Nesting and Foraging Ecology of Black Skimmers (*Rynchops niger*) in Coastal Louisiana following the BP Oil Spill: Final Report

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Abstract

The Isles Dernieres Barrier Island Refuge (IDBIR) in Louisiana represents an ecologically sensitive area that is historically important habitat for wintering and breeding waterbirds, and is currently threatened by habitat loss, disturbance, and climate change. Black Skimmers (*Rynchops niger*) relies on barrier island habitat for more than half their population nesting ground. This colonial species has a unique tactile foraging strategy in which they dip their longer lower mandible in the water while skimming the waters' surface to catch prey. Similar to other coastal birds, information on where skimmers forage and what prey species they deliver to the nest remains unknown. In this study, we monitored the nesting and foraging ecology of Black Skimmers on the IDBIR from May–July of 2011–2013 and 2016 to understand the birds' behavior following the BP oil spill. We used digital colony surveys, video recorders, radio-telemetry, and GPS data loggers to shed light on nesting selection, effort, and success; and foraging movements and diet. Here, we present a summary of years 2011-2013 and detailed results from the 2016 foraging monitoring. In 2016, we captured 2 skimmers (1 male and 1 female) and equipped them with GPS data loggers; only the male was recaptured. The male was tracked for 3 days and made 14 trips northeast of the colony, including 6 trips in the brackish waters of the coast, similarly to a skimmer GPS-tracked in 2013. Although the sample size is small, skimmers seem to forage mostly at night in the brackish waters of coastal Louisiana, where the BP oil spill spread and impacted the ecology of the marsh. Compared to data collected before the oil spill, the skimmer population size seems to be declining on the refuge. In addition to the 2010 BP oil spill, other ecological constraints (e.g., sea level rise, nutria) are causes for concern.

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Introduction

Major oil spills have both short- and long-term effects on colonial seabird distribution, breeding, and foraging ecology. The April 2010 BP oil spill in the Gulf of Mexico has severely affected numerous marine species and habitats (Barron 2012; http://tpx.sagepub.com/content/40/2/315.long). Black Skimmers (*Rynchops niger*) that nest on the barrier islands in the Gulf were directly and probably indirectly affected by the spill; however, there is a paucity of information as to how this species has been affected by oiling events.

Black Skimmers are classified on the National Audubon Society's 2007 watch list as a species of national concern, which are defined as having the potential for population decline or becoming rare. In addition, the U.S Fish and Wildlife Service (2008) listed Black Skimmers as a species of concern in six different regions nationwide, one of which is the Gulf Coastal Prairie. The outer barrier islands of coastal Louisiana, where this species nests, are currently threatened by erosion, climate, sea level rise, hurricanes, growing oil exploitation, and other anthropogenic disturbances (Barras et al. 2003). Previous studies in this area have suggested that skimmers and other colonial seabirds of high conservation concern may be excellent indicators of the ecological conditions of these barrier islands (Owen 2010, Raynor 2010).

The Isles Dernieres Barrier Islands Refuge (IDBIR) in coastal Louisiana provides suitable habitat for breeding Black Skimmers that is becoming increasingly rare throughout the Gulf region. Portnoy (1977) reported that there were approximately 37 Black Skimmer colonies with 29,970 breeding pairs throughout the Alabama, Mississippi, and Louisiana region. This estimate showed that the largest concentration of breeding Black Skimmers occupied the Gulf coast in comparison to the breeding colonies monitored in New Jersey, New York, Texas, Virginia, and Florida. In 2001, there was only an estimated 2,905 breeding pairs along southern Louisiana distributed among 20 colonies, which had a mean of 145 pairs per colony (Michot et al. 2004). However, since then the Gulf coast has experienced increased levels of erosion. Coastal Louisiana, in particular, is projected to lose over 1200 km^2 of land over the next 50 years (Barras et al. 2003). Erwin et al. (2003, 2010) have shown that the reduction and loss of coastal landmass from erosion has negatively impacted breeding waterbirds occupying the Chesapeake Bay region, similar to the Louisiana coast. Specifically, Molina and Erwin (2006) found that erosion has negatively impacted Gull-billed Terns (*Gelochelidon nilotica*) in the Alabama, Mississippi, and Louisiana region. For Gull-billed Terns, beach erosion and disturbances to estuarine habitat, where they breed and forage, are the main threats to an already declining population in the region since censusing began in the 1970s. Thus, protection of the IDBIR represents a conservation challenge that is crucial for breeding populations of not only Black Skimmers, but other coastal marine birds sharing the same habitat.

The existing data on Black Skimmers have been mostly focused on selected aspects of their breeding biology (e.g., Burger and Gochfeld 1990, Gochfeld and Burger 1994). There is a paucity of information available on skimmer foraging behavior, specifically on when they forage, where they forage, and what prey species they bring back to the nest (Gochfeld and Burger 1994). In Louisiana, virtually nothing is known about how breeding and wintering Black Skimmers utilize habitat for foraging.

In this study initiated by Breehan Furfey, Jim Bednarz, and Aaron Pierce, radio-telemetry was used to gather information about skimmer movements during the breeding season. Radio-telemetry may be one of a few feasible methods to gain information about the foraging ecology and movements of skimmers. The advantage of radio-telemetry is that radio-tagged birds do not need to be recaptured. On the contrary, birds equipped with GPS data loggers must be recaptured for the data to be retrieved. The cost of these data loggers is also prohibitive. However, this GPS-based method is not limited by the range of detection. We combined both methods to gain valuable insight on skimmer habitat use not only on the refuge, but also at other localities throughout the Gulf region. To our knowledge, our study represents the first time radio-telemetry or GPS-based tracking have been employed with Black Skimmers during the breeding season, in part, because of the challenges of capturing the birds on barrier islands. This research enabled us to identify key foraging habitats used by skimmers and to make recommendations for the protection of vital foraging areas from spills and other threats.

