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Short Communication

Migratory stopover sites used by Reddish Egrets: prioritization for conservation

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ABSTRACT. The conditions encountered during the migratory period, particularly at stopover sites, can influence individual survival, reproductive success, and population stability; therefore, knowledge of migration ecology is important for developing conservation strategies. We monitored stopover site use by Reddish Egrets (*Egretta rufescens*) marked with satellite transmitters between their breeding area in southern Texas, USA, and wintering sites in Mexico and El Salvador. The duration of time spent at stopover sites varied among individuals and seasons, ranging from 1 to 64 days at a particular site. Three of the four individuals that were tracked for multiple seasons flew farther between stopover sites during autumn migration compared to spring, and the average distance between stopovers ranged from 192 to 580 km among individuals. Laguna San Andres in Tamaulipas, Mexico, appeared to be the most important stopover site based on the proportion of the marked population that used it. Understanding the stopover ecology and habitat use of migratory individuals will help direct conservation efforts for the species.

Haltes migratoires utilisées par les Aigrettes roussâtres : priorisation pour la conservation

RÉSUMÉ. Les conditions rencontrées pendant la période de migration, en particulier sur les haltes migratoires, peuvent influencer la survie des individus, le succès de reproduction et la stabilité de la population. Par conséquent, il est important de connaitre l'écologie de la migration si l'on veut élaborer des stratégies de conservation. Nous avons suivi l'utilisation des sites de repos par des Aigrettes roussâtres (*Egretta rufescens*) marquées au moyen d'émetteurs satellites entre leur aire de nidification dans le sud du Texas, aux États-Unis, et leurs sites d'hivernage, au Mexique et au Salvador. La durée de séjour aux haltes a varié selon les individus et les saisons, s'échelonnant de 1 à 64 jours sur un site particulier. Trois des quatre individus qui ont été suivis pendant plusieurs saisons volaient plus loin entre les sites de repos pendant la migration d'automne par rapport à celle du printemps, et la distance moyenne entre les haltes allait de 192 à 580 km selon les individus. La lagune San Andres à Tamaulipas, au Mexique, s'avère le site de repos le plus important d'après la proportion de la population marquée qui l'utilise. La compréhension de l'écologie aux haltes et de l'utilisation de l'habitat des individus migrateurs aidera à orienter les efforts de conservation de l'espèce.

Key Words: *Egretta rufescens; Gulf of Mexico; migration; Reddish Egret; stopover*

INTRODUCTION

Knowledge of the routes, stopover sites, and habitat use of migratory species is necessary to identify potential threats and conservation needs throughout the annual cycle (Newton 2006, Buler and Moore 2011, Oppel et al. 2015). During migratory movements, birds are subjected to high energy demands, predation, and extreme weather events, which can lead to reduced body condition or mortality. Consequently, the majority of annual mortality occurs during migration for many species (Sillet and Holmes 2002, Klaassen et al. 2014, Studds et al. 2017). While not in flight, birds rely on stopover sites to rest and refuel during migration, and conditions at stopover sites also have been shown to influence reproductive success, survival, and population stability (Baker et al. 2004, Newton 2006, Studds et al. 2017). Coastal species in particular are often limited by the availability of stopover sites and can be susceptible to density-dependent effects at those sites (Newton 2006).

The Reddish Egret (*Egretta rufescens*), a coastal habitat specialist, is listed as near-threatened by the International Union for the Conservation of Nature (BirdLife International 2016) and as endangered in Mexico (SEMARNAT 2019). Little was known about the migratory nature of the species until a recent tracking study found that ~25% of the marked population breeding in the Laguna Madre, Texas, USA migrated long distances to wintering sites in Mexico and El Salvador (Koczur 2017). Understanding the migration ecology of Reddish Egrets and conserving habitat along the migration route is a major goal of the *Reddish Egret Conservation Action Plan* (Wilson et al. 2014). We evaluated movements during migration by adult Reddish Egrets marked with satellite tracking devices to evaluate the conservation importance of specific stopover sites.

