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Abstract.—Little is known about movements and habitat use of Brown Pelicans (*Pelecanus occidentalis*) in the northern Gulf of Mexico. We attached satellite transmitters to 18 adult Brown Pelicans (nine males, nine females) that were captured on Grand Isle along the Louisiana coast during 31 August-2 September 2010. Their movements and habitat use were tracked between September 2010 and March 2012. Nine of the Brown Pelicans remained proximate to the Louisiana coast; four ranged along the coasts of Alabama, Mississippi, and Louisiana; three moved from Louisiana to Texas; and two migrated across the Gulf of Mexico to the Yucatan Peninsula. Annual 99% home range estimates varied widely ($\bar{x}$ = 10,611 km^2, SE = 2,370), and males had larger ranges ($\bar{x}$ = 15,088 km^2, SE = 2,219) than females ($\bar{x}$ = 6,133 km^2, SE = 1,764). Habitats used by Brown Pelicans were primarily open water, estuarine emergent wetland, grassland, unconsolidated shore, and deep water habitat types. *Received 18 January 2013, accepted 20 August 2013.*

Key words.—Brown Pelican, Brownian Bridge Movement Model, habitat use, home range, Louisiana, migration, *Pelecanus occidentalis*, satellite telemetry.

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Brown Pelicans (*Pelecanus occidentalis*) are a charismatic and well-studied species (Johnsgard 1993; Shields 2002). Although well studied, most of the research on this species has been conducted in California and Florida (Briggs *et al.* 1981; Schreiber and Schreiber 1982; Anderson 1983; McNair 2000) with little research attention paid to Brown Pelicans in the northern Gulf of Mexico. Thus, little is known about movements and habitat use of Brown Pelicans in the northern Gulf of Mexico (Portnoy 1977; Visser and Peterson 1994; Shields 2002). However, Brown Pelican populations are recovering in the northern Gulf of Mexico (approximately 50,000 breeding adults) after regional extinction in the 1960s (Clapp *et al.* 1982; Shields 2002) and were recently removed from the Federal List of Endangered and Threatened Wildlife (United States Fish and Wildlife Service 2009). Regardless, this species is still vulnerable to catastrophic events (e.g., hurricanes) and long-term threats (e.g., human disturbances and habitat loss; Schreiber and Mock 1988; Klein *et al.* 1995). Although regional extirpation of Brown Pelicans from the northern Gulf of Mexico is unlikely, Brown Pelicans still face habitat loss in the coastal areas and barrier islands (Hingtgen *et al.* 1985; O'Connell *et al.* 2005) used for loafing and nesting habitats.

The objectives of this study were to estimate home ranges and determine habitat use of Brown Pelicans in the northern Gulf of Mexico. Data from this study can be used to establish baseline data on Brown Pelican local and regional movement patterns, home range sizes and habitat use in the northern Gulf of Mexico.

METHODS

Brown Pelicans were captured at their loafing sites on the bay side of Grand Isle, Jefferson Parish, Louisiana (29° 14' 09" N, 89° 58' 55" W; Fig. 1). We placed modified padded-jaw foot-hold traps (King *et al.* 1998) on rock jetties and on top of pilings at the end of jetties. Traps were secured to either large rocks (jetties) or pilings with heavy-duty twine. When using pole traps, the twine was tied to the pole near the waterline. Once a pelican was captured, it would glide to the water. We would then approach by boat and remove the bird from the trap. All captured pelicans were placed in ventilated animal crates and transported to a Louisiana Department of Wildlife and Fisheries facility on Grand Isle, Louisiana, for processing. The processing location was ≤ 3 km from all capture locations. All individuals captured were examined for general health. Age, culmen length, and sex were recorded for each. Sex was determined by culmen length (> 30 cm = male) (Schreiber 1976; Palacios 1992). Brown Pelicans with a white head and dark belly were aged as adult and those with a dark head and light belly were aged as immature (Schreiber *et al.* 1989). A 70-g solar-powered global positioning system (GPS) satellite transmitter (Microwave Telemetry, Inc.) was attached to adult pelicans with a backpack harness (Dunstan 1972; King *et al.* 2000). Transmitters were programed to record hourly locations. All birds were released at the processing site.