Also, in previous years of this study, camera systems were deployed at skimmers nests to improve our understanding of the breeding biology and the causes of nest failures of skimmer in a human-impacted environment. To our knowledge, this camera system installation has never been done before with a colonial nesting seabird, and represents a unique approach to studying the reproductive ecology of skimmers. Although we had some technical and weather-caused difficulties, the camera systems were shown to be useful for providing detailed daily coverage of nesting activities, specifically on adult attendance rates, prey delivery rates, determining the causes of nest failures, and documenting fledging events.

The long-term objectives of this study were to 1) quantitatively document impacts of the 2010 Deepwater Horizon oil spill on Black Skimmer populations residing adjacent to the Mississippi River Delta, Louisiana, and 2) devise remediation priorities to minimize long-term impacts of the Deepwater Horizon spill by identifying vital foraging areas used by Black Skimmers that would warrant priority rehabilitation and conservation protection related to future spill events and other disturbances. Three approaches were proposed to accomplish these long-term objectives:

1. Compare nest success data between pre-and post-spill years. This is crucial for management on the islands and for predicting future population trends.
2. Identify key foraging areas used by skimmers with radio-telemetry and GPS-based tracking. No data were available on the selected or most productive foraging habitat used by skimmers.
3. Use camera systems at nests to improve our understanding of the reproductive biology and causes of nesting failures of skimmers in a human-impacted environment.

In the following report, we present a summary of the results from seasons 2011–2013, detailed information gained in 2016, and a conclusion on skimmer reproductive success and foraging ecology following the BP oil spill.

Methods

Study Area

We conducted field research on the Islands in the Isles Dernieres Barrier Island Refuge (IDBIR), (29°03’ N, 90°57’ W to 29°05 N, 90°36’ W), located in Terrebonne Parish, Louisiana. The refuge is comprised of five barrier islands, which includes West and East Raccoon, Whiskey, Trinity, and Wine islands. The islands currently encompass approximately 9 km^2 of barrier islands; however, this land area is rapidly changing. The IDBIR is currently suffering from land loss, which has mostly been caused by erosion, subsidence, storm damage, and hydrological modifications throughout the region. For example, in 2010, Wine Island lost approximately 1 m^2 of land a week (S. Walters, University of Louisiana at Lafayette, Pers. Comm.).

According to NOAA (2010), the IDBIR had varying degrees of oil deposits that ranged from light to medium, and in some areas, heavy oil accumulation. These estimates were part of the Environmental Response Management Application (ERMA), which is assisting with response operations for the Deepwater Horizon spill following the spill. ERMA utilizes a mixture of satellite, radar, aerial imagery, and SCAT (Shoreline Clean-up and Assessment Technique) data, as well as wildlife observations and overall environmental quality measurements to quantify regions of varying amounts of oil accumulation. During a reconnaissance trip to these islands in 2010, we observed scattered tar washed up on shore in the IDBIR. Also, during this field visit to the skimmer colony on West Raccoon Island in July 2010, only one skimmer fledgling was observed relative to an estimate of 500 adult skimmers loafing in the area. Based on the ERMA maps, there is currently no oil observed on the refuge where skimmers are likely to nest. The only exception was Wine Island, which has light oil traces.

Breeding Success

We measured Black Skimmer nesting success on the Refuge from May until August 2011–2013. We scouted all the islands (late May-early June) to look for signs of colony formation. If there was a large congregation of skimmers that were not loafing on the shorelines and observed to be distributed in pairs, we suspected early colony establishment. To minimize disturbance, we confirmed a nesting colony by observing pairs build nest scrapes at a distance as well as visually confirming the presence of nest scrapes during very brief visits (<15 min). We continued to monitor the colonies as several locations showed signs of early nest scrape construction, but were later abandoned. For this study, a skimmer nest was defined as a scrape with at least 1 egg.

When several nests contained eggs, we selectively placed wooden stakes approximately 0.2 m away from individual nests that had two or more eggs. Each nest marker stake was numbered for later identification. We monitored these nests once weekly to measure nest success. Specifically, we checked for new eggs, recorded evidence of nest failure, and presence of chicks. Weekly nest monitoring continued until nest termination, either nest failure or success. Suspected causes of nest failures were also noted, which included predation, flooding, abandonment, or failed due to other undetermined reasons. Mayfield (1975) nest survival estimates were used to determine the daily survival rate (DSR) and hatching success of the nests monitored. A successful nest was defined as a nest that hatched at least one chick.

Nest Camera Sampling

Cameras were selectively deployed at active nests that had two or more eggs in 2011 and 2013. No camera was deployed in 2012 as flooding occurred before full establishment of the colonies. We used Sony Infrared (Waterproof High Resolution Infra-red Zoom Camera, Super Circuits, Austin, TX), which continuously recorded throughout the nesting period. Cameras were placed on wooden stakes set in the ground approximately 2 m from the nest. We placed a camouflaged (spray-painted sand color) bucket over the cameras to protect the cameras from inclement weather conditions. Cameras were powered by two deep-cycle marine batteries housed in pelican cases buried >100 m away from the colony. Video was recorded by a DVR system (H. 264 Micro Digital Video Recorder, super circuits) with SD memory cards. The memory cards were replaced every 3–5 days to ensure continuous sampling and no gaps in the data. Batteries were replaced once a week.

Video from the SD cards were uploaded on the SDR program (MDVR14-4, Super circuits, Austin, TX) and stored on a hard drive. We watched video from the recorded nests to look for adult attendance rates, causes of nest failures, prey species being delivered, and prey delivery rates.

Fledgling Density

We sampled transects running down the length of East and West Raccoon islands to estimate the fledgling density during the peak fledgling period (4–7 August 2011). We measured the length and area of the island using a GPS receiver. To minimize double-counting birds because young skimmers flush easily, we counted only the fledglings that flew past while walking transects, and recorded fledglings that were loafing at a distance. In addition, we estimated the lateral distance that fledglings were observed from the transect line. We used program DISTANCE 5.0 (Thomas et al. 2006) to adjust for imperfect detectability and estimate overall fledgling density for both islands.

