FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. TX E-137-R

F11AP00468

Endangered and Threatened Species Conservation

Habitat use of North Padre Island and Laguna Madre habitats by Piping Plovers and Red Knots in the vicinity of current and proposed wind energy development

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10 March 2014

FINAL REPORT

STATE: ____Texas_____ GRANT NUMBER: ___TX E-137-R-1__

GRANT TITLE: Habitat use of North Padre Island and Laguna Madre habitats by Piping Plovers and Red Knots in the vicinity of current and proposed wind energy development.

REPORTING PERIOD: ____1 Sep 11 to 31 Dec 13_

OBJECTIVE(S). To determine usage of the habitat mosaic of North Padre Island and wind-tidal flats of the Laguna Madre by Piping Plovers and Red Knots.

Segment Objectives:

Task 1. Sept 2011. All permits, bands, radio transmitters received.
Task 2. Sept - Oct 2011. Capture and attachment of radio transmitters on minimum 15 birds of each species.
Task 3. Mid-Sept 2011 - April 2012. Begin ground-based (2-4 days/week) and aerial (1/week) telemetry to relocate birds with radio transmitters; site visits to describe habitat characteristics.
Task 4. Nov 2011. Data entry; accuracy and content review.
Task 5. Mid-Nov 2011. Capture and attachment of radio transmitters to total up to minimum 15 birds of each species (including those that may still be transmitting).
Task 6. Jan 2012. Data entry; accuracy and content review.
Task 7. Mid-Feb 2012. Capture and attachment of radio transmitters to total up to minimum 15 birds of each species (including those that may still be transmitting).
Task 8. Apr 2012. Data entry; accuracy and content review.
Task 9. May 2012. Begin development of GIS and habitat use estimation.
Task 10. Aug-Sept 2012. Capture and attachment of radio transmitters on minimum 15 birds of each species.
Task 11. Sept 2012-Apr 2013. Ground-based and aerial telemetry to relocate birds with radio transmitters; site visits to describe habitat characteristics.
Task 12. Nov 2012. Data entry; accuracy and content review.
Task 13. 15 Nov 2012. Capture and attachment of radio transmitters to total up to minimum 15 birds of each species (including those that may still be transmitting).
Task 14. Jan 2013. Data entry; accuracy and content review.
Task 15. 16 Feb 2013. Capture and attachment of radio transmitters to total up to minimum 15 birds of each species (including those that may still be transmitting).
Task 16. Apr 2013. Data entry; accuracy and content review.
Task 17. May-Sept 2013. Complete development of GIS and habitat use estimation.
Task 18. Sept 2013. Submit GIS information from project to Texas Natural Diversity Database.
Task 19. Sept-Nov 2013. Complete analysis for final report.

Significant Deviations:

None.

Summary Of Progress:

Please see Attachment A. GIS files to be delivered to TPWD under separate cover.

Location: Nueces, Kleberg, and Kenedy Counties, Texas.

Cost: Costs were not available at time of this report, they will be available upon completion of the Final Report and conclusion of the project.

Prepared by: Craig Farquhar Date: 10 March 2014

Approved by: _____ Date: 10 March 2014

C. Craig Farquhar

ATTACHMENT A

Habitat use of North Padre Island and Laguna Madre habitats by Piping Plovers (*Charadrius melodus*) and Red Knots (*Calidris canutus*) in the vicinity of current and proposed wind energy development

Final Report
(Project E-137-R)

David Newstead
Coastal Bend Bays & Estuaries Program

March 7, 2014

Key findings
Red tide bad
Important overwintering sites and habitat for knots
Pre-migratory staging areas
Evidence for importance of Tamaulipas

Study Area Description

Padre Island consists of two long barrier islands separated by Mansfield Pass, which is maintained by engineered rock jetties and periodic mechanical dredging. The islands are referred to as North and South Padre Islands. The islands are composed of deep sands and dominated by Seacoast bluestem-Gulfdune Paspalum Series grasslands, and in cross section largely resemble a typical barrier island geomorphology (foreshore, backshore, dune ridge, deflation plane, and intertidal bay shoreline). Aerial images of the study area labeled with relevant land and water features are provided in Appendix 1.

Unique to this ecosystem is the large body of water which separates the barrier islands from the mainland shore. The Laguna Madre extends from the northern edge of the study area to the southern part of the study area in Texas, and continues beyond the Rio Grande Delta into the neighboring state of Tamaulipas, Mexico. Together, the Laguna Madre system is the largest of only five hypersaline lagoon systems in the world. Due to its high salinity, emergent marshes are virtually absent from the system, though black mangroves (*Avicennia germinans*) persist in the intertidal zone somewhat sparsely in the northern stretch and more prolifically in the southern extremes in Mexico, and intermittently where tidal exchange or freshwater inputs ameliorate extreme salinities. The majority of the tidal flat area of the Laguna Madre of Texas consists of a band of three microhabitat types that grade into one another, the persistence of each dependent on patterns of inundation and exposure. The lower sandflat represents the deepest portion of the flats available to small/medium shorebirds. It is inundated for most of the year and is typically only exposed during seasonal low tides coupled with wind-forcing events. At its deepest, it may support some sparse growth of submerged aquatic vegetation (*Halodule beaudettei*). Higher than this stratum is a blue-green algal flat dominated by *Lyngbya confervoides*, that forms a mat 1-3 cm thick which is felt-like when wet and leathery and cracked when dry (Withers 2002). This stratum is less frequently inundated than lower sandflat. Above the algal flat is an upper sandflat, which is only episodically inundated by excessively high tides often associated with storms. Though the tidal prism in the Laguna Madre is small, patterns of inundation and exposure are unique, complex, and can be considered a primary driver of shorebird habitat availability throughout the system. In decreasing order of importance, the tidal regime is affected by: long-period semi-annual pattern (with peaks in fall and spring, lows in summer and winter); meteorological forcing associated with strong winds; and a diurnal/semi-diurnal astronomical signal that appears as “noise” in the overall tidal signal (Tunnell 2002).

The area is known to be of major importance to migratory shorebird populations, including Piping Plover (*Charadrius melodus*, listed Threatened in US, Endangered in Canada), and the Red Knot (*Calidris canutus*). Two Red Knot subspecies likely occur in Texas. *C. c. rufa*, comprising the western Atlantic and Central flyway populations, is currently in process of listing as Threatened in US, and is

listed Endangered in Canada. *C. c. roselaari*, which breeds in northwest Alaska and Wrangel Island in Russia, represents the eastern Pacific flyway population and is listed Threatened in Canada.

Since 2002, the south Texas area has been heavily prospected by wind energy developers, and several projects consisting of over 500 turbines have since been constructed in coastal counties, including two large projects adjacent to the Laguna Madre in Kenedy County. Many other projects are planned along the coastal tier of counties, as well as a project consisting of several hundred turbines proposed in the nearshore Gulf of Mexico near South Padre Island.

Wind turbines are a documented source of avian mortality, and the proliferation of projects along the coast is of special concern for the millions of migratory shorebirds that pass through or spend the winter in the area. The Laguna Madre is known to support a substantial portion of the Northern Great Plains breeding population of Piping Plover during the nonbreeding period, but the size of the area and difficulty of access has resulted in limited research on bird movements. Drake et al. (1999) conducted radiotelemetry on Piping Plovers in the southern part of the Lower Laguna Madre, and described a mosaic of barrier island and mainland shoreline habitats used by birds in that segment.

Until recently, it was unclear where the Red Knots that were frequently observed on area beaches in fall and spring spent the winter months. Infrequent and anecdotal reports suggested that at least some birds spent the winter there. A study using geolocators (small light data recorders affixed to the leg) confirmed that most Red Knots do spend the winter in south Texas, and the winter habitats were suspected to be somewhere within the vast flats of the Laguna Madre (Newstead et al. 2013).

In order to locate the specific wintering areas, habitats, and general patterns of habitat use of Red Knots (REKN) and Piping Plovers (PIPL), we employed radiotelemetry techniques to track movements over the nonbreeding period of 2011-2012, and 2012-13. Because Red Knots are known to not migrate north to breed in their first summer, we also conducted radiotelemetry on oversummering birds in 2012. Thus, the study comprised five components based on species and period (PIPL 2011/12, PIPL 2012/13, REKN 2011/12, REKN SUMMER 12, REKN 2012/13).

Zones

The study area from north to south is relatively consistent in terms of geographic arrangement of habitats. The entire area was divided into zones from north to south based on gulf passes or, in the case of North Padre Island, significant features on the lagoon side. Long barrier islands separated from the mainland by bays and lagoons result in typical shorebird habitat consisting – from west to east – of mainland shoreline, barrier island bay/lagoon shoreline, and gulf beaches (Fig. 1). Descriptions of these areas, and the habitats contained within them, are provided in Appendix 2.

Figure 1. The study area divided into zones from north to south based on passes separating barrier islands, or other features on North Padre Island. The red line indicates the typical route flown during aerial relocation efforts. Refer to Appendix XX for descriptions of zones.

METHODS

Trapping

Most birds in the study were captured on gulf beaches of North Padre Island except one Red Knot on Mustang Island, and fourteen Piping Plovers in the Laguna Madre in 2012/13. Most birds were captured with a cannon net except one Red Knot and four Piping Plovers captured by whoosh net in 2011/12.

Lotek coded Avian Nanotags were affixed to the intrascapular region of the bird with epoxy. Model NTQB-3-2 (0.67g) were used for all Piping Plovers and most Red Knots, and some NTQB-4-2 (1.0g) were used on Red Knots in 2012/13. Feathers were worked away from a central point with thumbs until bare skin was visible, and the epoxy-coated transmitter laid in place. Feathers were then reset over and around the unit and held in place for several minutes until dry to touch. Upon release, birds were observed to determine if handling had any noticeable effect upon behavior. No negative consequences of transmitter attachment were evident after release. All birds were released at the site of capture except for three Red Knots that were weak and extremely light upon capture, and had been rehabilitated at the Animal Rehabilitation Keep at the University of Texas Marine Science Institute in Port Aransas. Once those birds had attained appropriate weight and were moving normally and capable of flight, transmitters were applied and the birds were released in the Yarborough Pass area of the Laguna Madre.

Radiotelemetry

Radio tracking of birds in the study commenced immediately following radio attachment and continued until no more active radios were detected by aerial relocation efforts. This consisted of ground and water-based visits (driving along beach, walking across flats, scanning from boat) as well as approximately weekly flights in a fixed-wing aircraft. Because of the very large study area, ground-based surveys were limited in scope to beaches of Padre and Mustang Islands, and boat-based surveys limited primarily to bay systems in the northern part of the study area. Aerial surveys were occasionally spatially limited by flight time (available fuel) or when all active radios had been found. Initially, flights were centered around the areas of capture and ranged from the north end of Matagorda Island south to the Mansfield Pass jetties, including habitat considered suitable on the bay shore of the barrier islands and the mainland. After several flights no radio-marked birds had been encountered north of Padre Island, and the search area was shifted south to encompass as much potential habitat as possible from Port Aransas at the north end of Mustang Island, south to Boca Chica Beach and the international border. The flight route included both shorelines of the Upper and Lower Laguna Madre, the Land Cut, South Bay, the eastern shore of Corpus Christi Bay and Redfish Bay, and the gulf beach from North Pass on San Jose Island south to the Mansfield Channel (Fig. 1). Over all but the northern portion of South Padre Island the island is narrow enough that flying over the middle of the island allowed sufficient range to detect signals on both the gulf beach and the Laguna Madre shoreline. After crossing Brazos Santiago Pass, most of Boca Chica Beach to the international border was also scanned for signals.