We estimated home ranges or movement paths of Brown Pelicans using the Brownian bridge movement model (BBMM; Horne *et al.* 2007). While equal time intervals between successive relocation are not a requirement of BBMM, the model uses a Brownian bridge and a variance parameter to approximate the movement path between subsequent locations (Horne *et al.* 2007). The BBMM estimates the probability that an animal used an area given the time and distance between successive locations and known estimates of GPS error (Horne *et al.* 2007). The BBMM explicitly makes use of auto-correlated telemetry data (Bullard 1991) and appears to be well suited to avian species that migrate or travel long distances (Takekawa *et al.* 2010; Walter *et al.* 2011). GPS receiver accuracy testing revealed a 12-m location error. We removed the top 1% of locations by the difference in time between sequential locations. Missing GPS locations can artificially inflate the BBMM variance and potentially overestimate probability of use (Walter *et al.* 2011; Nielson *et al.* 2012). The maximum time lag between sequential locations was estimated for each Brown Pelican to include variation among individuals. We estimated 50% BBMM and 99% BBMM home ranges to represent the core area of use and the standard range size, respectively. We calculated BBMM in R (R Development Core Team 2012) using the BBMM package (Nielson *et al.* 2012).

We estimated home ranges for a 7-month period (31 August 2010-31 March 2011) and a 12-month period (31 August 2010-31 August 2011). These temporal periods were selected based on transmitter longevity and sample size constraints. We then calculated average 50% and 99% home range sizes and standard error (± SE) by sex. We used a t-test to compare mean 7-month 50% and 99% home range sizes between male and female Brown Pelicans at the significance level of 0.10 due to relatively small sample size (n = 5 per sex). We used natural log transformation to normalize home range data. We did not compare mean annual home range sizes between the sexes due to relatively small sample size (n = 3 per sex).

We intersected our Brown Pelican locations with the National Oceanic and Atmospheric Administration (NOAA) Coastal Change Analysis Program's (C-CAP) land cover dataset (National Oceanic and Atmospheric Administration 2005) to identify land-cover types available to pelicans that remained near the United States Gulf Coast. We then calculated relative use frequency (%) of a land-cover type for each Brown Pelican (pelicans) location divided by the total number of locations per bird. We computed average (± SE) use frequencies for each land-cover type.

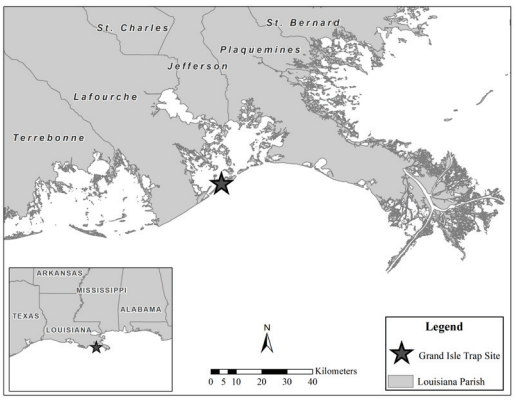


Figure 1. Brown Pelican capture site on Grand Isle, Jefferson Parish, Louisiana, during 31 August-2 September 2010.

RESULTS

Brown Pelicans (n = 29) were captured in 9 hours of trapping using ≤ 11 traps during 31 August-20 September 2010 on Grande Island, Louisiana (Fig. 1). Satellite transmitters were attached to 18 adult pelicans (nine male, nine female; Table 1). Brown Pelicans showed no visible signs of capture-related injuries and appeared healthy. Eight transmitter-equipped pelicans were not used in home range analyses. Analysis of the transmitter data showed that four transmitters were stationary for > 21 days, indicating that either the transmitters had dropped off or the birds

Table 1. Bird identification (ID), sex, culmen length (cm), age (years), date of capture and initial data transmission (Cap. Date), date of last transmission (Last Trans.), number of locations (Loc.), and number of transmitting days (Days Trans.) for Brown Pelicans (n = 18) captured at Grand Isle, Louisiana, and fitted with satellite transmitters.