Trapping

Skimmers were trapped using both mist nets and a radio-controlled bow net. Mist nests were used on West Raccoon Island at night during peak activity, and were placed approximately 200 m away from the active colony on the shoreline. We used 60-mm mesh nets erected along shoreline. We also used skimmer decoys to help attract skimmers to the area where the nets were placed. We checked nets approximately every 15 min to minimize the time skimmers were in the net and to release any by-catch (e.g., Royal Terns [*Sterna maxima*], Sandwich Terns [*Sterna sandvicensis*]).

A bow trap was used on East Raccoon Island because of the small colony size and because of the high density of terns breeding in the area. The radio-controlled bow net was buried in the sand around an active nest. When the adult returned to the nest and resumed incubation, we triggered the bow net. Typically, the second adult skimmer of the pair would tend the clutch while we were processing the captured adult. Bow net trapping occurred during early morning hours (0800-1000) to reduce the chances of the eggs overheating when adults were away from the nest. To minimize disturbance, we did not trap more than two skimmers at the colony per trapping session.

We banded each bird with a USGS aluminum band as a unique combination of color bands for future identification. We also took morphological measurements to determine sex. Measurements included mass, wing chord, upper and lower bill length, bill depth, and tarsus length. We aged and sexed the birds following measurements given by Pyle (2008). For all birds, lower bill length and bill depth were the most reliable characteristics to distinguish males from females. Mass was also used, but because there was some overlap between sexes, other morphological characteristics provided a more accurate confirmation of sex.

Bird tracking

In addition to taking morphometric measurements, 46 Skimmers captured in June 2011 were equipped with VHF radio-transmitters (Holohill Inc., Ontario, Canada) weighing less than 8 g (<3% of body mass; Meyburg and Meyburg 2009). To attach the transmitter, we used the modified figure-eight harness technique (Rappole and Tipton 1991). The transmitter rested on the birds lower back while harnessed around the upper legs with elastic thread that should degrade over time. We tied the transmitter on snug enough to stay secure but loose enough (a pencil could fit between the birds' body and the elastic leg loops) to not constrict leg movement. During release, the skimmers often walked away before flying. This allowed us to ensure the transmitter attachment was not impairing their movement. In addition, we applied the transmitters as quickly as possible to minimize handling time and stress on the bird. The mean time between capture and release was 20 min (6–60 min). Several marked birds were re-sighted actively foraging and feeding nestlings throughout the season, and none showed signs of adverse effects related to the transmitter harness.

We attempted to track each marked bird at least 30 times throughout the study period. We used a combination of H, Yagi, and Omni antennas for tracking. An Omni antenna was placed on the highest location of the boat, and we programmed a scanning receiver to cycle through all frequencies to help detect birds while we traveled to and from the islands. The Omni-antenna helped us find several birds away from the colony or birds that had departed from the nesting colony. Once a bird was detected with the Omni antenna away from the nesting colony, we determined its location by using the Yagi antenna on the boat by triangulation. We tracked each bird at least once during different time blocks of the day (e.g., 0700–0800, 0800–0900, and 1300–1400). We did not track the same bird within 1 hour of getting its last location to ensure that the locations would be independent.

We confirmed some of the radio-tagged skimmers' nests by homing and using spotting scopes at a distance. As the field season progressed, we suspected foraging activity mostly occurred from dusk until dawn. During these hours, three observers were posted at different locations on the islands, spaced >150 m apart. Using 2-way radios, we took azimuths on one bird simultaneously to get a location on a moving skimmer by triangulation. Once we detected an individual bird, we coordinated by radio and took three azimuths simultaneously to improve the probability of obtaining an accurate location. If possible, we made two separate triangulations in quick succession (<3 min) and the location with the lowest error polygon was used in subsequent analysis. Based on the azimuths and the geographic coordinates of receiver sites, we estimated the location of the bird by using program Locate II (1990).

In June 2013, we supplemented radio-telemetry with GPS-based telemetry and 2 skimmers were fitted with a waterproofed 10.5-g mini-GPS data logger (earth&Ocean Technologies GmbH, Kiel, Germany). Only birds weighing > 350 g were selected for this procedure. In 2016, we again equipped two skimmers with a GPS unit of the same model. The GPS unit was attached to the back of the bird using Tesa tape on three layers of feathers (Wilson and Wilson 1989; Fig. 1). Camera data from 2011 (Furfey 2014) revealed that skimmers seemed to forage mostly at night. Therefore, the GPS units were set to record a location every 1 h during the day and every 15 min at night in 2013, and every 15 min day and night in 2016. To retrieve the GPS locations recorded on the loggers, we attempted recapturing the skimmers at their nest 2-5 days after initial capture and attachment. We used the same bow net technique as described above.

Figure 1. Data logger on a Black Skimmer showing the teas tape attachment method.

All VHF and GPS locations for each bird were mapped on and around the islands using ArcGIS v9.3.1 and v10.3.1 and 2010 NAIP imagery of Terrebonne Parish or 2011 National Land Cover Database for Louisiana and county lines from Natural Resources Conservation Services. ABODE (Laver 2005), an ArcGIS tool, was used to determine fixed kernel density estimates from VHF locations, but kernel densities from GPS locations were determined with packages adehabitatHR and adehabitatLT (Calenge 2006, Calenge et al. 2009) in program R. For both kernel density estimations, we used a Least Squares Cross Validation (LSCV) as our smoothing parameter to determine the appropriate probability use contours (Horne and Garton 2006).