The term “relocation” rather than “location” is used throughout this report to refer to the actual or approximated location of a bird tracked by telemetry, to avoid confusion with other meanings of “location.”

Several flights were made to the upper Texas coast in association with a separate project, which resulted in two relocations of birds from this project. Also, some birds (including these) were relocated by other researchers conducting a project in the Galveston Bay area using the same methods as this study. Relocations of birds that were trapped as part of this project but encountered outside the study area are included in calculation of range, though that area was not regularly surveyed as part of this project.

Relocations were usually recorded with a handheld GPS, and adjustment was made to the point in ArcMap based on recorded notes and knowledge of the area. Since accurate triangulation of signals is not practically possible with aerial radiotelemetry from fixed-wing aircraft, a waypoint was taken when the detection of a particular signal was highest. The location was then manually corrected (moved) to the likely location of the bird in ArcMap. For instance, during flights along linear features such as the gulf beach the plane was operated at some distance from shore with the antenna pointing at an angle towards the beach. When a detected signal was strongest, a waypoint was recorded. In this case, the point based on the GPS waypoint (appearing several hundred m from shore) was shifted to the gulf beach in the shapefile. In some cases only one waypoint was recorded when multiple signals were detected and could not be spatially discriminated. If the signals were from the same species they were maintained as one point in the shapefile. If they were of two species, points associated with one of the species were moved nearby (within ~20m) so that they would appear as spatially distinct for viewing purposes. Some heavily used areas were relatively small in size, and it was not possible to estimate a specific location of a signal. For such areas, a single point was created within the habitat and all relocations of the species from that area were assigned to that point. These areas generally contained a mosaic of habitat types that were variously used by shorebirds (as confirmed by ground visits) depending on water level, substrate and other features.

Minimum convex polygons

A minimum convex polygon (MCP) is a measure of the area of the smallest polygon containing all points in a given spatial data set, and is one commonly-used metric to estimate home range. MCPs were created using the “genmcp” function in Geospatial Modeling Environment (Beyer 2012). MCP area (km^2) was then calculated from the polygons in the resulting ArcGIS shapefiles.

Wind energy mapping

The data used to create a shapefile of wind energy projects in south Texas was derived from the Federal Aviation Administration’s website (oeaaa.faa.gov/). A subset of data including wind turbines and meteorological towers was selected for all notices in Texas south of 31^o N, and a shapefile created. In many cases, the dataset did not include many actual installed turbines along the coast which are known to be operational, and confirmed by overlaying this layer on basemap imagery. Points were manually added to the shapefile where turbines were located based on the imagery. Each point feature includes a status category for each element – either “proposed,” “scheduled,” or “built.” In

several cases, data was incomplete or had not been updated to reflect the actual status. If a turbine had obviously been constructed in the location where the data indicated "proposed" or "scheduled" status, its status was corrected to "built." Appendix 3 shows the locations of wind turbine and meteorological towers against the landscape throughout the study area.

RESULTS

Forty-one Piping Plovers and 110 Red Knots were captured and tracked with radiotransmitters for this study over the two-year period (Table 1).

Table 1. Summary information on birds in radiotelemetry study. MCP is Minimum Convex Polygon.

	n birds	Date of first capture	Date of last relocation	*n* transmitter days	*n* relocations
Piping Plover					
2011/12	5	10/13/2011	2/1/2012	183	21
2012/13	36	9/7/2012	5/2/2013	2135	310
TOTAL PIPL	41			2318	331
Red Knot					
2011/12	12	10/11/2012	1/19/2012	444	50
2012 summer	22	4/21/2012	7/12/2012	1015	134
2012/13	76	9/27/2012	5/10/2013	3399	449
TOTAL REKN	110			4858	633
BOTH SPP	151			7176	964

Habitat use by zone/segment for each bird in the study, as well as by species and time period, is summarized in Appendix 4.

RED KNOT

Red Knot - Overwintering

Red Knot movements in winter generally fit one of three categories. Descriptions of patterns of usage are limited to the 2012/13 nonbreeding season for which there is the most data. Mean MCP was 423.4 km^2 and 386.7 km^2 for the 2011/12 and 2012/13 time periods, respectively. Bird movements were categorized as Local if the maximum distance between locations throughout the tracking period was <30 km, Regional if >30 km and <100 km, and Extensive if >100 km.

Local

Thirty (52.6%) of birds were relocated in a fairly small geographic area, especially in the Upper Laguna Madre area and North Padre Island beach. For many of these individual birds, a relatively small

(usually ~30 km) stretch of gulf beach and nearby flats in the Laguna Madre comprised all of the relocations.

Regional

Nine (15.8%) birds were relocated over a wider geographic area, often comprising a longer stretch of beach and several bay systems or several areas of the Laguna Madre system.

Extensive

Eighteen (31.6%) birds made use of gulf beaches and the Upper Laguna Madre as well as Lower Laguna Madre area. Movements were not always unidirectional over time, with some birds relocating back and forth from Upper to Lower Laguna Madre and beaches multiple times. One bird was relocated three times (by another project) on the upper Texas coast near San Luis Pass at the west end of Galveston Island. The majority of these large ranges of movement were oriented southward of the original catch area.

Red Knot – Oversummering

Mean MCP was 582.9 km^2 for all birds in the oversummering time period. All relocations of nonbreeding knots followed through the summer were either south of, or very close to, the original latitude of capture. Three sites were used with much greater frequency in this study period than in the two years of overwintering: 1) the east side of Nine Mile Hole, especially along the shore and near the spoils associated with access channels; 2) the west side of Nine Mile Hole – north and south of the main channel entering the area from the Land Cut; and, 3) a flat at the southern end of the Land Cut at the junction with the Lower Laguna Madre locally known as Pintail Lake. Most relocations of birds in April and May were concentrated at these sites as well as nearby gulf beaches. In June, birds were dispersing southward and by July most birds were in the Lower Laguna Madre.

Red Knot MCP

MCP ranges for individual Red Knots varied widely, and are reflective of the range of local to widespread movement patterns previously described. During the 2012/13 period, a greater proportion of birds stayed relatively local than in the 2012 oversummering period. The wider and higher range of the middle 50% of MCP sizes in the oversummering period is consistent with the fairly ubiquitous movement of all of these birds into the Lower Laguna Madre (Fig. 2).

PIPING PLOVER

Piping Plovers are known to have relatively small home ranges during winter periods. Though some birds in this study made long-distance movements (resulting in very large MCP), they soon settled into one of four general areas and did not make additional long-distance movements for the remainder of the period they were tracked. Capture and tracking of Piping Plovers in the 2011/12

period was severely hindered by red tide effects, and subsequently only minimal data could be collected with regard to home range. The following area use descriptions are based primarily on 2012/13 data.

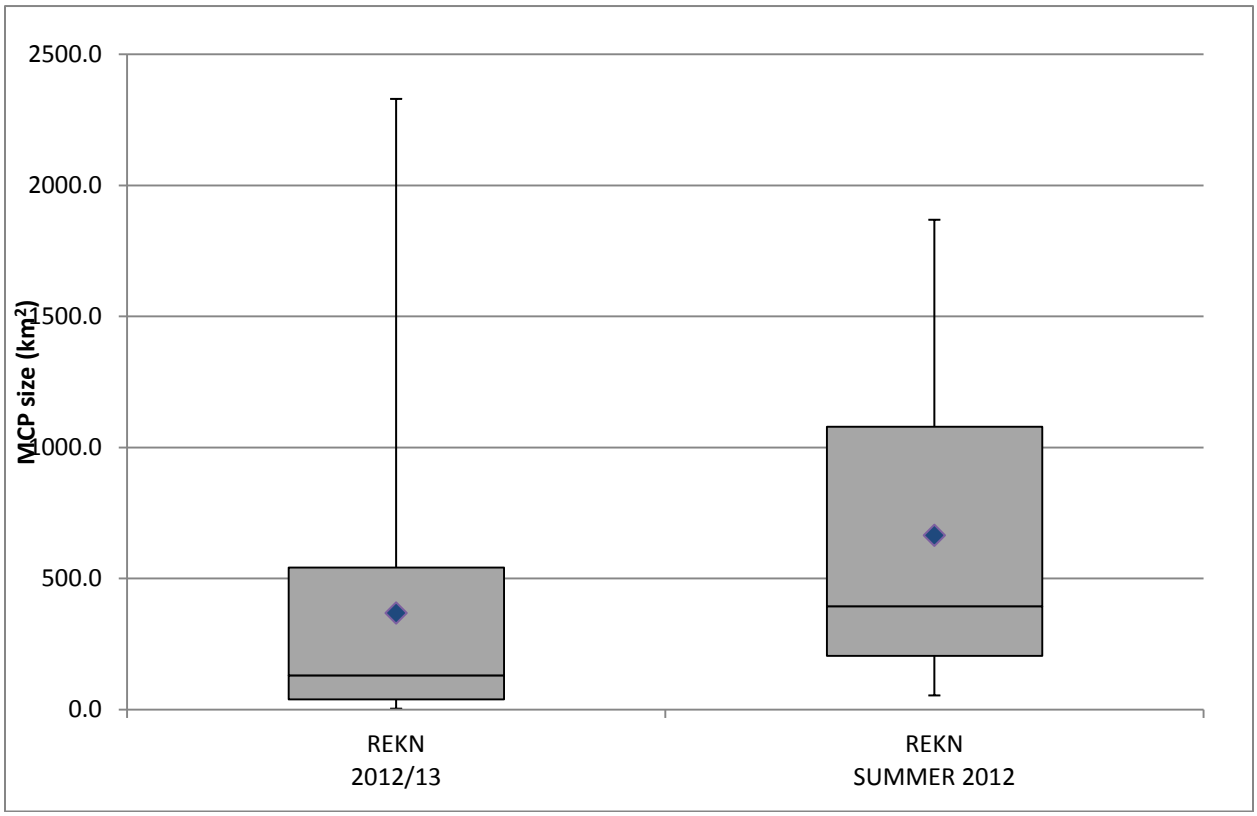

Figure 2. Box and whisker plot on Minimum Convex Polygon size for Red Knots relocated at least 4 times.

Nighthawk Bay/Gulf Beach

A total of 21 PIPL were captured either on the gulf beach north of Malaquite Beach Pavilion or in Nighthawk Bay in the 2012/13 period. One was not relocated after capture. One (144) departed the area after capture on 2/14/2013 and spent the remainder of the winter in the west Galveston Bay area, detected there in association with a different project. Of the other nineteen, one was relocated twice at the southern edge of zone 2, and one transmitter (64) was recovered on a spoil island at the northern edge of zone 4. No other PIPL from this group were relocated outside of this zone. Fifteen of them were relocated only on the gulf beach or Nighthawk Bay flats and spoil islands, suggesting these two areas essentially constitute the entire winter home range of most of the birds encountered in this zone.