ID	Sex	Culmen	Age	Cap. Date	Last Trans.	Loc.	Days Trans.
BRPE01	M	33.0	2	9/1/2010	3/22/2012	8,785	568
BRPE02	F	28.5	3	9/1/2010	3/22/2012	10,682	568
BRPE03	M	34.3	3	9/1/2010	1/6/2011	2,191	127
BRPE04	F	29.2	3	9/1/2010	12/24/2010	2,159	114
BRPE05	M	30.5	3	9/1/2010	2/12/2012	9,733	529
BRPE06	M	30.5	2	9/1/2010	2/13/2011	3,124	165
BRPE07	F	29.2	3	9/2/2010	3/22/2012	9,061	567
BRPE08	F	26.0	3	9/2/2010	4/13/2011	3,661	223
BRPE09	M	30.0	3	9/2/2010	2/5/2012	10,943	521
BRPE10	M	30.5	3	9/2/2010	8/24/2011	7,034	356
BRPE11	M	30.2	3	9/1/2010	6/10/2011	5,570	282
BRPE12	F	28.6	3	9/1/2010	9/5/2011	7,432	369
BRPE13	F	29.2	3	8/31/2010	5/27/2011	1,418	269
BRPE14	F	29.5	3	8/31/2010	8/16/2011	6,524	350
BRPE15	F	28.6	3	8/31/2010	12/26/2010	2,573	117
BRPE16	F	29.2	2	8/31/2010	10/3/2010	588	33
BRPE17	M	30.2	3	9/1/2010	1/16/2011	2,278	137
BRPE18	M	30.5	3	9/1/2010	1/23/2011	2,454	144

had died. These data showed no evidence of transmitter damage, battery drain, or decreasing charging capacity. We were able to recover only one of these four transmitters from a desiccated pelican carcass. The fate of the other four pelicans is unknown.

A total of 96,210 locations were received from 18 Brown Pelicans tracked from 33-568 days (Table 1). Individual pelicans (n = 18) were tracked for a mean of 302 days (± 43.2 SE; Range = 33-568 days), with means of 5,345 (± 818 SE; range = 588-10,943) locations per bird, and 17.7 (± 0.8 SE; range = 5-21) locations per day (Table 1). Pelican locations were recorded along the coasts of Alabama, Mississippi, Louisiana, Texas, and Mexico. No transmitter-equipped pelicans moved east of the Alabama coast (Fig. 2). Nine pelicans remained in the coastal Louisiana area throughout the study (within ≤ 72 km of the capture site; Fig. 3). Four pelicans ranged along the Louisiana, Mississippi, and Alabama coasts

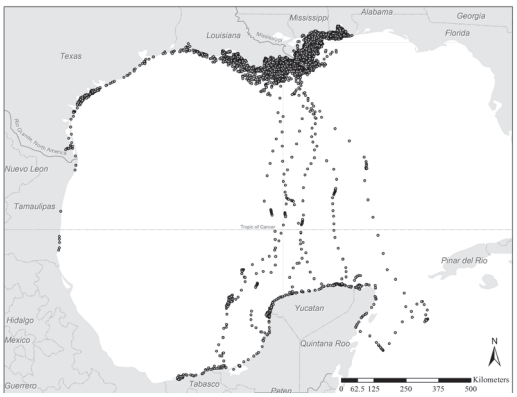


Figure 2. Locations of Brown Pelicans (n = 18) captured and fitted with satellite transmitters on Grand Isle, Louisiana, 31 August-2 September 2010. Locations were recorded from 31 August 2010-15 March 2012.

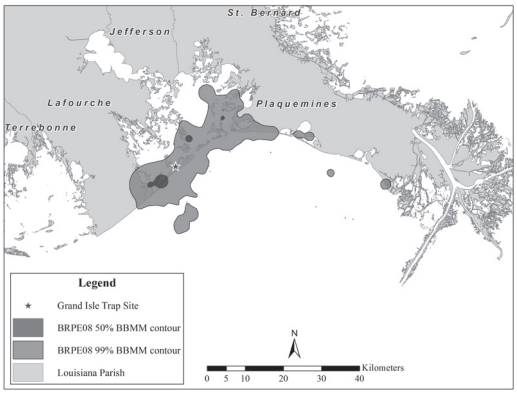


Figure 3. Example of Brownian Bridge Movement Model home ranges (99%) and core use (50%) areas of a Brown Pelican captured and fitted with a satellite transmitter on Grand Isle, Louisiana, 2 September 2010. Individual "BRPE08" ranged along Barataria Bay, Louisiana, area. Locations were recorded from 2 September 2010-13 April 2011.