Results & Discussion

Breeding Success

During 2011-2013 and 2016, Black Skimmers attempted to nest on four of the five islands. Furfey (2014) found that West Raccoon Island supported the largest colonies (550–1,191 nests), followed by East Raccoon (48–487 nests), and Wine Island (6–55 nests). Whiskey Island could not support nests due to mammalian predation pressure. Successful nesting occurred only during 2011 and was restricted to two sites (West and East Raccoon Islands). Complete reproductive failure occurred at all sites in 2012 and 2013 due to flooding impacts. Skimmers nesting on the IDBIR were consistently unsuccessful in early colony establishment in their nesting sites. Eighty-five percent of monitored colonies (n = 13) failed during the initiation phase, and only 15% successfully hatched young. Breeding pair estimates on the refuge declined 54% from 2011 to 2013. During 2011, 53.2% of the 62 nests monitored hatched young successfully, whereas 46.8% of nests failed due to abandonment, predation, or flooding. Of the total 396 monitored nests in 2011–2013, 88% (350 nests) failed before hatching (34% flooding, 26% predation, 18% other causes). Compared to data collected prior to 2011, this research suggests that the breeding population on the IDBIR is currently in decline. More long-term data is needed on reproductive output to evaluate skimmer population trends, threats, and future outlook for the species.

In 2016, heavy rain events destroyed part of the skimmer colonies. Some individuals attempted to renest on West Raccoon. Both skimmers that we equipped with GPS data loggers in 2016 (see *Foraging Behavior and Diet*) failed their nesting attempt due to a combination of rain and predation. The area was very silty and with the rain, the sediment encased the eggs. Although birds stayed on the nests, eggs were eventually predated.

Foraging Behavior and Diet

Using cameras, Furfey (2014) found that skimmers fed young mostly at night (63% feedings occurred at night; n = 38) with a mean food provisioning rate of 2 fish per hour, each a single prey delivery. Females made more prey deliveries (66%) to nests than the males (n = 38 total feedings). Five of 35 (14%) skimmers captured were carrying fish, which primarily included pogie (Brevoortia partornus), mullet (Mugil cephalus), and silverside (Menida peninsulae).

Furfey (2014) captured 67 skimmers, 46 of which were equipped with radio-transmitters. She recorded 203 radio-locations, most of which were within 800 m of the colonies. Twenty-six locations (10%) were documented at dusk and at night when skimmers were actively foraging. According to kernel density estimates, the mean home-range size was 50 ha and ranged from 10.62 to 243.78 ha (SD = 74 ha, n = 11; Fig. 2). Conventional VHF-telemetry methods seemed biased and likely ineffective for tracking skimmer foraging movements because birds could not be detected beyond 800 m of nesting colonies. Therefore, GPS-tracking was attempted in 2013 and in 2016.

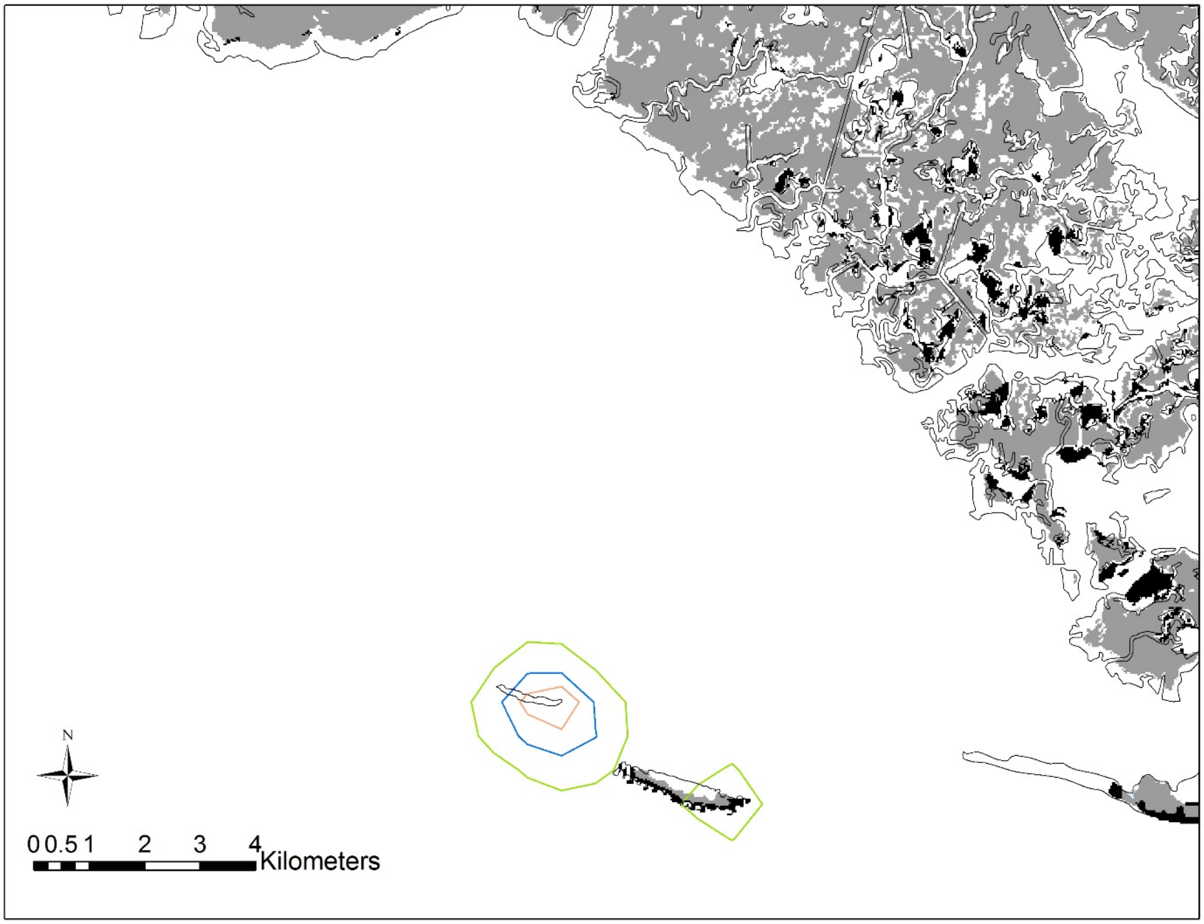

Figure 2. Home range based on radio-telemetry data collected in 2011, and estimated with fixed kernel densities (green: 95%, blue: 75%, orange: 50%).