STUDY AREA

Reddish Egrets are restricted in their distribution to a narrow band of coastal habitat, and require shallow, unvegetated tidal flats for foraging throughout the annual cycle (Koczur et al. 2020). The Reddish Egrets tracked in this study occurred along the Gulf of Mexico coast, from Texas, USA, to Campeche, Mexico, and on the Pacific Coast, from Oaxaca, Mexico, to Usulután, El

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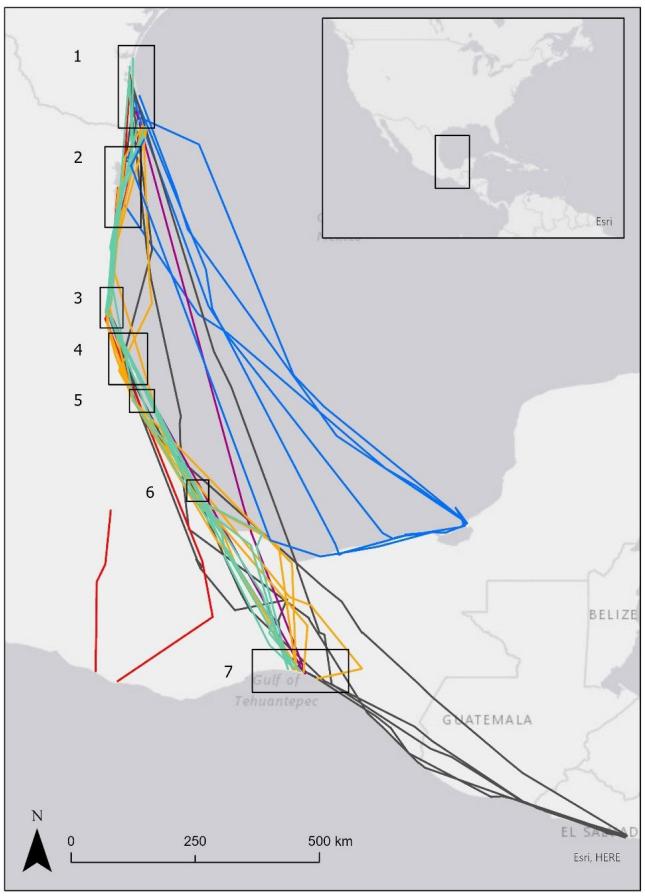
Salvador. There are several lagoon systems along the Gulf of Mexico Coast, including the Laguna Madre of Texas and Tamaulipas, Laguna San Andres, Laguna Tamiahua, and Laguna Tampamachoco (Fig. 1). The habitat along Mexico's Gulf Coast includes thorn-scrub and tidal flats along lagoons. Moving southward along the Yucatan Peninsula, the vegetation becomes dense and grows relatively close to the shoreline. Land uses in these coastal areas include livestock and agricultural practices, and urban development, with commercial fisheries and salt extraction occurring in coastal areas (Britton and Morton 1989, Mendoza-González et al. 2012). The Laguna Madre of Tamaulipas is designated as a Natural Protected Area.

Fig. 1. Migration paths and stopover sites used by adult Reddish Egrets (*Egretta rufescens*) that migrated from Texas, USA, to the Pacific Coast of Mexico and El Salvador during 2010-2016, with different individuals represented by different colors. (1) Laguna Madre, Texas, (2) Laguna Madre, Tamaulipas, (3) Laguna San Andres, (4) Laguna Tamiahua, (5) Laguna Tampamachoco, (6) Rio Antigua, and (7) Laguna Superior/Laguna Inferior/Laguna Mar Muerto system.



On the Pacific Coast of Mexico, a large lagoon system occurs south of the Isthmus of Tehuantepec along the coasts of Oaxaca and Chiapas, Mexico, comprising Laguna Superior, Laguna Inferior, and Laguna Mar Muerto (Fig. 1). Lagoons in this system contain mud flats and mangrove swamp along their edges (Binford 1989). Other lagoons and wetlands occur along the coasts of Guatemala and El Salvador and there are also protected natural areas along the coast. Other land uses in the area include cattle ranching and agriculture (Shelton 2012).