Padre Island/Yarborough Pass north

All relocations of the three birds captured between Malaquite Beach Pavilion on PAIS and ~5 km south of the end of the paved road were either along that beach or on flats and sandbars in the Upper Laguna Madre across from the northern edge of Baffin Bay and south to the Yarborough Pass area.

Padre Island/Yarborough Pass south to Nine Mile Hole

Eight of the birds captured between 13-29 km from the end of the paved road were relocated primarily along the same beach stretch as well as flats between Yarborough Pass and into Nine Mile Hole; however, three of these made at least one significant movement out of the area – two were relocated once each in the Lower Laguna Madre, and the other was not relocated by this project but was detected multiple times over the course of a day at a site in Galveston Bay by researchers on a separate telemetry project.

Lower Laguna Madre

Five birds captured on the gulf beach of PAIS subsequently made major movements into the Lower Laguna Madre. This included the four southernmost captures. All subsequent relocations of these birds were in bayside habitats.

Curiously, the one plover that was relocated >5 times during the 2011/12 period – captured on Malaquite Beach, later used bay habitats across from the mouth of Baffin Bay before moving to Yarborough Pass area and further into the Nine Mile Hole area.

Piping Plover MCP

Mean MCP was 1.2 km^2 in 2011/12 and 178.7 km^2 in 2012/13. The MCP for 2012/13 is very high when compared with comparable estimates of home range for the species in other areas (Drake et al 2001, Cohen et al 2008). However, this is a result of very high MCP values for some birds that were trapped prior to settling into a typical winter pattern. Therefore, their MCP encompasses not only their wintering range but parts of a distant migratory stopover range as well, with a strong effect on the mean value for MCP. Excluding those birds that were presumed to be in migration when captured, the MCP sizes for Piping Plovers during the 2012/13 period were in a more typical range (Fig. 3).

Bird movements beyond study area

Several birds from this study in the nonbreeding season of 2012/13 were detected outside the study area. These relocations were recorded by researchers working on a separate radiotelemetry project in the Galveston area. These relocations are included in the data for all relocations (and MCP), since they compose the actual range exhibited by the individuals regardless of project. However, that project was much more limited in geographic scope, so there is a reasonable likelihood that other individuals also moved out of these two study areas and went unreported which would make the MCP ranges reported in Table 1 very conservative estimates for some birds.

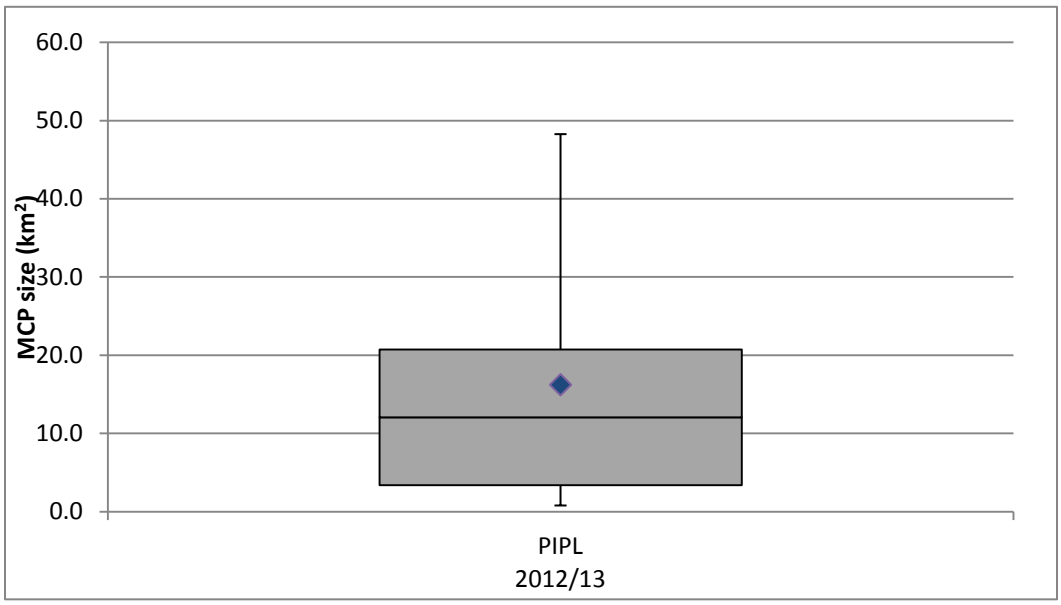

Figure 3. Box and whisker plot of Minimum Convex Polygon size for Piping Plovers that were relocated at least 4 times in 2012/13. This does not include seven birds that relocated into the Lower Laguna Madre or the Upper Texas Coast.

Since flights were conducted on an approximately weekly basis, the mean interval between relocations should be close to seven for birds that were only relocated by aerial efforts, and somewhat less for those that were in areas that were more frequently accessed by ground or boat. This assumes that there is minimal movement of birds during the flights, and that the study area encompasses the entire habitat used by each individual bird. When this mean is significantly higher than 7 there are several potential explanations. Weak or malfunctioning transmitters, or major radio interference which prevented the radio operator from being able to use an adequate gain setting, are possible explanations. However, while the means among the three components of the project for which there was substantial data were very similar – between 7.0 and 7.6 days, with 75% of the birds being relocated just over 8 day intervals – the differences in high values between the components were much larger (Fig. 4). High values were usually associated with birds that were not relocated for multiple weeks, or even months, at a time, but were subsequently relocated back in the study area. For instance, one bird was not relocated after capture until 79 days later, and was never relocated again. The differences between the study components in terms of the variability between birds is indicative of different patterns of movement and suggest substantially more movement outside the study area by Red Knots than by Piping Plovers during the nonbreeding period. The range of mean interval between relocations for oversummering birds was much smaller, consistent with the observed data showing a fairly uniform series of movements southward through that period.

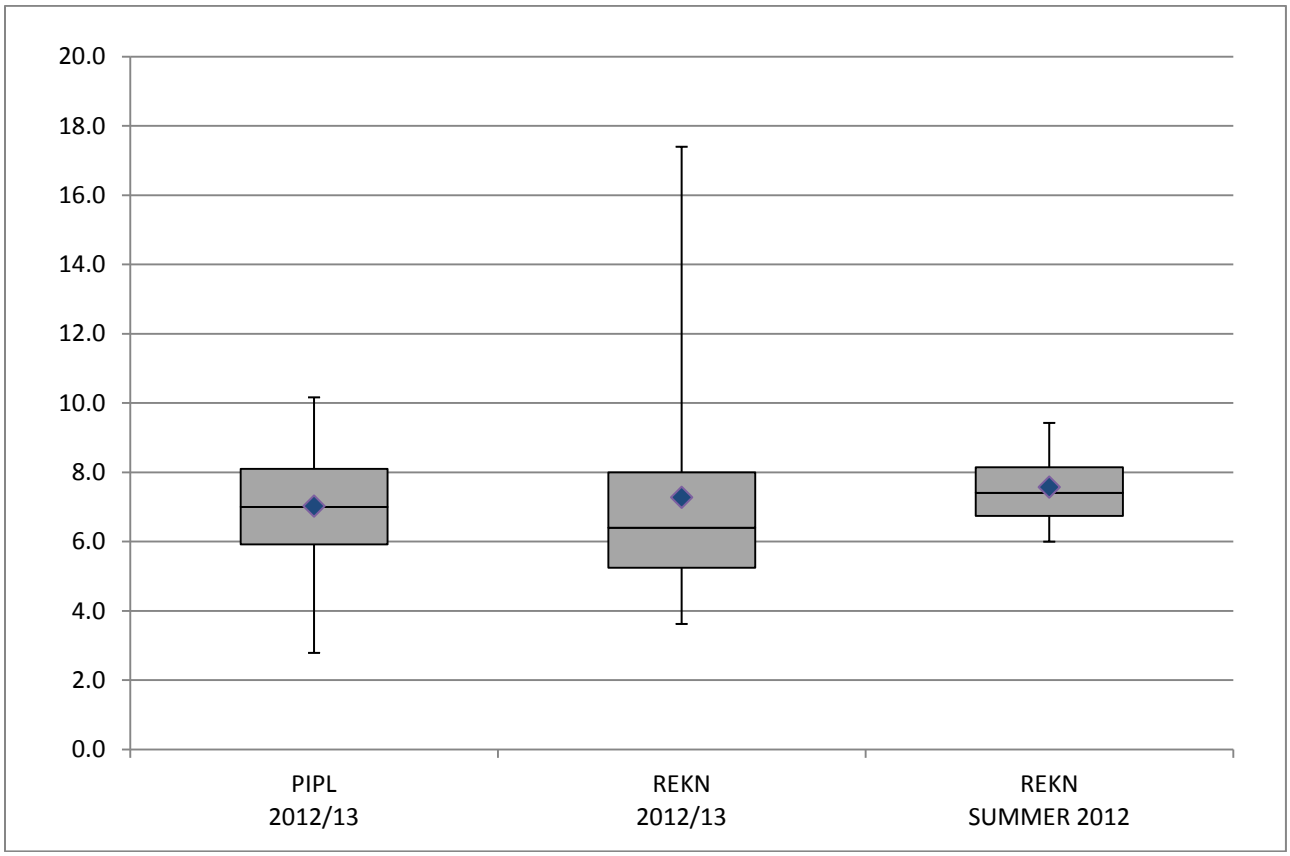

Figure 4. Box and whisker plot on mean number of days between relocations for birds in study for which at least 4 relocations were recorded, calculated as (*n* days elapsed between deployment and last relocation/*n* relocations).

Beach vs bay presence relative to water level

To illustrate the relationship between water level and the presence of birds on the beach vs in bayside habitats, the Upper Laguna Madre section (including barrier island beach) of the study area was divided into two areas north (Northern ULM) and south (Southern ULM) of latitude 27.415 deg N (Fig. 5). These correspond generally, but not exactly, to Zones 3 and 4. This line was chosen for several reasons: 1) Water level data is available from two gauges throughout this long stretch of the Laguna Madre; 2) lagoon-side relocations are concentrated a significant distance north or south of that line, since relatively little tidal flat habitat habitat exists between Nighthawk Bay and the flats north of the junction with Baffin Bay; and 3) the orientation of the flats is different enough that the influence of water level changes may be different between the areas. Aerial relocation data between latitude 27.000^{o} N (south end of Nine Mile Hole) – 27.614^{o} N (Packery Channel) from 2 October 2012 through 30 May 2013 was selected and divided into Northern ULM and Southern ULM. On the lagoon side, this separated "groups" of relocations into those centered along Nighthawk Bay in the north end, and the flats from Baffin Bay into Nine Mile Hole and the Land Cut on the south end. The BIRDIS (Bird Island) and BAFFIN (Baffin Bay) gauges were used as proxy estimators of water level in the two areas, respectively, and gulf beach water level was estimated by the BOBHAL (Bob Hall Pier) gauge (data from

Texas Coastal Ocean Observation Network, operated by Division of Nearshore Research at Conrad Blucher Institute, Corpus Christi, Texas; http://lighthouse.tamucc.edu/pq).