In 2013, only one of the two GPS-equipped males was successfully recaptured and 15% of 202 locations were identified as foraging activity between June 27 and July 1, according to time of day and elevation. This male made 11 trips directly north of the breeding colony (west Raccoon island), most of which (81%) were made counterclockwise, and traveled a maximum distance of 16.4 km (mean = 12.6 km, SD = 3.6 km) from the breeding colony (Fig. 3). On average, this bird traveled 25.9 km for round-trip foraging trips (range 13.8–34.3 km) at an average speed of 22.3 km/h. The maximum speed recorded by the GPS was 46.7 km/h. This male's trips were about 115 min long, at least 75 min apart, and all at night (between 1800 and 0530). Interestingly, each first trip of the night started earlier than the previous night (between 36 min and 70 min). With all locations (nest, loafing, and foraging), the total 95% fixed kernel home range was 123 km^2, but when only trips were considered (i.e., movements around the nests were excluded), the home range expanded to 256 km^2 (Fig. 4).

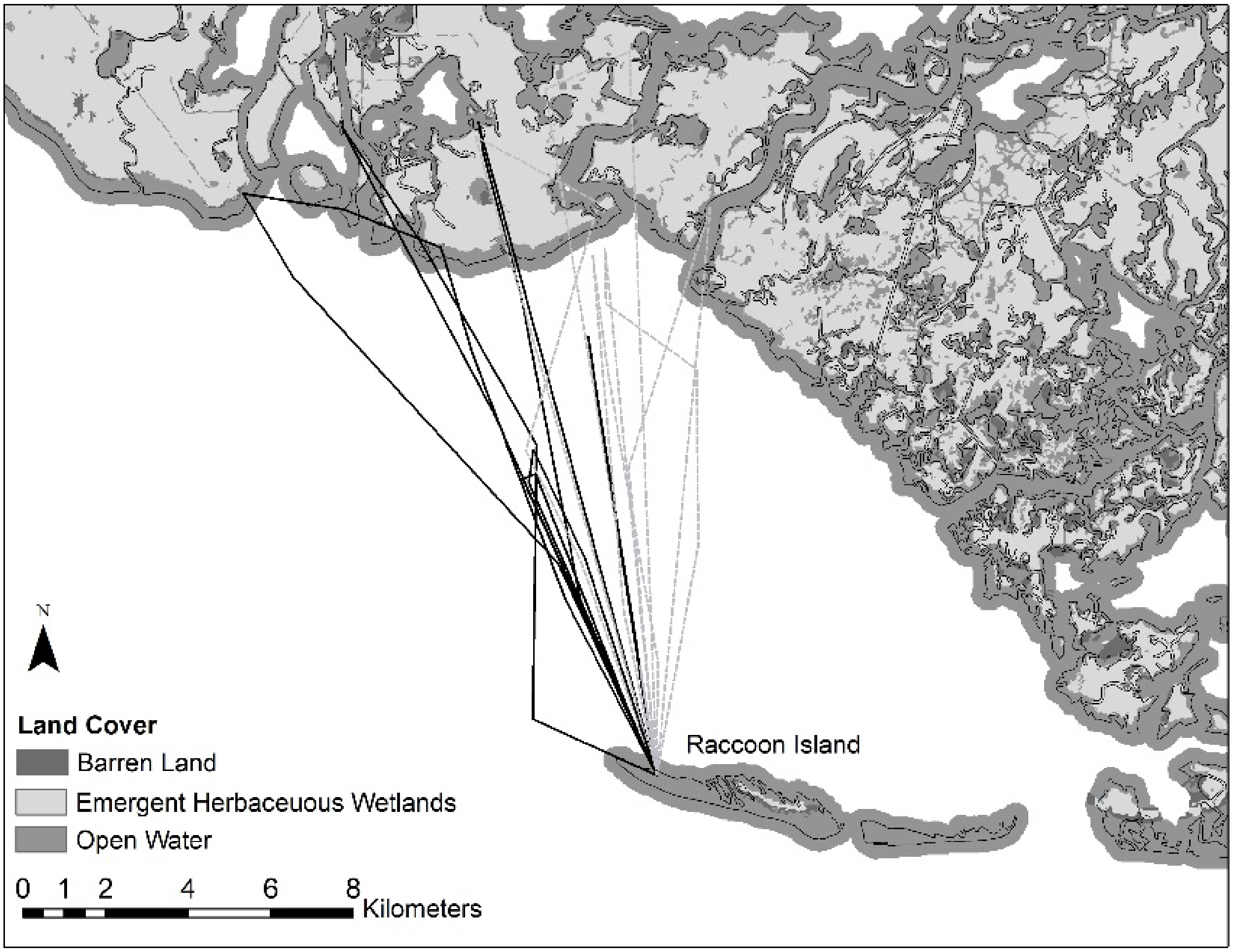

Figure 3. Foraging trips made by a black skimmer male equipped with GPS 364 and tracked June 27–July 1, 2013.