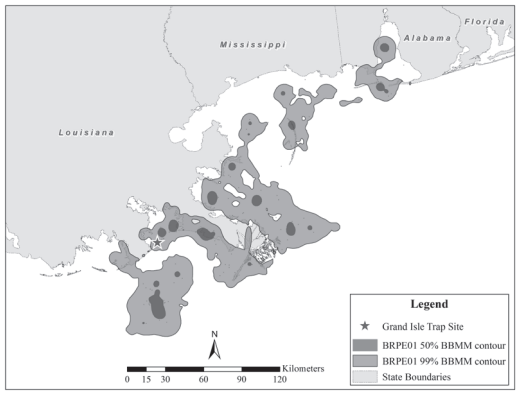


Figure 4. Example of Brownian Bridge Movement Model home ranges (99%) and core use (50%) areas of a Brown Pelican captured and fitted with a satellite transmitter on Grand Isle, Louisiana, 1 September 2010. Individual "BRPE01" ranged along the coasts of Louisiana, Mississippi, and Alabama. Locations were recorded from 1 September 2010-22 March 2011.

(within ≤ 236 km of the capture site; Fig. 4), three pelicans ranged from Louisiana to Texas (within ≤ 724 km of the capture site; Fig. 5), and two pelicans migrated from Louisiana across the Gulf of Mexico to the Yucatan Peninsula, Mexico (approximately 900 km from the capture site) for the winter and back to Louisiana in the spring (Fig. 6a,b).

We calculated BBMM home ranges for 10 pelicans during the 7-month period and 6

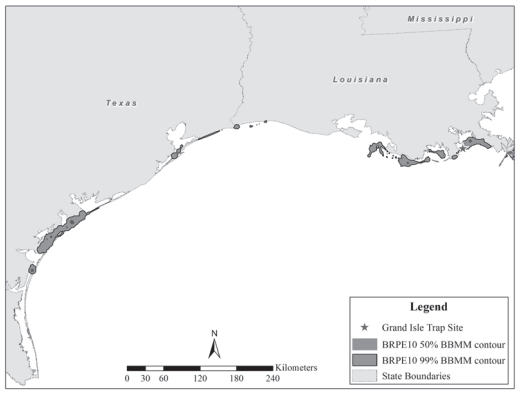
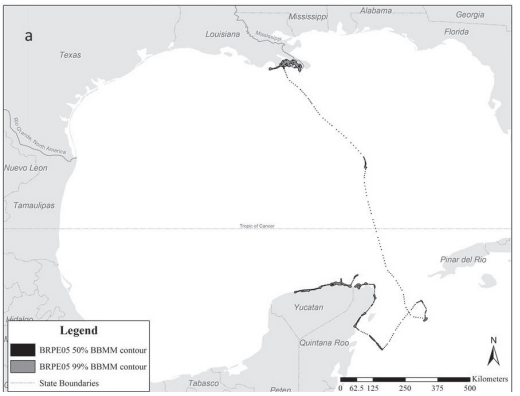


Figure 5. Example of Brownian Bridge Movement Model home ranges (99%) and core use (50%) areas of a Brown Pelican captured and fitted with a satellite transmitter on Grand Isle, Louisiana, 2 September 2010. Individual "BRPE10" ranged along the Louisiana coast to southern Texas. Locations were recorded from 2 September 2010-24 August 2011.



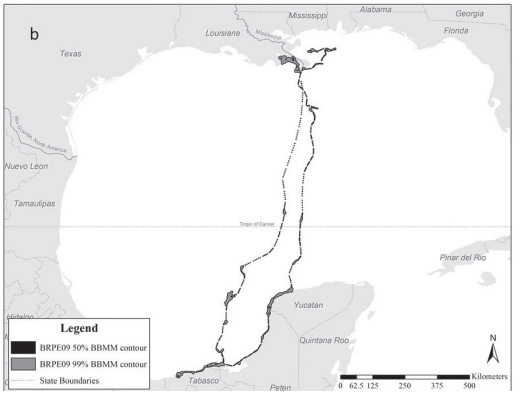


Figure 6a,b. Examples of Brownian Bridge Movement Model home ranges (99%) and core use (50%) areas of Brown Pelicans captured and fitted with a satellite transmitter on Grand Isle, Louisiana, 1-2 September 2010. Individuals "BRPE05" (a) and "BRPE09" (b) ranged along the Louisiana coast and crossed the Gulf of Mexico to winter along the Yucatan Peninsula, Mexico. Locations were recorded from 1-2 September 2010 to 5-12 February 2012.

