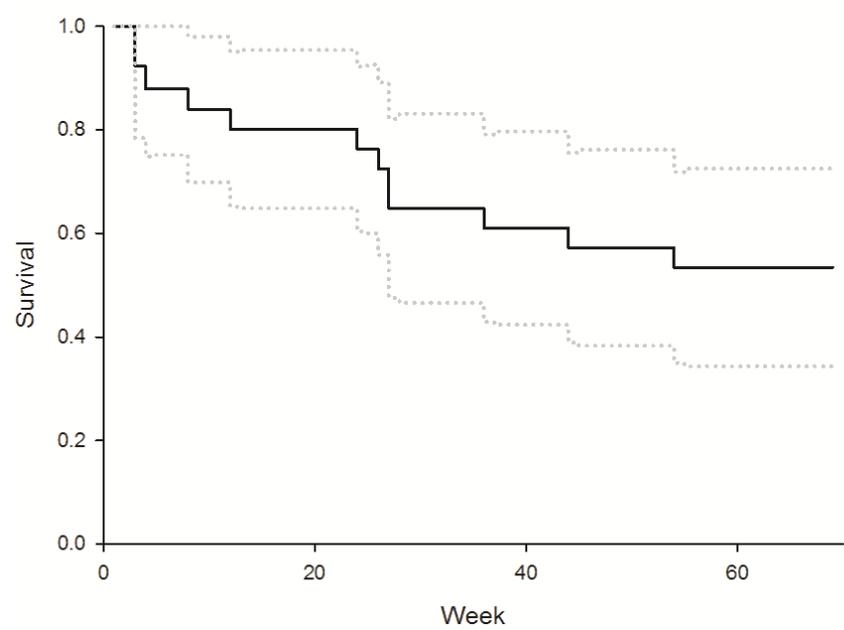


Figure 7. Kaplan-Meier survivorship curve (June 2010 – October 2011) for the entire cohort of juvenile Reddish Egrets. Dotted lines represent 95% confidence intervals.

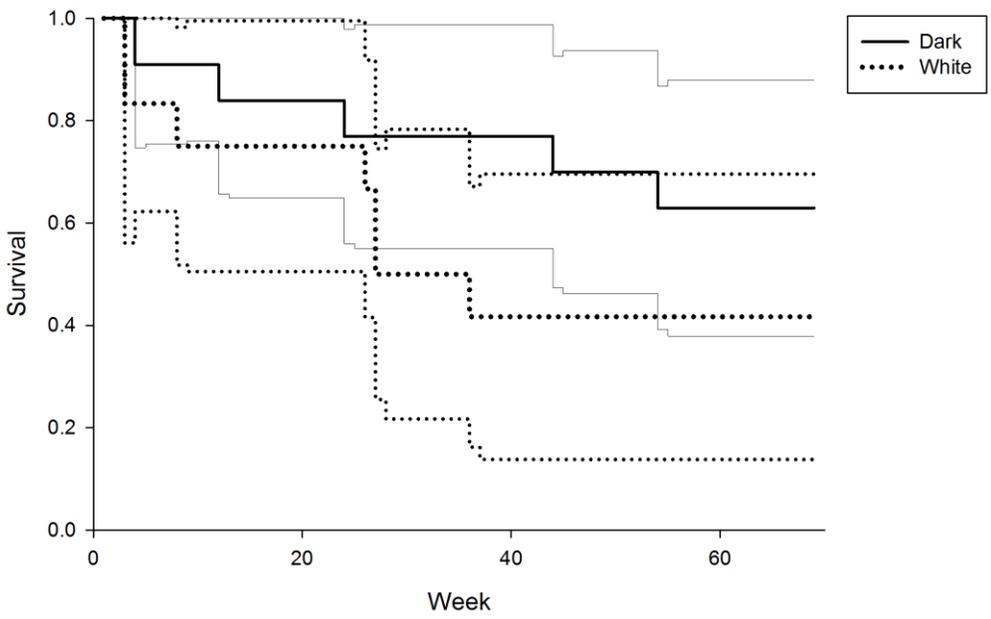


Figure 8. Kaplan-Meier survivorship curves (June 2010 – October 2011) for dark- and white-morph juvenile Reddish Egrets. Thinner lines represent 95% confidence intervals.