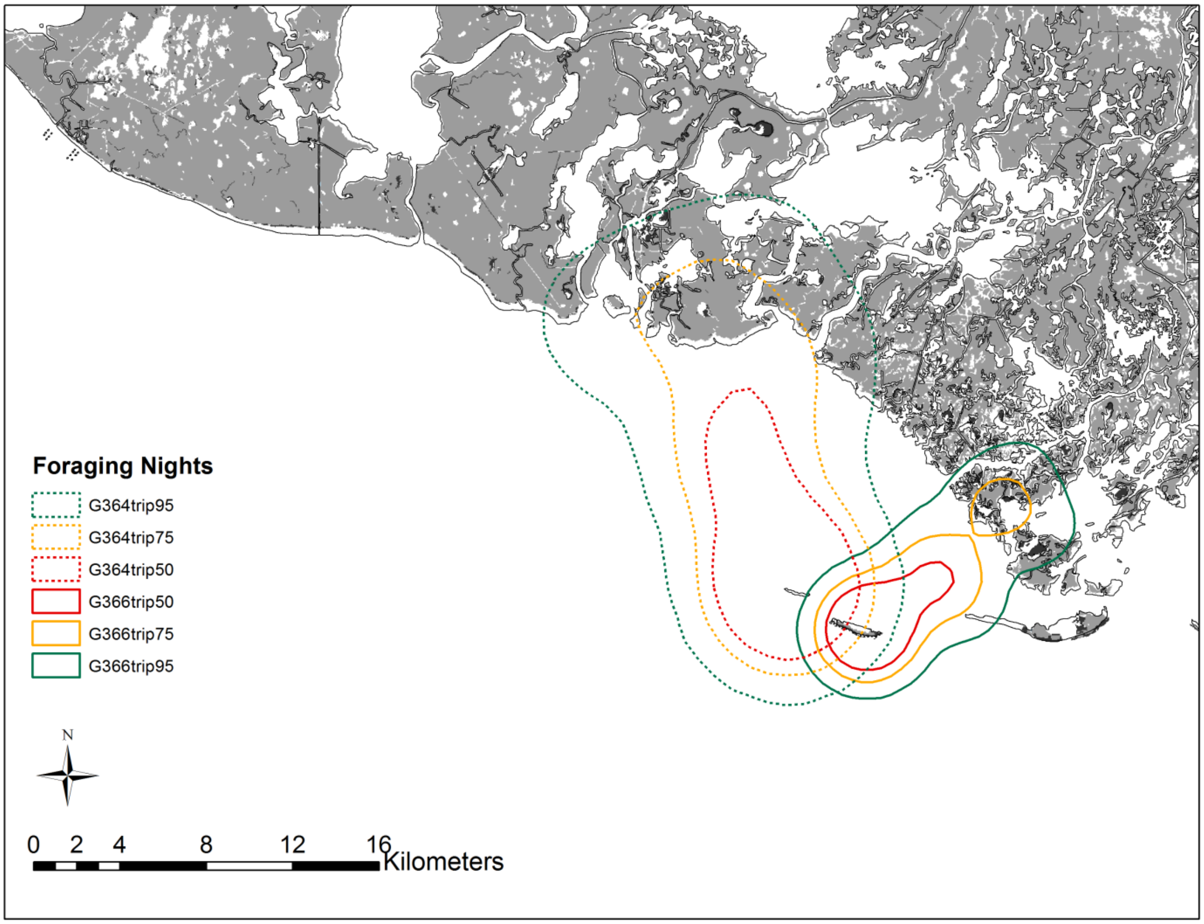

Figure 4. Foraging trip range of two male black skimmers GPS-tracked from West Raccoon island in 2013 (dotted polygons) and from East Raccoon island in 2016 (solid polygons), off coastal Louisiana. Green, orange, and red polygons represent 95%, 75%, and 50% fixed kernels, respectively.

In 2016, of the two GPS-equipped skimmers (Table 1), only the male was recaptured. Although we resighted the female 3 days later with the GPS unit still on her back, she did not go back on her nest and we could not recapture her.

Table 1. Measurements recorded for one male and one female black skimmers, both captured during incubation, on East Raccoon island, Louisiana, in 2016.

Band Number	Date	Mass	Bag	Wing Chord	Tarsus	U. Bill	L. Bill	Bill Dep.	Age	H+Bill	Sex	Notes
1813-15101	5/30	405	30	400	35	75.2	98.2	31.6	AHY	137.8	M	GPS 366
1813-15102	6/8	334	30	361	27.6	61.5	82.4	26.2	AHY	137.1	F	GPS 351

The GPS recorded 261 locations for the male between May 30 and June 2, 10% of which were identified as foraging activity. This male made 14 night trips northwest of the breeding colony (east Raccoon island; Fig. 5). All of his trips were shorter in time (~ 62.5 min) and distance than the male in 2013, but more frequent. He travelled a maximum distance of 10.6 km (mean = 6.2 km, SD = 2.7 km) from the breeding colony, with round trips being about 12.7 km (range 6.2–21.4 km) at an average speed of 17 km/h. The maximum speed recorded by the GPS was 54.7 km/h. This male's trips were so short and frequent that we often obtained only 1 location for a trip – he was at the nest 15 min before and 15 min after this location, and after 15 min at the nest, another location at sea or in the marsh would be recorded again. The 95% fixed kernel home range for this bird was much smaller, all locations included (16 km^2), or only trip locations considered (86 km^2; Fig. 4). Trips made by both males are summarized in Table 2.