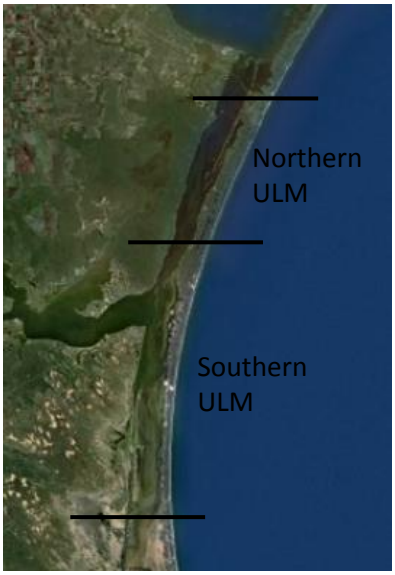

Figure 5. Upper Laguna Madre area and divisions used to separate Northern ULM and Southern ULM.

Relocations were tabulated as either "Beach" or "Bay" based on the NWI major habitat classification as either E (Estuarine, for Bay) or M (Marine, for Beach). Some stretches of gulf beach along the Padre Island shoreline are not classified as wetland habitats in the inventory (an apparent error in the shapefile). In these cases, beach relocations were classified as M2 (Marine, intertidal) by the investigator for the purpose of tabulation.

To characterize the general water level of bay and gulf waters during aerial relocation efforts, hourly water level readings between 0700h and 1300h (the usual timeframe of the flights) were acquired from a gulf beach gauge (014 – Bob Hall Pier), and two gauges in the Upper Laguna Madre (013 – Bird Island Basin; 068 – Baffin Bay). The mean of these seven readings was calculated for each of the flight dates for which the entire area of interest was covered. Since the tide gauges are indexed to different datums, a full year (2012) of hourly readings were acquired from each of the gauges, a mean was calculated from all values for each gauge. The raw data were then adjusted by subtracting this mean from each of the values used, so that positive and negative values are reflective of the number's deviation from the mean water level for the whole year. Data from the 2011/12 season were not included.

Data presented in Figs. 6-9 clearly illustrate that the water level in the Laguna Madre is a key driver of whether birds (both species, both areas) were found in bay or beach habitats. With lowest bay water levels, almost all relocations were in bay habitats, and the converse – during high bay water levels, most relocations were on the beach – was also true. It can also be observed in the data that beach water levels were not as strong an influence. That is, when beach water levels were low, this did not necessarily result in a higher proportion of relocations on the beach, unless bay water levels were high. When both bay and beach water levels were high, most birds were on the beach. These data illustrate that in general both species prefer bay side habitats when available at least during the fall-through-spring period, but become dependent on beach habitats when bay water levels are high. This

is also reflected in the commonly-observed phenomenon that both species are present on the beach in higher numbers in the fall and spring, coinciding with high seasonal tides that typically push water levels much higher in bays to the point where wind-forcing events are less likely to expose preferred tidal flats.

While these findings illustrate that there is a preference for bay habitats when they are available (in the Upper Laguna Madre), it is also clear that the beach is providing alternative habitat for substantial periods of the fall and spring. Rather than regarding beach habitats as "of secondary importance," they are a critical part of the habitat mosaic used by birds in the Upper Laguna Madre.

Red Knots appear to be far more sensitive than Piping Plovers to high water levels in the bay. Though their habitat preferences are not mutually exclusive, it is generally true that knots are strongly associated with lower sandflat habitats, while plovers will opportunistically use lower sandflat when available but otherwise are most strongly associated with algal flats. Hence, both moderate and high relative water levels would result in inundation of lower sandflats (forcing knots to the beach), while only high levels would inundate algal flats (forcing plovers to the beach).

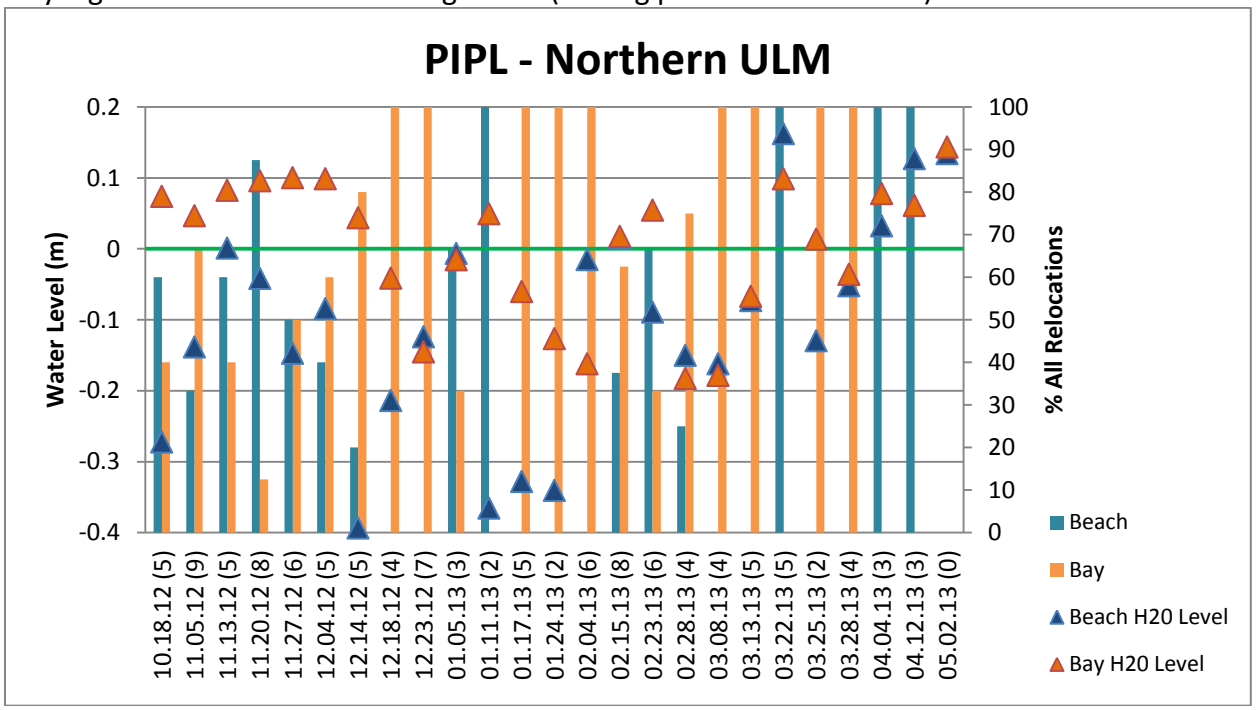

Figure 6. Water level and proportions of Piping Plover relocations on gulf beach and bay for all aerial survey dates in 2012/13 within the ULM region. Water levels are based on deviation from mean (green line) of all hourly readings for 2012 at BOBHAL ("Beach") and BIRDIS ("Bay") gauges.

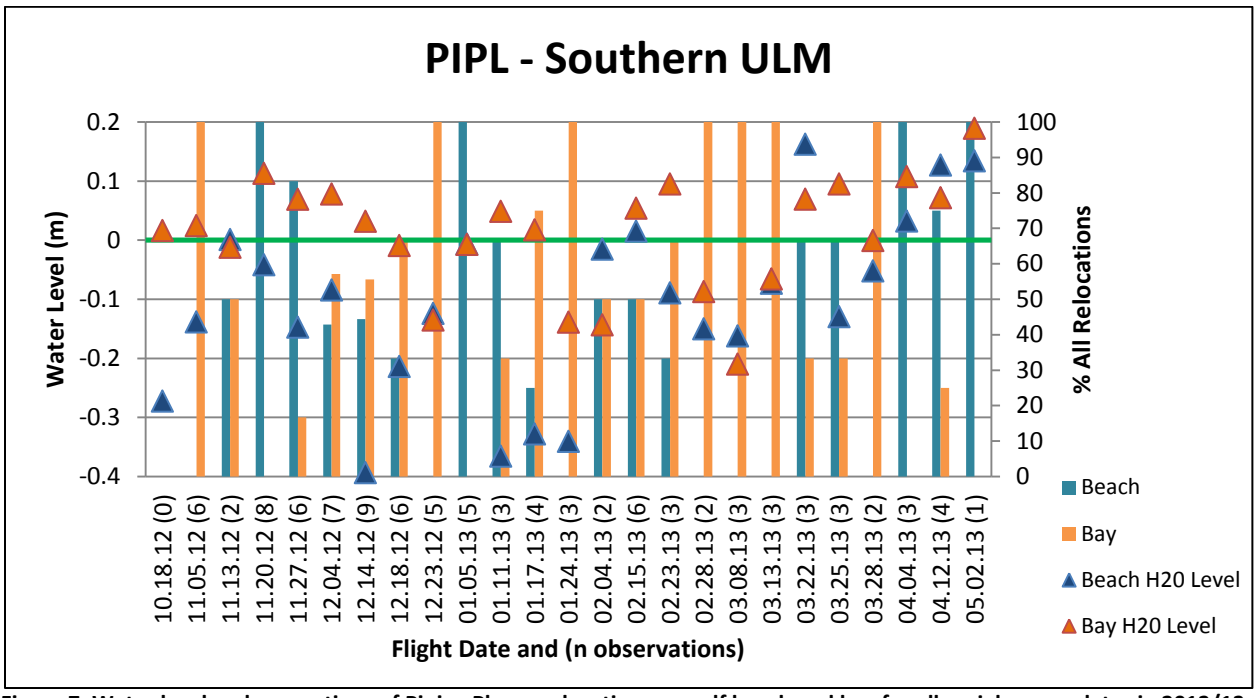

Figure 7. Water level and proportions of Piping Plover relocations on gulf beach and bay for all aerial survey dates in 2012/13 within the ULM region. Water levels are based on deviation from mean (green line) of all hourly readings for 2012 at BOBHAL ("Beach") and BAFFIN ("Bay") gauges.

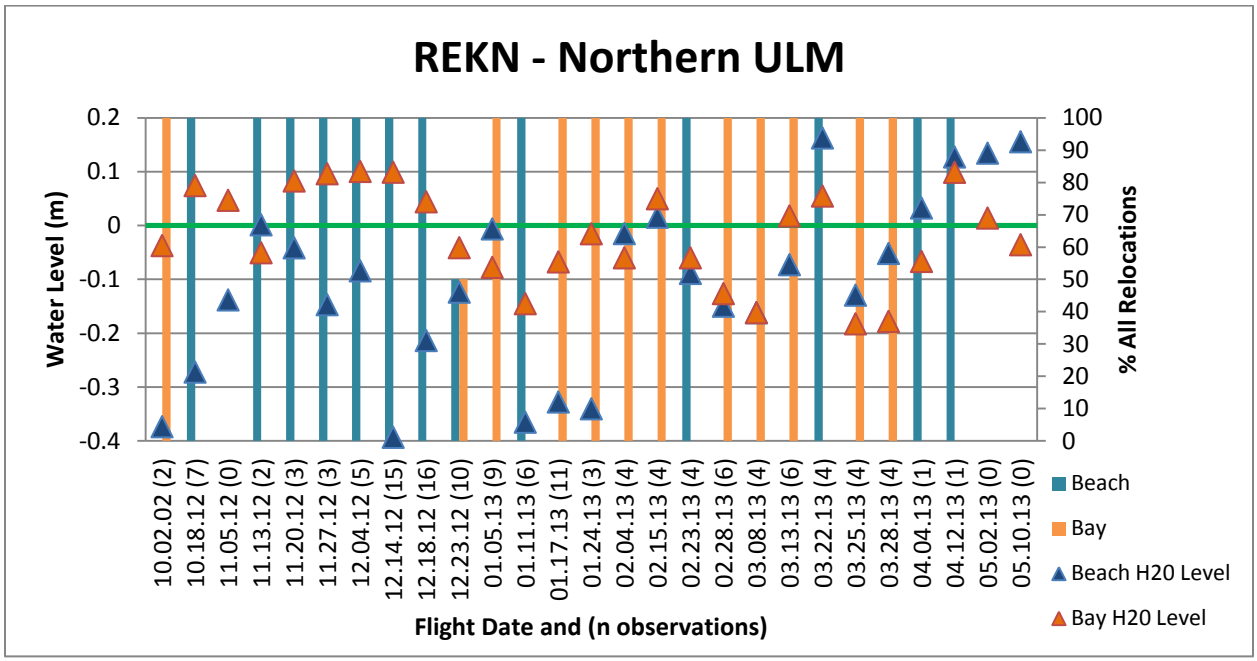

Figure 8. Water level and proportions of Red Knot relocations on gulf beach and bay for all aerial survey dates in 2012/13 within the ULM region. Water levels are based on deviation from mean (green line) of all hourly readings for 2012 at BOBHAL ("Beach") and BIRDIS ("Bay") gauges.