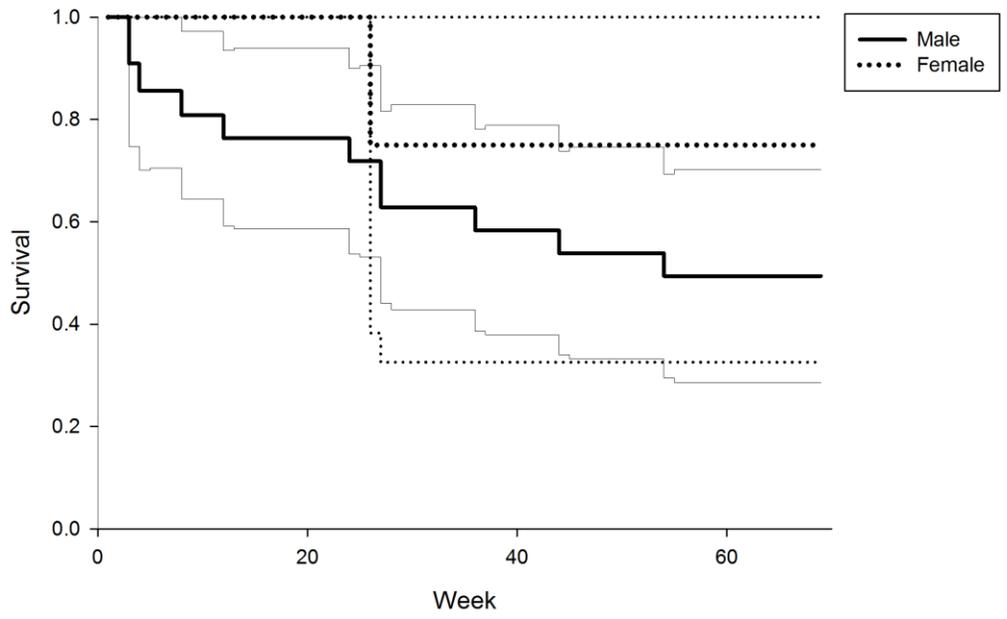


Figure 9. Kaplan-Meier survivorship curves (June 2010 – October 2011) for male and female juvenile Reddish Egrets. Thinner lines represent 95% confidence intervals.