METHODS

We trapped adult Reddish Egrets (n = 30) during the breeding seasons of 2010-2012 and 2014 at breeding colonies in the Laguna Madre, Texas, USA (Fig. 1). The Laguna Madre of Texas supports the largest concentration (~1/3) of breeding Reddish Egrets in the world (Green 2006). Each individual was outfitted with a 22 g, solar-powered GPS transmitter (PTT-100, Microwave Telemetry, Inc.) as a backpack with Teflon ribbon harness using the Y-attachment methods described by Buehler et al. (1995). Each transmitter was programmed to record six locations per day, at 08:00, 09:00, 16:00, 17:00, 24:00, and 01:00 (CST) to coincide with diurnal foraging and nocturnal roosting and was accurate to 18 m based on field verification. The locations were downloaded weekly from the Argos system (https://www.argos-system.org/) or automatically to MoveBank (Wikelski and Kays 2016). We obtained a total of 2599 locations across 473 individual migration days during 2010-2016, averaging 375 locations and 67 days/individual.

About 40% of individuals migrated, and long-distance migrants (relative to other migrants in the population) were considered to be those individuals that migrated southward along the Gulf Coast of Mexico, across the Isthmus of Tehuantepec, and wintered on the Pacific Coast of Mexico, Guatemala, and El Salvador (a distance > 700 km) or flew across the Gulf of Mexico to winter along the Yucatán Peninsula. We defined stopover sites as locations in which an individual remained for at least two consecutive location fixes to ensure it was not in flight. We determined fidelity to stopover sites across successive migrations by examining GPS locations in ArcMap10.3.1 (ESRI 2011). Fidelity was defined as the return to a specific lagoon system during any subsequent migration. We also measured the straight-line distance between successive stopover sites used during migration and report the mean distance between stopover sites for autumn and spring migration for each tracked Reddish Egret.

Lastly, we prioritized the importance of stopover sites by ranking the proportion of the population that used each site, either during spring or autumn migration. The trans-Gulf migrant was not included in the ranking process because it used a stopover site only one time during the study period. Any tracks that were not complete for a migration due to transmitter issues or mortality were not included.

RESULTS

Long-distance migrant Reddish Egrets departed breeding areas in the Laguna Madre of Texas at varying times during autumn, with average departure dates across individuals ranging from 08 October to 17 November. Migrants primarily traveled down the Gulf Coast of Mexico, crossed the Isthmus of Tehuantepec, and wintered in coastal Chiapas and Oaxaca or moved further south to winter in El Salvador. One individual made successive trans-Gulf migrations from the Laguna Madre of Texas to the Bay of Campeche on the Yucatan Peninsula. Average spring departure

Table 1. Number of spring and autumn migrations that stopover sites were used and the total number of days (in parentheses) spent at each stopover site across all migrations of tracked Reddish Egrets (*Egretta rufescens*) during 2010–2016.

Bird ID	Migration Period	Total Migrations	Laguna Tamaulipas	Laguna San Andres	Laguna Tamiahua	Laguna Tampamachoco	Rio Antigua
49150	Autumn	3	2 (4)	3 (6)	0	0	1 (2)
49150	Spring	3	2 (6)	2 (2)	0	0	1 (1)
49195	Autumn	4	3 (25)	1 (10)	1 (3)	1 (7)	1 (1)
49195	Spring	3	1 (2)	3 (7)	0	3 (71)	1 (2)
129772	Autumn	2	0	0	1 (1)	0	0
129772	Spring	2	1 (2)	2 (2)	0	0	0
49156	Autumn	1	1 (5)	1 (2)	0	0	0
49166b	Spring	1	0	1 (1)	0	0	0
129770 †	Autumn	1	0	1 (8)	0	0	0
49154 ‡	Spring	1	1 (4)	0	0	0	0
49154 ‡	Autumn	1	1 (1)	0	0	0	0

† Incomplete track was not included in prioritization scoring.
‡ Individual mostly migrated across the Gulf of Mexico so was not included in prioritization scoring.

dates ranged from 01 March to 15 April across individuals, and individual Reddish Egrets migrated along similar routes during spring that they used during autumn.