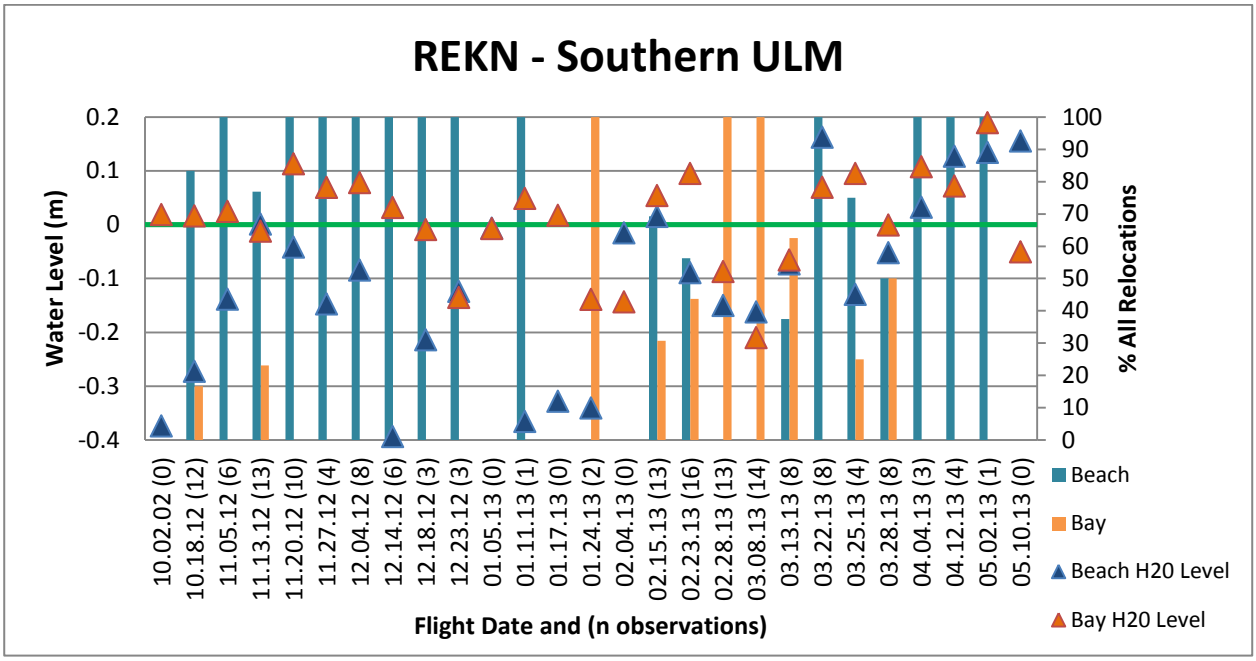

Figure 9. Water level and proportions of Red Knot relocations on gulf beach and bay for all aerial survey dates in 2012/13 within the ULM region. Water levels are based on deviation from mean (green line) of all hourly readings for 2012 at BOBHAL ("Beach") and BAFFIN ("Bay") gauges.

DISCUSSION

Red Knot

Laguna Madre/Padre Island beaches

Red Knots were most typically associated with lower sandflat habitats when in the Laguna Madre. If water levels were rising and had begun to inundate the algal flat on one side of the lagoon, knots were generally found either on the opposite side of the lagoon or on the gulf beach. During times when water levels had been low and were continuing to expose flats in the lagoon, there were virtually no relocations of knots on the gulf beach. Since the seasonal long-period astronomical tides are lowest in mid-winter, and winds associated with cold fronts (northerly) regularly punctuate periods of steady onshore winds (south-southeasterly) during this season, it is anomalous for there to be no lower sandflat exposed over the entire stretch of the Laguna Madre in Texas. Since the Laguna Madre in Texas is separated into Upper and Lower reaches by the dry sandflat and narrow constriction of water flow in the Land Cut, these changes in winds have contrasting effects on water levels between these two areas. As the flats of the Yarborough Pass and Nine Mile Hole areas (Upper Laguna Madre) become inundated by rising water force up on them during the passage of northers, flats at the north end of the Lower Laguna Madre become exposed relatively rapidly (Fig. 10). Considering that Red Knots are clearly capable of making regular flights of over 100 km, at least some of this preferred habitat is almost always available to them during the winter months. This is also reflected in the seasonality of the species occurrence on gulf beaches, when peaks in fall and spring coincide with highest water levels in the lagoons which effectively reduces available lower sandflat habitat throughout the entire area. Though knots are not frequently reported in winter months in Texas, this is more likely a function of accessibility since the lower sandflat habitats are mostly very remote and cannot be comprehensively surveyed on foot or by boat.

When birds were encountered in the Laguna Madre, they were typically either roosting in shallow water, or probe-feeding in the substrate. When prey items could be discerned, they mostly appeared to be a small white-shelled bivalve. One of the most common shallow subtidal bivalves in the area is the dwarf surf clam (*Mulinia lateralis*), which is known to be a primary prey item of knots in other areas.

On gulf beaches, knots were sometimes encountered roosting in tight groups either just above the swash zone, or during spring atop mounds of *Sargassum* spp – a planktonic brown algae that washes into Texas shores in spring and summer, sometimes forming “drifts” above the high tide line up to 0.5 m in height and covering ~10 m width of beach. At high tide and with strong surf, waves can push against this wall of algae for extended periods eliminating the opportunity for birds to forage in the sand. On several occasions knots were observed foraging among the *Sargassum*, but it was unclear what prey items they were capturing. More frequently, knots were able to forage on the sand in the swash zone for coquina clams (*Donax* spp). Dense patches of these bivalves were observed frequently throughout the nonbreeding period in 2012/13, even in midwinter when knots were rarely encountered there. Breeding age knots in fall are undergoing an energetically costly flight feather molt, and throughout the months of April and May are in need of rapidly increasing fat reserves for

migration to breeding areas in the Arctic, so the availability of this resource during those periods is likely of major consequence for the population.

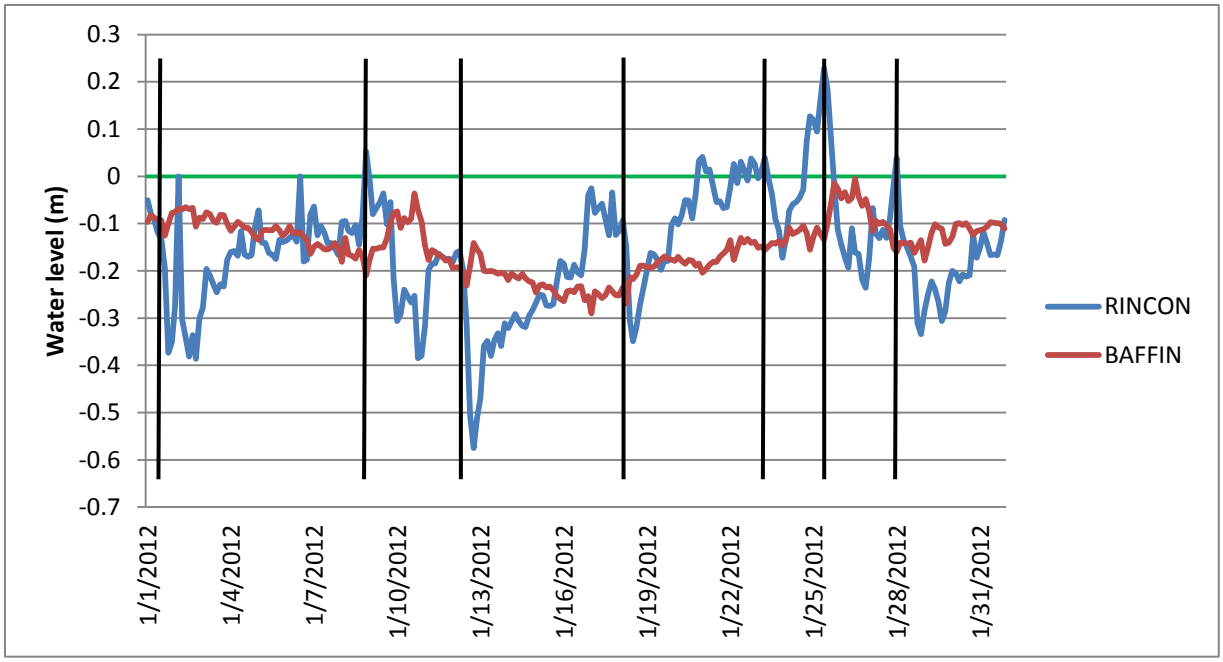

Figure 10. Water level (3-hr intervals) at gauges north (Upper Laguna Madre - "BAFFIN") and south (Lower Laguna Madre - "RINCON") of the Land Cut in January 2012 as an example of wind-forcing effects on water levels. Passage of northerly frontal boundaries are estimated by vertical lines. Water levels are expressed as deviations from mean of all hourly values for 2012 for each gauge (green line).

While the gulf beach of North Padre Island is clearly of great importance to Red Knots, it is remarkable that there were no relocations of knots on any gulf beach south of zone 5. The linear beach distance between the southernmost gulf beach relocation of a knot and the southern edge of the study area at the mouth of the Rio Grande is ~ 130 km. Red Knots are known to occur on those beaches, especially on the northern end of South Padre Island and Boca Chica beach. One possibility is that the spatial arrangement of bayside habitats in the Lower Laguna Madre is such that lagoon shore habitat is almost always available during the wintering period, so birds are less frequently forced off the flats than they are in the Upper Laguna Madre.

Additional areas of importance prior to spring migration

Though the main intention of the study of oversummering second-year Red Knots was to determine patterns of habitat usage through the summer months, flocks encountered during aerial and ground-based relocation were composed of both second-year and after-second-year birds (showing substantial breeding plumage). Hence, this component of the project revealed additional insight into areas of importance for knots in the month leading up to migration of adults to breeding grounds. The two primary areas used during this time period which were not commonly used during the other seasons were the west shore of Nine Mile Hole, and the Pintail Lake area. While the east shore of Nine Mile Hole is characterized by the typical pattern of algal and sandflat zonation, substrate on the west shore is composed of finer sediments and the detritus from seasonal sloughing of

shoalgrass in varying stages of decay. The flats on the north side of Pintail Lake were also heavily used during this period, with large flocks being regularly observed especially in the weeks prior to the dates of known migratory departure.