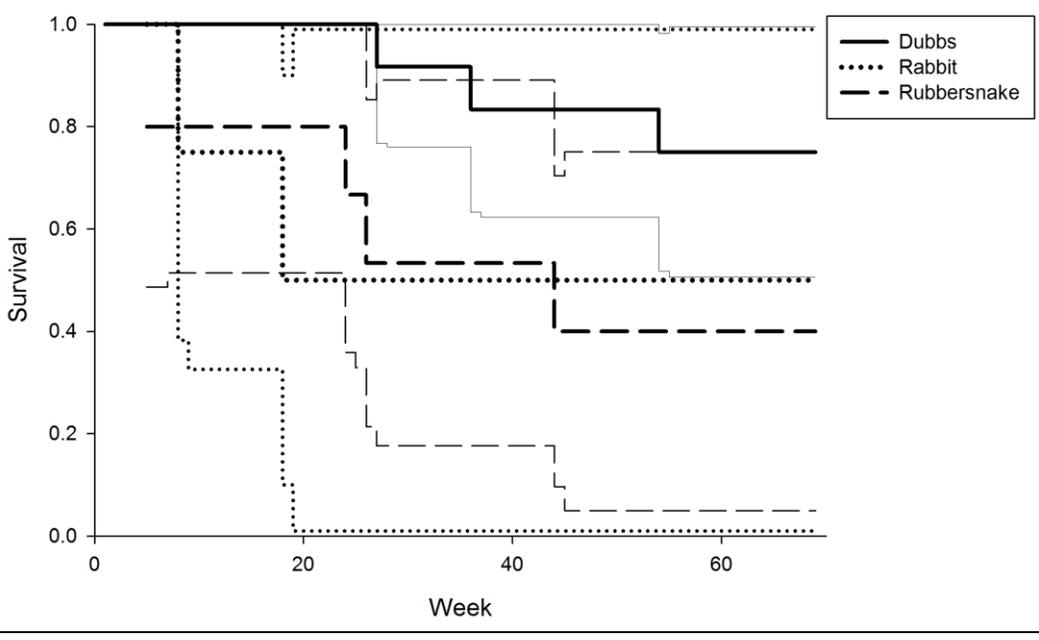


Figure 10. Kaplan-Meier survivorship curves (June 2010 – October 2011) for juvenile Reddish Egrets, categorized by natal colony. Thinner lines represent 95% confidence intervals.

DISCUSSION

From these data, it would seem that mortality in juvenile Reddish Egrets is rather high, and could be the life stage that limits population growth. Future studies should make use of additional technology such as mortality sensors when observing Reddish Egrets across such long distances, especially now that it is known that their size permits the additional load. Long-term color banding data could also be used to further estimate survival rates, as loss of color bands is very infrequent, though this would not account for birds that permanently emigrate to inaccessible areas where bird resightings would prove difficult. Once mortality rates are more accurately assessed, survival of juveniles can be compared to nestlings (Holderby et al., in press) and adults in order to more confidently define the life stage that keeps population numbers low. The survival measurements of this study show juvenile Reddish Egrets to have lower mortality than some of its congeners (Ryder 1978, Telfair 1979). Comparisons of more accurate measurements with juvenile survival rates of other species could help to reveal how various environmental conditions differentially impact the demography of the Gulf coast's various waterbird species.

Assumed mortality did not occur until week 4, suggesting that fledged juveniles remain relatively safe as they explore the natal colony. This is probably due to a “safety in numbers” effect, as many breeding colonies in this area are dense with breeding waterbirds, all of which were observed to attack what they perceived as threats to their young. The only young birds that appeared to be in danger during visits to the colonies

for this project were those that ventured too far into the water (mostly tern chicks). This behavior was not exhibited by any young Reddish Egrets; contact with water was mostly avoided by the birds, even during the research team's pursuit of individuals for transmitter attachment. The presence of predators on these islands is probably rare at best, since these islands are consistently used by waterbirds and would not be constantly selected for nesting if predation were a problem (Frederick and Collopy 1989). Predator control has also been a primary objective of some conservationists on the Texas coast (M. C. Green, pers. comm.), so it is unlikely that any animals that feed opportunistically on young waterbirds would reach these islands before the juveniles were capable of powerful flight.

Assumed mortality occurred at a mostly constant rate throughout the observation period and across the study area, implying that mortality risk is no greater at any particular time and/or location along the Gulf coast. If this is true, then factors contributing to the deaths of individual Reddish Egrets are probably abiotic, unique to the individual's circumstances, or the result of chance. Naive behavior in perilous situations or mismanagement of activity budgets are probably the primary causes of death for the lost birds, and would suggest that this may indeed be an age at which many birds do not survive. This interpretation of the data is supported by Rodgers (1983), who noted that fledgling herons are not "trained" by their parents but must learn to maximize their foraging success on their own. Many juveniles simply may not "catch on" quickly enough to correctly utilize the various foraging behaviors innate to the species and expend too much energy to survive. Other studies have noted that mortality is highest before two years of age in other heron species (Mead et al. 1979, Telfair II et al. 2000), so it remains

to be seen if this mostly constant rate of assumed mortality levels off somewhat after additional data is collected.

Exact estimates of survival from confirmed mortalities could not be derived from this cohort due to the limitations of the satellite transmitters' location accuracy to confirm mortalities across this large study area. However, any bias in this method of calculating survival is constant across all individuals, giving greater validity to the comparisons presented, which suggest constant survival rates of juvenile Reddish Egrets across all measured groups. As mentioned previously, future telemetry studies should incorporate additional technologies to give even greater confidence to exact measurements of survival.