Twenty-two migrations by adult Reddish Egrets marked with tracking devices identified the use of 29 stopover sites along the Gulf Coast of Mexico and Pacific Coast of Mexico and Guatemala, with five stopover sites used consistently (i.e., used by > 1 individual, used for an extended period of time, and/or used by the same individual during > 1 migration; Fig. 1). Use of stopover sites varied greatly, with more northerly sites being used by more individuals (Table 1). We observed variation in migration strategies (e.g., number of stops, duration of stops, and distance between stops) within and among individuals; however, most individuals made fewer stops and flew longer distances between stops in autumn compared to spring (Table 2). Average stopover duration was relatively short for Laguna San Andres (2.3 days) and tended to be longer in autumn than spring. The average stopover duration at the Laguna Madre of Tamaulipas was 4.4 days, and similar to Laguna San Andres, stopover duration was generally longer in autumn than in spring. Laguna Tampamachoco was used by one marked Reddish Egret during multiple migrations and had the longest average stopover duration of all sites (19.5 days). This was largely driven by a 64-day stopover during one spring migration.

Stopover site fidelity was highest for Laguna San Andres and Laguna Madre of Tamaulipas, particularly during spring. Of the Reddish Egrets with multiple years of data, Laguna San Andres was visited on 88% of spring migrations and Laguna Madre on 50% of spring migrations (Table 1). Laguna Tampamachoco was visited in successive spring migrations from a single individual, but no other sites were visited on multiple migrations by marked Reddish Egrets. Prioritization of stopover sites revealed the Laguna San Andres and Laguna Madre of Tamaulipas to be of greatest importance to migratory Reddish Egrets based on our marked sample. The Laguna San Andres was the only site used by all individuals, aside from the trans-Gulf migrant, followed by the Laguna Madre, with use by 66% of individuals (Table 1). The Laguna San Andres was used as a stopover by all individuals (excluding the trans-Gulf migrant) during every spring migration and in all but one autumn migration (Table 1).

Table 2. Total number of stops (n) and mean distance (km) traveled between stopover sites across all autumn and spring migrations for long-distance migrant Reddish Egrets (*Egretta rufescens*) during 2010-2016.

	Autumn			Spring		
Bird ID	*n*	Mean	SD	*n*	Mean	SD
49150	11	317.1	221.2	14	252.9	133.0
49195	14	250.1	164.9	18	192.9	127.4
49166b	2	580.2	405.5	3	391.0	273.8
129772	30	196.4	234.2	11	349.6	165.7
49156	4	327.4	202.1			
129770	1	368.1				

Of the six stopover sites identified, four have at least one designation in terms of their ecological importance, including being listed as an Important Bird Area (BirdLife International), and/or a Wetland of International Importance (Ramsar; Table 3). Laguna San Andres and Laguna Tampamachoco do not currently have any designations.

DISCUSSION

We were able to identify important stopover sites for Reddish Egrets by using satellite tracking devices on migratory adults. Laguna San Andres appeared particularly important for migratory Reddish Egrets because every tracked individual that migrated along the coast used it as a stopover site. The Laguna Madre of Tamaulipas was also an important site; it was the last stopover for many birds before making a final flight to breeding colonies in the Laguna Madre of Texas.

Within the annual cycle of many species, the migratory period is critical in terms of its influence on survival, reproductive success, and population stability (Ketterson and Nolan 1982, Owen and Black 1991, Moore and Simons 1992). Most mortality in migratory Reddish Egrets occurs during migration (Koczur et al. 2017). Despite this knowledge, stopover sites are rarely incorporated into conservation planning, even though their exclusion can compromise the optimization of conservation strategies (Russell et al. 1994, Sheehy et al. 2011). One of three

Table 3. Current designations related to ecological importance for Reddish Egret (*Egretta rufescens*) stopover sites.