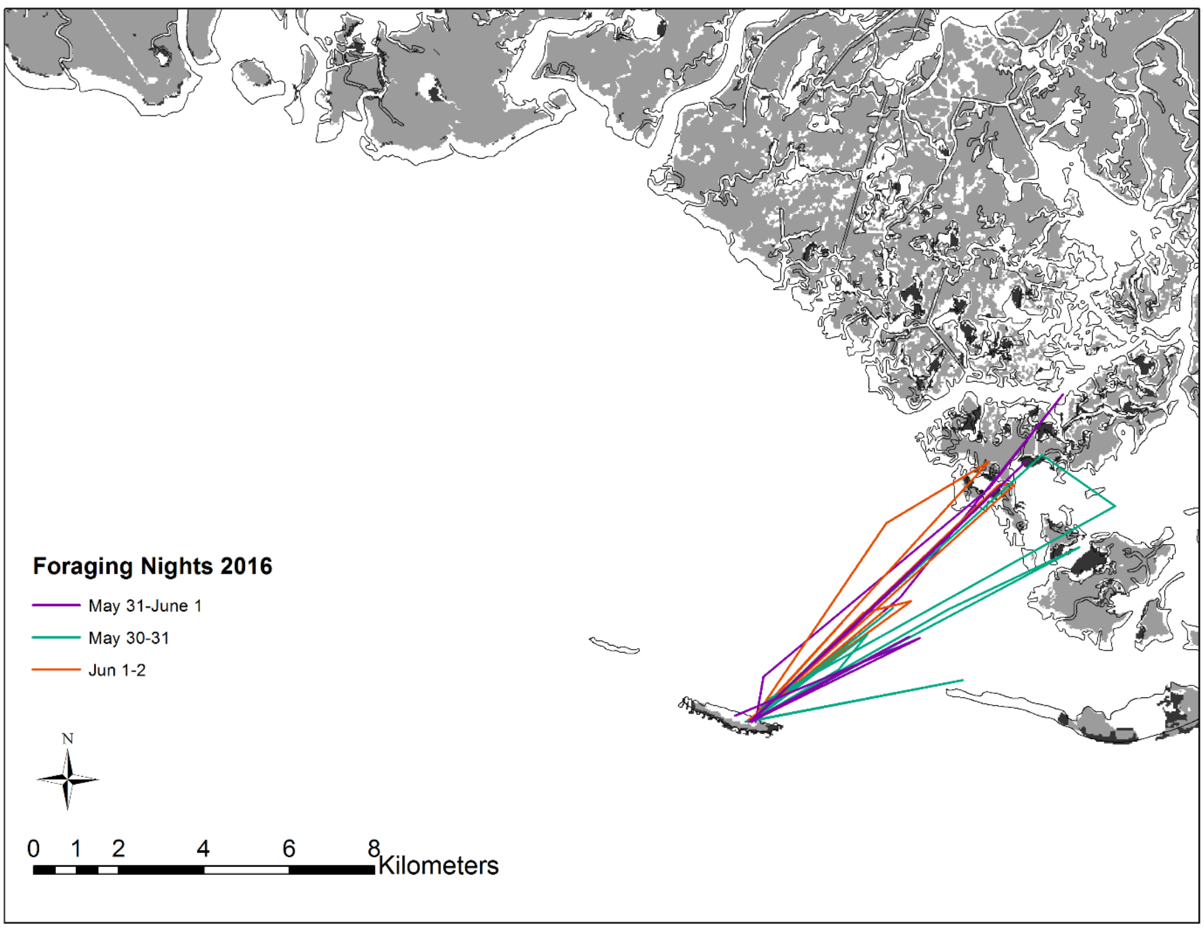

Figure 5. Foraging trips made by a black skimmer male equipped with GPS 366 and tracked May 30–June 2, 2016.

Table 2. Round-trip travel distances and duration of two male skimmers GPS-tracked in 2013 and 2016. The number of locations includes the last nest location before departure and the earliest nest location upon return. Departure time is the time at which the last location before departure was recorded. Duration represents the time from and back to the nest. Maximum distance is the longest distance from the nest. Trips for which locations were missing (i.e., not gathered every 15 min) are indicated with an asterisk.

(A) Skimmer GPS-364, tracked June 29-July 1, 2013

Trip	No. Locations	Departure Time	Duration	RT Distance	Max Distance
1	7	2327	77	23.21	11.55
2*	4	0216	144	19.12	9.56
3*	4	2218	158	25.72	12.76
4	5	0211	63	13.76	66.52
5	5	0428	61	14.55	7.22
6*	4	1707	180	34.34	16.42
7	6	2154	138	31.88	14.91
8	9	0229	136	34.04	16.19
9*	6	2118	126	24.65	11.67
10	6	0040	89	30.44	15.18
11	7	0411	93	32.75	16.33

(B) Skimmer GPS-366, tracked May 30-June 2, 2016

Trip	No. Locations	Departure Time	Duration (min)	RT Distance (km)	Max Distance (km)
1	4	2018	46	6.84	3.34
2*	3	2104	48	8.50	4.25
3*	3	2152	66	10.09	5.04
4	4	0030	64	17.41	8.70
5	6	0408	77	21.29	9.90
6	3	2027	30	8.39	4.19
7	3	2112	32	8.79	4.40
8*	4	2159	116	17.71	8.86
9	6	2355	78	21.41	10.58
10	4	0446	45	16.66	8.24
11*	5	2004	80	16.68	8.29
12	3	2209	30	6.27	3.14
13	4	2342	46	9.49	4.68
14*	3	0201	119	7.96	3.98

The GPS units on occasions did not record a location after 15 min. Therefore, some trips may have been shorter in duration. A concern with the GPS in 2013 is that we may have missed foraging trips during the day because of the 1-h interval set to record locations. However, the GPS used in 2016, which was set with a 15-min interval at all hours, did not reveal any foraging trips made during the day. The differences in speed, distance, and frequency between the two skimmers are likely a result of the distance of the marsh from the breeding colony. West Raccoon is further from the northern border of the coastline than East Raccoon is to the east. These two different habitat patches might reflect some segregation among colonies, but we cannot rule out a year effect (e.g., weather, spatiotemporal heterogeneity in productivity).

With only 2 birds equipped with GPS, we can conclude that Black Skimmers forage at night in the productive marshy waters of coastal Louisiana, which have likely been affected by the BP oil spill in 2010 and where impacts could still be detected 1.5 years later (Mishra et al. 2012). This foraging observation is in agreement with the skimmer's diet sampled in 2011 (needlefish, pogie, striped mullet, and Atlantic silverside), which consisted of fishes that can all be found in brackish waters of estuaries.