Minimum number of birds using study area in spring

Radiomarked birds, and the flocks that they may have accompanied, could not always be counted and tallied, but flock size was noted when groups were incidentally observed, and several counts tallied from these notes provide a minimum estimate of the numbers of knots that used the study area immediately prior to migration. On 4/30/2012, a total of 1102 knots were noted, over 95% of which were in Nine Mile Hole. On 5/8/2012, a flock of 400 was observed on the Pintail Lake flats, four groups totalling 155 on the west side of the Land Cut, in Nine Mile Hole, and north of Yarborough Pass, as well as 1147 on the gulf beach of North Padre Island. This total of 1702 Red Knots was the highest count tallied from notes taken during aerial surveys, but is likely very conservative since many relocated birds were not directly observed.

Evidence for movement beyond study area

Most habitat considered potentially suitable for Red Knots in the study area was covered by weekly aerial relocation efforts, though not all active transmitters were relocated on each flight. While first relocations after a prolonged absence were both north and south of capture area (suggesting movements out of the study area could have been in either direction), most of these were in the southern part of the area. Of 76 birds with transmitters in 2012/13, nineteen of them (25.0%) were either never subsequently relocated by radio signal or relocated only once. Considering that knots are capable of making substantial movements even within a nonbreeding period, it is probable that some if not most of these birds moved beyond the study area, at least until radios were no longer active or had been shed.

Probable movement into Laguna Madre de Tamaulipas

During the oversummering study, the nonbreeding birds were frequently encountered in flocks with birds in breeding plumage until mid- to late-May, which is known to be the general period of spring departure for breeding birds leaving Texas (Newstead et al 2013). Following 5/21/2012, no birds were relocated north of their initial capture location, and nearly all of the birds with active radios moved into the Lower Laguna Madre. There was a general continuation of this southward movement with remaining active radios through June, and on the last day active radios were detected, one of those two was with a flock of 45 knots in the Boca Chica Flats at the southern limit of the study area just north of the Rio Grande. This consistent southward movement by oversummering knots, as well as the evidence that birds departed from the study area in a southerly direction, suggest that the Laguna Madre de Tamaulipas is also important to Red Knots.

Piping Plover

Piping Plover habitat use

Roosting Piping Plovers were typically encountered in groups in the Laguna Madre, most frequently in moist lower sandflat or drier algal flat habitats contiguous with the lagoon-shore of the barrier island, or occasionally on dry sand on the eastern edge of spoil islands on the east side of the GIWW. They were typically found together in a large group with Snowy Plovers, though there was usually segregation between the species within the group.

When feeding in the Laguna Madre, they most frequently exhibited typical stop-run-peck foraging behavior on the algal flats. At times of very low water levels when bars covered with sparse seagrass growth became exposed, birds were commonly observed foraging using both stop-run-peck methods, as well as "foot-trembling" where one foot appears to scratch the sand, normally followed by a peck at a prey item.

When on gulf beaches, the most typical feeding style was the "foot-trembling" method in the upper part of the swash zone, where a long reddish-pink polychaete was the most commonly observed prey item. Stop-run-peck foraging was also observed among wrack scattered higher on the beach. While feeding, birds were typically very aggressive towards conspecifics, but appeared to have greater tolerance for Snowy Plovers which were often found in the vicinity of Piping Plovers. Conspecific aggression typically did not last more than a minute, resulting in one of the birds moving some distance along the beach.

Piping Plovers were occasionally found roosting on the gulf beach. They were frequently found with conspecifics and Snowy Plovers, but usually not in groups greater than 10 total birds. Roosting activity on beaches was most frequently observed on the Malaquite Beach area of PAIS, and on stretches of beach north of PAIS that typically do not see heavy traffic.

Patterns of movement

Aside from the two birds that made significant northward movements out of the study area (where they were relocated in the Galveston Bay area), all other birds tracked stayed within the study area. Most of the birds spent the full duration of the study period within a mosaic of habitats defined by barrier island gulf beach and nearby shorelines of the Laguna Madre. The three patterns of distribution observed in the Padre Island and Upper Laguna Madre part of the study area were similar and illustrate a very tight coupling between proximate beach and bay habitats, distinct from the pattern exhibited by birds that moved into the Lower Laguna Madre. Though there were some movements between areas and some individual birds did not fit comfortably into one of the four described patterns, 28 of the 34 birds for which MCP ranges could be created did fit one of the described patterns, with very little overlap between patterns.

The linear gulf beach distance between the northernmost and southernmost relocations of birds that used Nighthawk Bay was approximately 20 km. Since birds are often territorial on gulf beaches in winter, it is likely that the majority of birds encountered on the beach between Bob Hall

Pier and Malaquite Beach on PAIS are also dependent on the complex of flats in Nighthawk Bay. A total count of Piping Plovers in that segment was not an objective of this study, but a count of 118 individuals was recorded on the flat on January 23, 2009 (Maddock 2010). The water level on that date was one of the lowest of the year, so this total probably represents the majority of the wintering birds that depend on those flats, and the nearby beach when water levels rise and inundate the flats.

The birds that moved into the Lower Laguna Madre region provide additional insight into the dynamics of migration. This group consisted of the four southernmost captured birds (all captured on 10/30/2013) and one captured slightly further north on 11/6/2013, indicating that in this area birds encountered on the beach at least until this time period may still be in migration. The fact that these birds were never relocated in bayside habitats of the Laguna Madre in the northern part of the study area, yet were only relocated in bayside habitats in the Lower Laguna Madre suggests that the gulf beach is a part of the core wintering range for some Piping Plovers while serving as a migratory stopover for others. Once in the Lower Laguna Madre system, none were relocated on gulf beaches of either South Padre Island or Boca Chica Beach. In a radiotelemetry study focused on the Lower Laguna Madre/South Padre Island area, Drake et al (1999) found that algal flat and lower sandflat habitats accounted for 83.5% of relocations during the winter (defined as December 1 through 15 February based on chronology of molt and migration), with zero relocations on the beach during that period, consistent with the pattern seen in this study. This contrasts with the habits of birds in the northern part of the study area, where beach usage was relatively common even through the winter.

One of the birds that moved into the Lower Laguna Madre area was found eleven consecutive times in the flats around South Bay. In the interval between capture (10/30/2012) and its first relocation in South Bay (11/5/2012) it had moved just over 160 km. In its last relocation (1/24/2013) it had moved ~ 55 km north from South Bay to the algal flats on the west side of South Padre Island. There were no obvious changes in condition to the South Bay area with respect to inundation/exposure of the flats to explain this movement. Maddock (2010) found 239 individual Piping Plovers in the South Bay area on 2/3/2009, and 63 in the adjacent and hydrologically related Boca Chica flats on 1/31/2009. Though little can be inferred from only one radiomarked bird known to have used the South Bay area, this at least suggests the possibility that the South Bay area is part of a broader habitat mosaic for some birds, so that impacts to habitat that affect birds there could have consequences at a more regional level. It also illustrates variability in the plasticity of individuals with respect to "season." Though analysis of research and survey data often requires the designation of timeframes representative of migratory (fall, spring) and winter periods, some movements apparently defy these categorizations.

In a radiotelemetry study on South Padre Island and the adjacent Lower Laguna Madre (Zonick et al, 1998), only 2% of radio relocations of birds were on habitats classified as Dredge Material Placement Areas (DMPAs). By contrast, one of the birds from this study that moved into the area was most frequently encountered on one specific flat on a spoil island in a DMPA, accounting for 4 of its 7 total relocations after it entered the Lower Laguna Madre. An important difference between the studies is that the Zonick et al study was primarily based on ground visits centered along the beaches and flats of South Padre Island, and aerial methods were only employed when a "substantial portion of the plovers" could not be relocated by ground. Considering most DMPAs in the Lower Laguna Madre are on the mainland side of the lagoon, this means that relocations in those habitats would likely only

have occurred during infrequent aerial efforts. In this study, relocations of Piping Plovers in the Lower Laguna Madre area were entirely by aerial telemetry which allowed for consistent and complete – though not as frequent – coverage of the study area, possibly indicating that Piping Plovers use habitats associated with these sites more often than suggested by the previous study. Another possibility is that these habitats have changed substantially enough over the intervening fifteen year period in terms of substrate and benthic communities that conditions are now more attractive to plovers.

Proximity to current and proposed wind energy installations

Birds may be affected by wind energy projects in several ways. There may be an avoidance or attraction response that affects their choice of habitat, or the habitat modification around the turbines themselves could indirectly lead to habitat being altered some distance away. Mortality from strikes with structures or turbine blades obviously require passage through the turbine field, and there are two general circumstances under which this may occur. First, birds may fly through the area while making daily or short-term movements between sites during the extensive nonbreeding season. Second, they could be susceptible when arriving and departure between south Texas and breeding grounds.

A large wind farm installation lies directly to the north of Pintail Lake and the adjacent flat in Kenedy County, with the closest turbine at present approximately 11 km from the nearest relocation of a radiomarked bird (at that specific site). Flocks of knots were also regularly encountered on flats along the western edge of the Land Cut, in some locations less than 2.5 km from the nearest wind turbine. Both of these areas – especially the Pintail Lake area – were used in spring, just prior to migratory departure for Red Knots. This particular wind energy installation is within the straight-line path between this site and stopover sites used by Red Knots, and breeding sites of Piping Plovers, in the Northern Great Plains of the US and Canada. Geolocator data from another project suggests that knots have a fairly specific flight vector upon departure towards a northbound stopover. The level of risk from collision impact from wind turbines during migratory departure would depend on a number of factors – in particular, how quickly birds attain sufficient altitude to clear the rotor swept height of the turbines, and to what extent they are capable of avoiding moving blades (assuming clear weather conditions). Though we were not able to visit the Pintail Lake flat by land or water, observations during several of these flights indicated that considerable numbers of *Charadrius* (most likely Piping and/or Snowy) plovers were also present on this flat, though these were not confidently identified to the species level from aircraft at altitude.

The easternmost turbine locations of a proposed wind energy project along State Highway 100 in Cameron County, directly north of the Bahia Grande Complex, are approximately 4 km from a straight line connecting the two westernmost relocation points of Red Knots in 2012/13. Knots regularly made substantial movements between sites >50 km apart during the wintering period. Assuming their flights are typically direct and nearly straight, the risk to the species from this proposed project would partly depend on the extent to which they use the entire Bahia Grande Complex and the flats of Rattlesnake Bay immediately east of the main unit of Laguna Atascosa National Wildlife Refuge. This study confirms that Bahia Grande flats were used by Red Knots, but a more focused study on how the birds use the entire system would be necessary to further evaluate this risk.