Site	Designation(s)	Source
Laguna Madre Tamaulipas	Natural Protected Area; UNESCO-MAB Biosphere Reserve; Ramsar Site, Wetland of International Importance; Important Bird Area	BirdLife International 2021*a*
Laguna San Andres	None	
Laguna Tamiahua	Ramsar Site, Wetland of International Importance; Important Bird Area	BirdLife International 2021*b*
Laguna Tampamachoco	None	
Rio Antigua	Within the Centro de Veracruz Important Bird Area with multiple designations	BirdLife International 2021*c*
Laguna Mar Muerto	Within the Istmo de Tehuantepec - Mar Muerto Important Bird Area with multiple designations	BirdLife International 2021*d*

key conservation targets that influence population growth in Reddish Egrets is the quality and quantity of foraging habitat available during different periods of the annual cycle (Wilson et al. 2014). Understanding the spatial arrangement of foraging habitat during migration (i.e., stopover sites) is a priority for informing future conservation strategies of the Reddish Egret (Wilson et al. 2014). Our findings directly address the need for information on stopover site use and provide compelling evidence that Laguna San Andres and Laguna Madre of Tamaulipas are stopover sites that should be considered for conservation measures.

Variation in stopover site use by individual Reddish Egrets may reflect individual strategies, or environmental variability within and among seasons. Although all of our egrets were of breeding age (i.e., captured while nesting), one individual spent a longer than average amount of time at one stopover (64 days) and did not attempt to breed that spring (Koczur 2017). Also, stopover duration is often determined by the distance from the previous stopover, number of stopover opportunities en route, and the quality of the stopover site. Across heron species, stopover duration appears to be directly related to distance between stopovers and indirectly related to the number of available stopover sites (van der Winden et al. 2010, Ledwoń and Betleja 2015, Stier et al. 2017). Often, stopover duration is inversely related to stopover quality (Russell et al. 1994), with high-quality sites allowing for optimal foraging conditions and efficient acquisition of energy. In our study, Reddish Egrets migrated relatively short distances between stopover sites; therefore, a long stopover duration is probably not required for individuals stopping at high-quality stopover locations.

Stopover site fidelity at the population level is well documented for many species of migratory birds (Moore et al. 1990, Castro and Myers 1993, Morris et al. 1996). Individual stopover site fidelity has been documented in shorebirds (Taylor and Bishop 2008, Buchanan et al. 2012) and in a few species of wading birds (Pigniczki et al. 2016). Conservation of stopover sites is particularly important when birds exhibit fidelity and habitat is limited, either in spatial extent or due to specialization as in the Reddish Egret.

In this study, seven individuals migrated long distances and used stopover sites along the Gulf of Mexico. Our results are also based on multiple migrations from the same individuals; therefore, we considered the possibility of pseudoreplication. We included multiple years because there was individual variation in stopover site use across years, as well as variation among individuals, and several sites still remained important as stopover habitat. Future efforts should be made to track a greater number of individuals, or to conduct surveys at these sites to further our understanding of their importance to migratory Reddish Egrets.

CONCLUSIONS

Of the stopover sites identified, the Laguna Madre of Tamaulipas is the only one with any formal protection (e.g., declared a Natural Protected Area). Still, the ecological integrity of the Laguna Madre and other lagoons is threatened by dredging, habitat alteration, fishing pressure, wastewater effluent, and agricultural development and subsequent runoff (Castaneda and Contreras 2001, BirdLife International 2021*a*).

Laguna San Andres appears to be a priority for protection because of its use by all migratory Reddish Egrets migrating down the eastern coast of Mexico. Further research at these stopover sites could improve our understanding of their quality as stopover sites (e.g., proportion of time spent foraging, foraging success, etc.) as well as potential factors threatening their stability as stopover sites (e.g., alteration to hydrology, human development, etc.).

Responses to this article can be read online at:
https://www.ace-eco.org/issues/responses.php/1973

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