pelicans during the 12-month period (Table 2). The 50% home range estimate ranged from 15 km^2 to 709 km^2 for the 7-month period and from 22 km^2 to 1,004 km^2 for the 12-month period, whereas the 99% home range estimate ranged from 502 km^2 to 10,894 km^2 for the 7-month period and from 2,612 km^2 to 18,787 km^2 for the 12-month period. Although mean male 7-month 50% home range (210 km^2) was almost four times that of females (55 km^2), they were not significantly different (t = -1.766, P = 0.115) probably due to relative small sample size (Fig. 7a). Mean male 7-month 99% home range estimate (5,852 km^2) was three times that of females (1,713 km^2) and was significantly greater than that of females (t = 1.766, P = 0.087; Fig. 7b).

Table 2. Home ranges (km²) of Brown Pelicans equipped with satellite transmitters near Grand Isle, Louisiana, during September 2010-March 2011 (7 months; *n* = 10) and September 2010-September 2011 (12 months; *n* = 6).

		7 months		12 months	
ID	Sex	50%	99%	50%	99%
BRPE01	M	70,8.6	10,893.9	1,004.6	18,787.3
BRPE02	F	20.6	1,258.1	22.4	2,612.1
BRPE05	M	113.9	4,207.3	223.6	11,114.1
BRPE07	F	149.3	4,097.1	195.1	8,093.4
BRPE08	F	14.9	502.2		
BRPE09	M	114.7	10,053.5	237.1	15,363.6
BRPE10	M	75.9	3,272.0		
BRPE11	M	35.2	830.8		
BRPE12	F	45.9	1,851.1	179.1	7,693.7
BRPE14	F	43.4	860.5		

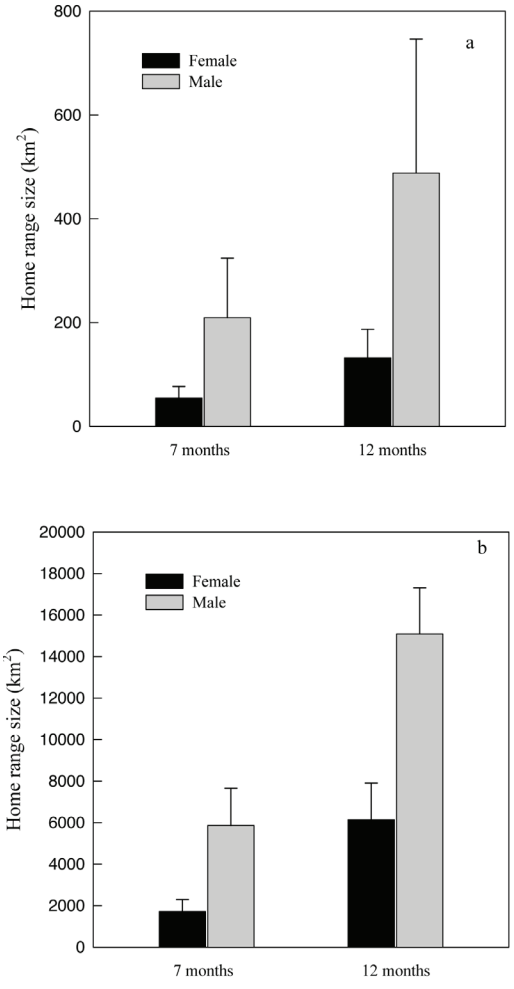


Figure 7. Means of (a) 50% and (b) 99% home range sizes of male and female Brown Pelicans for 7- and 12-month periods in the Gulf of Mexico coastal region.

Brown Pelicans (*n* = 15) remained near the United States Gulf Coast and used 18 different habitat types at different relative frequencies (Table 3). We defined a habitat type with > 2% relative use frequency as a main habitat type. The main habitat types used by Brown Pelicans included water, estuarine emergent wetland, grassland, unconsolidated shore, and deep water (> 5 km from shore), with water having the highest relative use frequency (Fig. 8).