The use of broad sandflats in the study area by both species appears to be related to long-term patterns of inundation and exposure by tidal waters, which determines the type of benthic communities present. Much of the area of flats west of the Land Cut in Kenedy County is only infrequently inundated, and would be characterized as upper sandflat in the typical zonation pattern seen in the Laguna Madre. While birds in this study were not found in habitats currently adjacent to windfarms, the vast low-relief flats around them are likely to be the first to be affected by sea level rise. Use of specific areas by birds depends primarily on the habitats present, so if sea level rise results in habitat changes to this area that make it more favorable for either of these species, risks would increase accordingly.

Finally, three turbines are currently filed as "proposed" for construction in the nearshore Gulf of Mexico. These are considered a pilot project for a future installation of a much larger project over a lease block that could accommodate up to 160 turbines. Offshore wind turbines are considerably larger than onshore turbines, and technological advances continue to make larger models available. While it is unknown if Piping Plovers make trans-Gulf migrations, data from another project has shown that some Red Knots do in fact cross the Gulf (Newstead, unpublished data). An array of turbines spread over an area of 20,000 acres in the nearshore Gulf would present a significant set of obstacles. Knowledge of flight vectors and altitudes of birds over a wide range of weather conditions would be necessary to assess the risk to Red Knots as well as a wide range of other species that use a trans-Gulf migratory route.

Red tide

A red tide bloom (*Karenia brevis*) began affecting the mid and south Texas coasts beginning in late September 2011, eventually affecting the entire Texas coast. These conditions persisted through at least December 2011. At the time trapping efforts were initiated, large quantities of fish had been washing up along the gulf beaches of the entire study area. This situation worsened throughout the coming weeks which made trapping conditions very uncomfortable due to respiratory difficulties from the aerosols as well as the stench of rotting fish. We encountered one recently-deceased Red Knot and two so weakened that they could not stand or fly. Two of the birds captured in nets were considered to be in such poor condition that they, along with the other two captured by hand, were taken for rehabilitation at the Animal Rehabilitation Keep at University of Texas Marine Science Institute in Port Aransas, along with a Piping Plover that had been captured by hand by a beach visitor. One of the knots died in transit. Two knot carcasses were taken to Dr Paul Zimba of the Center for Coastal Studies at Texas A&M University-Corpus Christi who was testing tissue samples of deceased organisms for brevetoxin concentrations. "Three subsamples were analyzed: GI tract, liver, and muscle. Liver samples in both cases exceeded 2400 ng PbTX-3/gram tissue (wet weight). Muscle and GI samples were also positive, but at least an order of magnitude lower. These levels are extremely high and surely accounted for bird mortalities" (P Zimba, pers. comm.).

Several of the radiotracked birds remained on the gulf beach for several months despite the persistence of red tide conditions and a massive fish kill. On many occasions, knots were observed feeding on carcasses of dead fish. It is not known whether they were feeding on fish flesh or on insect larvae that were growing in the decaying flesh.

Differences in mass between birds captured in 2011/12 and the 2012/13 suggest that birds of both species may have suffered from the red tide conditions. Mass of captured birds in the 2012/13 study period remained fairly consistent through the period of capture, the end of which probably precedes the time at which individuals begin increasing fat stores prior to migration. The difference in mass between the 2011/12 season and 2012/13 season was significant (Table 2). Piping Plover mean mass was 13.6 % lower in 2011/12 (during red tide) than in 2012/13 (no red tide). Similarly, Red Knot mean mass was 19.6 % lower during the red tide period. The weights of two of the knots captured in 2011/12 were not only much lower than the mean for that year but over 32% lower than the mean for the comparable time period in 2012/13, indicating that these birds may have already passed a critical point where recovery may not have been possible without intervention. It is probable that red tide killed or chronically weakened many more Red Knots than we encountered.

Table 211. Mass (g) of birds at capture. During the 2011/12 study period, no PIPL were captured after 11/30/11 and no REKN after 11/26/11. For 2012/13 study period, data presented includes all captures of radiomarked birds as well as a subset corresponding to the period of capture in 2011/12 for comparison.

	Date range	*n*	mean	min	max	SE
PIPL 2011/12	10/11/11 - 11/30/11	5	46.3	43.0	49.5	1.2
PIPL 2012/13	9/27/11 - 11/6/11	21	53.7	43.8	61.5	0.9
PIPL 2012/13	9/27/11 - 2/14/12	36	53.6	43.8	61.5	0.6
REKN 2011/12	10/11 - 11/26	12	105.5	83.0	122.0	3.1
REKN 2012/13	9/27-10/9	29	131.2	104.0	149.5	3.1
REKN 2012/13	9/27/11 - 2/14/12	75	129.3	104.0	156.0	1.3

The known mortality of the Piping Plover occurred within a week of its initial capture in a severely red tide-affected area of the beach. Since the carcass was mostly consumed, no tissues were available to be tested for brevetoxin concentrations, but the circumstances surrounding the mortality suggest the bird may have been significantly weakened or poisoned by the red tide event which led to its predation.

The impacts of red tide and other harmful algal blooms on shorebirds is largely unknown but potentially significant since they can occur on almost any shoreline used by shorebirds. The results of the lab analyses prove that red tide toxin is easily capable of accruing to lethal concentrations at least in Red Knots, either from consumption of affected prey or passive uptake of toxin in the swash zone where they feed. However, the total number of knots seen on the gulf beaches during fall 2011 was by far the lowest in recent years. Though it is unknown how many knots may have died as a result of red tide, evidence from resighting of marked individuals later in the winter and following spring indicate that some birds avoided the area during the red tide.

The mortalities we were able to document and have analyzed outside the scope of this project provide strong evidence that harmful algal blooms are capable of killing Red Knots and at least significantly weakening Piping Plovers. Previously this has been a matter of some uncertainty due to lack of testing of carcasses of these species. Though we cannot quantify the impact at a population

level, the results of these investigations warrant further study since harmful algal blooms occur throughout much of the known wintering range of the species including remote parts of South America.

Conclusions and Management Recommendations

Considering that approximately 75% of the species population winters in Texas, with most of them in the Laguna Madre area, the effectiveness of conservation efforts in this area have major implications for species recovery. The concept of habitat mosaic is commonly used in reference to shorebirds and especially Piping Plover. This study provides greater detail of information with regard to the core features of the habitat mosaic for these species over a large stretch of south Texas. Conservation of all components of these mosaics is fundamentally important for these and other shorebirds in south Texas. While much of the barrier island habitats of south Texas are federally protected, several critical areas remain without formal long-term protection.

Use of the Nighthawk Bay flats and the beach habitats between Bob Hall Pier and the northern boundary of Padre Island National Seashore was so tightly coupled that any activity that negatively impacts usage in one habitat could degrade the capacity of that area to support these two species (and others) that rely on that mosaic. The permanent protection of the property in this area would ensure the site's long-term viability as habitat for shorebirds.

Development in and north of the town of South Padre Island have effectively eliminated shorebird habitat on the Laguna Madre, and intensive beach grooming and sand replenishment projects have probably further reduced the capacity of the southern edge of South Padre Island from supporting birds of either species. While much of the property north of current development is protected as a unit of Laguna Atascosa National Wildlife Refuge, many substantial tracts of property which run east to west ("beach to bay") are still privately held. Currently, one elevated roadway (the Queen Isabella Causeway) crosses the Lower Laguna Madre connecting the town of South Padre Island to Port Isabel on the mainland. In recent years, planning and scoping for a possible second causeway has been advanced. Most of the proposed routes would connect to the island north of the current limit of development. This would likely result in hastening the continued northward path of development, further eliminating habitat and fragmenting the expansive stretch of algal flats that are currently heavily used by Piping Plovers.

The South Bay and Boca Chica flats area is also mostly under state/federal protection, but the a space launch facility for a private company (SpaceX) has been proposed on a small tract within the complex. Given the well-established importance of this area, the activities associated with launching rockets could negatively impact usage of this area. Extensive pre- and post-construction monitoring is recommended including the study of banded or radiomarked individuals to determine whether operational activities affect the birds' typical use of the site.

Aside from the residential/commercial development at the far north (Corpus Christi) and far south (South Padre Island) ends of the Laguna Madre in Texas, most of the barrier islands and mainland shores are currently undeveloped. The broad and infrequently inundated upper sandflats in

the Land Cut area, on both the Padre Island and mainland sides, while not used by birds in this study, represent areas where sea level rise may result in the upslope migration of suitable habitat. The protection of these sites could have substantial positive long-term consequences for shorebird conservation. Incrementally increasing sea level will likely also have the effect of reducing the amount of time that currently suitable habitat is exposed and thus available to birds in the Laguna Madre. As a result, beaches are expected to become even more important since they already appear to support a ready food source even in midwinter. Beach activities that degrade the quality of beach habitat or negatively impact the species' ability to utilize that habitat should be minimized where possible, since their implications will likely increase proportionally with sea level rise.

Impacts of wind energy projects in south Texas on all birds remain unknown, yet additional projects continue to be built without a requirement for monitoring due to lack of a permitting nexus. Their effects on these two shorebird species could be consequential since many of these projects lie directly between pre-migratory staging concentrations of birds and their breeding grounds. The lack of information available on mortality from windfarms is a significant "black box." Data on the flight vectors and altitudes of birds in migration are necessary to quantify potential risk, but will be limited in inference if actual mortalities go unreported.

Though this project was not intended to study red tide effects on shorebirds, the onset of one of the most extensive and severe red tides ever recorded in Texas provided the opportunity to witness and document substantial impacts of a frequently cited conservation threat to shorebirds about which relatively little is known. Partly, this paucity of information may be a function of the unpredictability of red tide occurrence, and the difficulty for researchers to spontaneously plan, find funding for, and mount a more detailed study. Efforts incorporating relatively simple survey methods combined with carcass recovery could be developed to more quickly respond to red tide events and quantify their effects.

This study gives emphasis to a series of additional questions, particularly with regard to the short- and long-term survival of birds exposed to red tide, and the location of additional wintering areas outside the study area. The results of this study indicate that some Piping Plovers and many Red Knots undertake substantial movements even in the midwinter period. Surveys and monitoring efforts in the future should incorporate resighting of marked birds, in order to validate or adjust assumptions based on the results of surveys conducted over broad time periods (during which birds may have moved and been either missed or counted multiple times), provide important information about movements and migratory connectivity, and allow for improved estimates of survival.