CHAPTER V: CONCLUSIONS

From the results of my analyses, it would appear that juvenile Reddish Egrets do not differ markedly in their dispersal behaviors from other juvenile waterbird species. The trend of high mortality in juveniles seems to hold in Reddish Egrets as well. While these similarities may seem to indicate that some aspects of a Reddish Egret conservation plan need not be substantially different from those of other waterbirds, the species' unique habitat requirements (Lowther and Paul 2002) and foraging behaviors (Rodgers 1983) still highlight the need for a new and separate plan. Furthermore, these results do not offer any evidence that Reddish Egrets possess any additional resilience to the disturbances faced by coastal waterbird species. In fact, as weak migrants and mostly obligate habitat specialists due to the depths at which they forage (Lowther and Paul 2002, Green 2005), Reddish Egrets may be particularly vulnerable to the habitat alterations currently impacting the Gulf coast. As coastal development increases due to human populations shifting toward coasts (Cendrero and Fischer 1997), habitat is gradually replaced by man-made structures (Leu et al. 2008). Habitat is also being lost to rising sea levels in the region, a problem exacerbated by increasing severity and frequency of hurricanes in the Gulf of Mexico (Gornitz 1995, Leberg et al. 2007). With its apparent reluctance to move inland (Lowther and Paul 2002), Reddish Egret populations cannot be sustained at their current numbers if habitat continues to be lost. In addition, according to the results of this project, the relative lack of long-distance

migrations and potential gene flow between populations in this species (Hill et al. 2012) compared to other waterbirds (Kenow et al. 2002, Miller et al. 2005, Bryan et al. 2008) suggest that not all Reddish Egrets will be able to successfully relocate when their individual home ranges are lost. This could lead to increased crowding in what little habitat remains, eventually causing a severe decline in overall numbers as birds are forced out by both inter- and intra-specific competition at roosting and foraging sites.

Further research into the movement ecology and survival of Reddish Egrets should make further attempts to confirm whether differences exist between morphs in this population, especially as resighting evidence suggests that dark morphs may migrate further than white morphs. Additional comparisons of sexes would also be informative, as the capture effort for this project produced a highly skewed ratio of males to females. This cohort still has the potential to yield additional informative data, as locations will continue to be gathered until all transmitters fail. This could be of interest if enough transmitters provide location data as these birds enter adulthood and changes in life histories of individuals can be documented and analyzed. Finally, similar studies should be conducted within the other recognized populations of Reddish Egrets (Baja California, Florida/Bahamas) to assess the potential variability in movement strategies and survival rates across the species' range.

The information gathered over the course of this project could also provide additional insight into the response of Reddish Egrets to severe weather events. Tropical depressions, tropical storms and hurricanes are not uncommon in the Gulf of Mexico, and four tropical systems passed over our study site during this observation period. Hurricanes and tropical systems have been shown to affect waterbird nesting and

dispersal as well as direct effects on breeding habitat such as colonies (Shepherd et al. 1991, Michener et al. 1997, Leberg et al. 2007, Green et al. 2011); the examination of the effects of severe weather on movement and survival of our study cohort are of conservation interest. Waterbirds are considered by some to be bioindicator species whose presence can be used to gauge ecosystem health (Custer et al. 1991, Kushlan 1993, Erwin et al. 1996, Kushlan 1997). Significant negative effects on waterbirds due to these storms could be indicative of severe habitat degradation: the raised sea level brought on by multiple storms could submerge breeding colonies for entire summers, and could also make former foraging grounds unsuitable for birds to hunt. This would encourage greater emphasis on the protection of this important ecosystem due to the frequency of these storms and expected increase in frequency and strength under many climate change scenarios (Michener et al. 1997, Webster et al. 2005). Taken together, the completion of these various datasets will contribute substantially to the understanding and conservation of North America's rarest and most unique heron species.

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