DISCUSSION

Brown Pelicans from Florida were used to restock Brown Pelicans into Louisiana (O'Connell *et al.* 2005), so it would seem logical that pelicans from Louisiana and Florida would intermingle. Schreiber and Mock (1988), however, noted that no Brown Pelicans banded in Florida were recovered in Louisiana. Our results may indicate that there are regional metapopulations of Brown Pelicans in the Gulf of Mexico. Most of the pelicans in this study either stayed in the general area of capture or ranged along the northern Gulf of Mexico. Although some pelicans spent considerable time in known colony areas, we were unable to ground-truth the locations and therefore make no assumptions regarding breeding status. Similar results were found in Brown Pelicans that tended to stay in their breeding colony regions in California and Florida, with some shifts due to cold weather or reduced forage availability (Briggs *et al.* 1981; Schreiber and Schreiber 1982; Schreiber and Mock 1988).

Table 3. Relative frequencies of land-cover types used by Brown Pelicans (n = 18) in the United States Gulf of Mexico coastal region from September 2010-March 2012.

Habitat type	Percent (%)	SE
Water	61.80	4.070
Estuarine Emergent Wetland	25.51	3.086
Grassland	3.92	3.905
Unconsolidated Shore	2.71	1.161
Deep Water	2.39	0.864
High Intensity Developed	0.78	0.746
Medium Intensity Developed	0.70	0.624
Scrub/Shrub	0.62	0.477
Estuarine Aquatic Bed	0.61	0.162
Bare Land	0.39	0.074
Palustrine Emergent Wetland	0.26	0.182
Low Intensity Developed	0.22	0.114
Estuarine Scrub/Shrub Wetland	0.06	0.031
Cultivated Land	0.01	0.005
Palustrine Forested Wetland	0.01	0.004
Palustrine Scrub/Shrub Wetland	0.01	0.003
Palustrine Aquatic Bed	> 0.01	0.001
Pasture/Hay	> 0.01	0.002

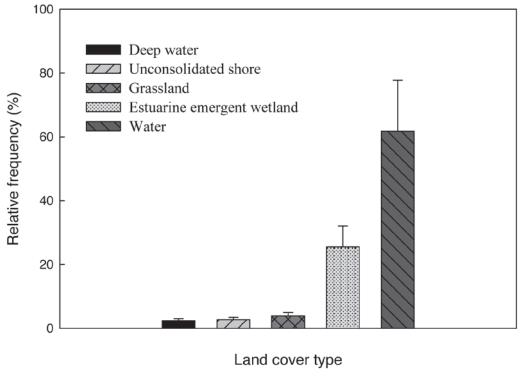


Figure 8. Relative frequencies of main land cover types (> 2%) used by Brown Pelicans in the United States Gulf of Mexico coastal region from September 2010 to March 2012. Habitat delineation was based on the National Oceanic and Atmospheric Administration Coastal Change Analysis Program's land cover dataset (National Oceanic and Atmospheric Administration 2005).

Brown Pelicans have been known to move long distances during migration along the Atlantic and Pacific coasts, and across the Sea of Cortez (Briggs *et al.* 1981; Schreiber and Mock 1988; D. W. Anderson, unpubl. data). The distances traveled by two migrant pelicans in this study from Louisiana across the Gulf of Mexico to the Yucatan Peninsula (a straight line distance of nearly 900 km) are much greater and were over open water. Both birds stayed in Mexico throughout the winter and traveled back across the Gulf of Mexico to Louisiana in the spring. The reasons for such long movements are unclear and warrant further study.

Brown Pelicans in this study used habitats similar to pelicans in coastal Texas, Florida, and California (Briggs *et al.* 1981; Schreiber and Schreiber 1982). Water and estuarine emergent wetlands were most likely used as foraging habitats, while grassland and unconsolidated shore habitats were probably used as nesting or loafing sites. We feel that pelican locations in deep water habitats may have occurred when birds were flying to other locations. However, more detailed analysis should be conducted to confirm this speculation. Future studies with larger sample sizes should be conducted to further elucidate Brown Pelican home ranges and habitat use. To our knowledge, this is the first study to document the ranges and habitat use of Brown Pelicans in northern Gulf of Mexico. These data provide baseline information on the movements and habitat use of Brown Pelicans in the Gulf of Mexico.

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