We also now know that radio-telemetry is not an appropriate technique to track movements of black skimmers or estimate their home range, as evidenced by the much larger range recorded by GPS than the island-centric picture provided by radio-telemetry (Figs 2-4). GPS technology gives a more accurate picture but is associated with an important drawback, that of recapturing the birds on the nest before hatching, which can be made impossible in stormy weather. Newer GPS units may allow tracking and downloading locations remotely without recapture (Lotek, personal communication).

These data on movements and diet provided valuable insight into skimmer habitat use on the refuge, which may be representative for other skimmer colonies throughout the Northern Gulf of Mexico. Furfey (2014) showed that the skimmer population size seems to be declining on the refuge since 2011 and compared to pre-BP oil spill. However, the loss of nesting habitat with continuing sea level rise as well as other ecological pressures (e.g., depredation by nutria) may be greater causes for concern.

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Literature Cited

Barras, J.A., S. Beville, D. Britsch, S. Hartley, S. Hawes, J. Johnston, P. Kemp, Q. Kinler, A. Martucci, J. Porthouse, D. Reed, K. Roy, S. Sapkota, and J. Suhayda. 2003. Historical and Projected Coastal Louisiana Land Changes: 1978-2010. USGS Open File Report 03-334.

Barron, M.G. 2012. Ecological impacts of the Deepwater Horizon Oil Spill: Implications for immunotoxicity. Toxicologic Pathology 40: 315-320.

Burger, J., and M. Gochfeld. 1990. The Black Skimmer: Social Dynamics of a Colonial Species. Columbia University Press, New York, NY.

Calenge, C. 2006. The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. Ecological modelling 197, 516–519.

Calenge, C., S. Dray, and M. Royer-Carenzi. 2009. The concept of animals' trajectories from a data analysis perspective. Ecological Informatics 4, 34–41

Erwin, M.R. Brinker, D.F., Watts, B.D., Costanzo, G.R., and D. D. Morton. 2010. Islands at bay: rising seas, eroding islands, and waterbird habitat loss in Chesapeake Bay (USA). Journal of Coastal Conservation 15:51-60.

Erwin, M.R. Allen, D.H., and D. Jenkins. 2003. Created versus natural coastal islands: Atlantic waterbird population, habitat choices, and management implications. Estuaries 26: 949-955.

Furfey, B.C. The reproductive and foraging ecology of Black Skimmers (*Rynchops niger*) on a Barrier Island Refuge in Coastal Louisiana. M.S. Thesis, Arkansas State University, Jonesboro, AR.

Gochfeld, M. and J. Burger. 1994. Black Skimmer: Birds of North America (108). Washington, D.C.

Horne, J.S. and E.O. Gorton. 2006. Likelihood cross-validation versus least-squares cross validations for choosing the smoothing parameter in kernel-home range analysis. Journal of Wildlife Management 70: 641-648.

Laver, P.N. 2005. Kernel home range estimation for ArcGIS, using VBA and ArcObjects. Virginia Department of Fisheries and Wildlife Sciences, Virginia Tech, Blacksburg, VA.

Meyburg, B.U. and C. Meyburg 2009.Travels with a backpack: satellite tracking of birds. Der Falke 56: 256-263.

Mayfield, H.F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

Michot, T. C., C. W. Jeske, W. J. Vermillion, J. Mazourek, and S. Kemmerer. 2004. Atlas and census of wading bird and seabird nesting colonies in south Louisiana, 2001. Barataria Terrebone National Estuary Program Report No. 32. Thibodaux, LA.

Mishra, D.R., H.J. Cho, S. Ghosh, A. Fox, C. Downs, P.B.T. Merani, P. Kirui, N. Jackson, and S. Mishra. 2012. Post-spill state of the marsh: remote estimation of the ecological impact of the Gulf of Mexico oil spill on Louisiana salt marshes. Remote Sensing of Environment 118: 176-185.

Molina, K.C. and M.R. Erwin. 2006. The distribution and conservation status of the Gull-billed Tern (*Geolochelidon nilotica*) in North America. Waterbirds 29: 241-295.

National Audubon Society 2010. Important Bird Areas in the U.S. Available at http://www.audubon.org/bird/iba

National Oceanic and Atmosphereic Administration [NOAA]. 2010. Environmental Response Management Application (ERMA). NOAA, Online, available at: www.GeoPlatform.gov/gulfresponseDate Accessed: 1 October, 2010.

Owen, T. 2010. Habitat requirements and productivity of colonial waterbirds nesting on the Isles Dernieres Barrier Island Refuge, Louisiana. M.S thesis, Nicholls State University, Thibodaux, LA.

Portnoy, J. 1977. Nesting Colonies of Seabirds and wading birds-Coastal Louisiana, Mississippi, and Alabama. U.S. Fish and Wildlife Service, Biological Service FWS/OBS 77/07, Washington, DC.

Pyle, P. 2008. Identification Guide to North American Birds, Part 1: Columbidae to Ploecidae. Slate Creek Press, Point Reyes Station, CA.

Rappole, J.H., Tipton, A.R. 1990.New harness design for attachment of radio transmitters to small passerines. Journal of field Ornithology 62: 335-337.

Raynor, E.J. 2010. Understanding the use of barrier islands as nesting habitat for Louisiana waterbirds. M.S thesis, Nicholls State University, Thibidoux, LA.

Thomas, L., J.L. Laake, S. Strindberg, F.F.C. Marques, S.T. Buckland, D.L. Borchers, D.R. Anderson, K.P. Burnham, S.L. Hedley, J.H. Pollard, J.R.B. Bishop, and T.A. Marques. 2006. Distance 5.0. Release 2. Research unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

U.S Fish and Wildlife Service. December 2008. Birds of conservation concern 2008. United States Department of the Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp. Online version available at: http://www.fws.gov/migratorybirdsDate accessed: 1 October 2010

Wilson, R.P. and M.P. Wilson. 1989. Tape: A package attachment technique for penguins. Wildlife Society Bulletin 17: 77-79.