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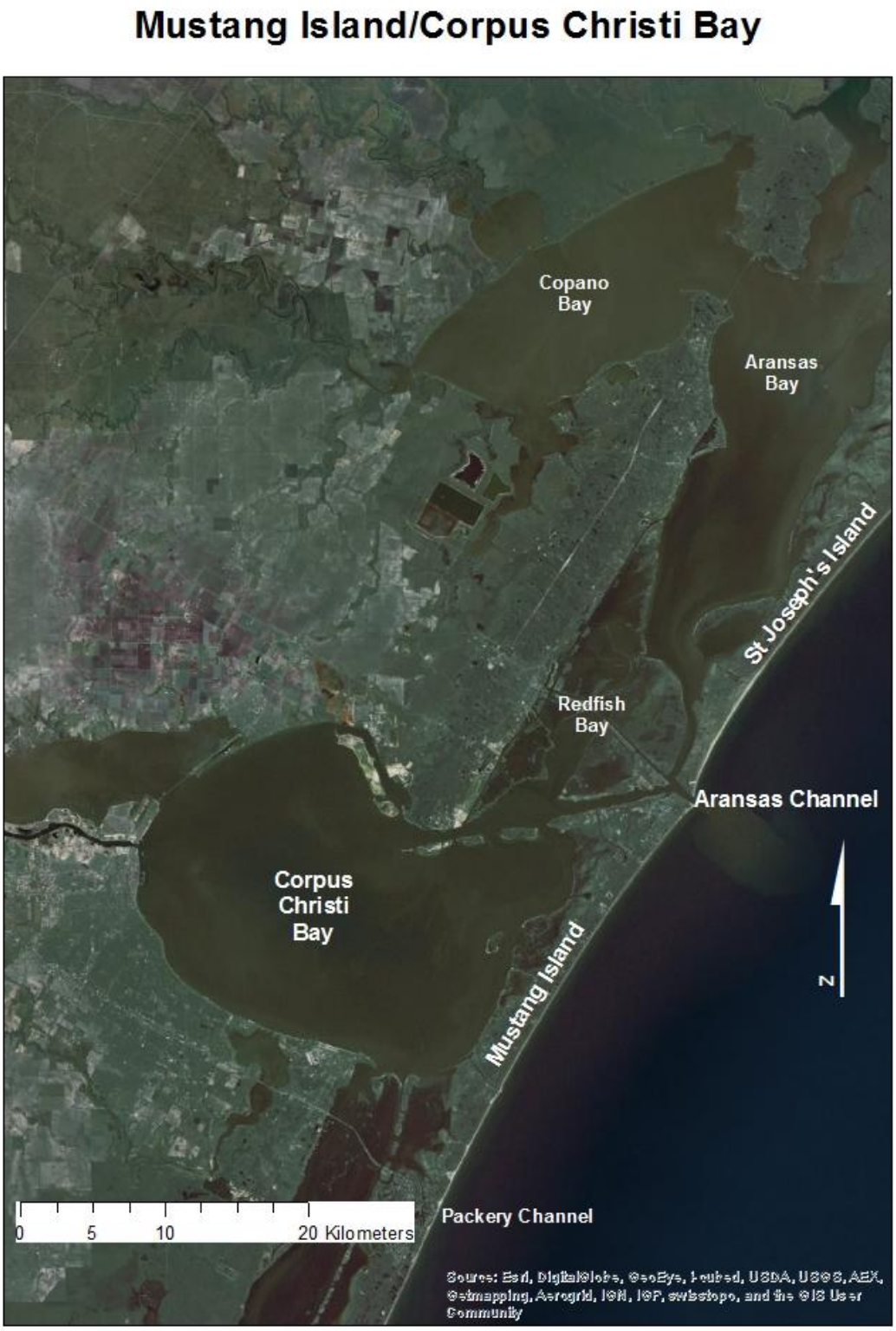
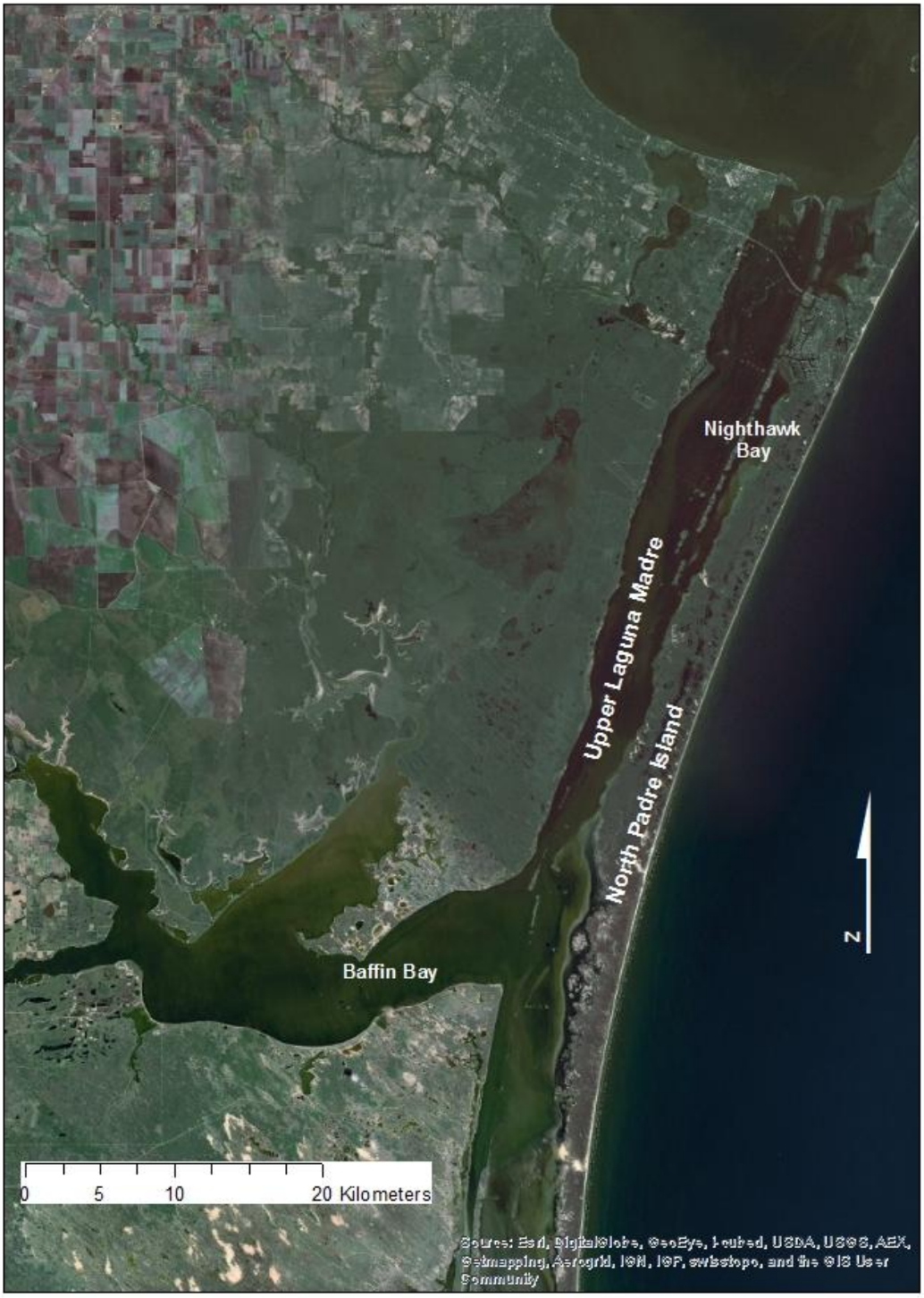
Appendix 1. Study area divided into four regions with relevant land and water features labeled.

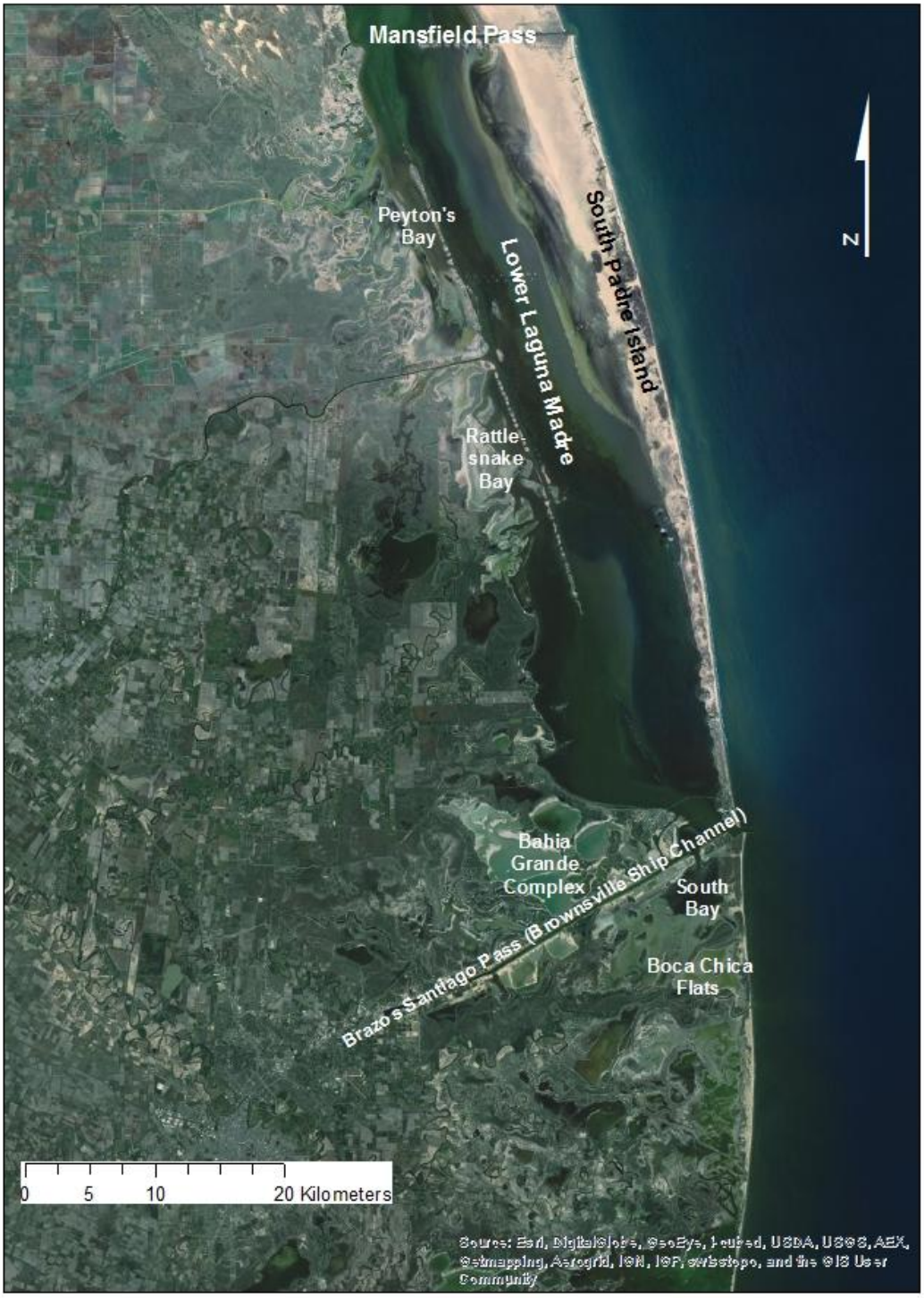


Padre Island/Laguna Madre (North)



Padre Island/Laguna Madre (Central)

Padre Island/Laguna Madre (South)



Appendix 2. Zones and habitat segments in study area, with descriptions of key habitats used. Percentages by species are based on total relocations over the duration of the study.

Zone	Mainland shoreline (M)	Barrier Island shoreline (B)	Gulf shoreline (G)
1		**1B) *Redfish/Aransas Bay*** – Much of the shoreline area of Redfish Bay is either coarse shell or emergent marsh, though some expansive areas of mudflat become exposed during seasonally low water levels.	**1G) *St. Joseph's Island*** – the beaches of St. Joseph's Island receive only minimal impacts from human recreational disturbance, and this predominantly at the southern end adjacent to the North Jetty of the Aransas Pass to the Gulf. While the beaches are subject to the same laws as all Texas beaches, vehicular access to the island is essentially non-existent with the exception of the property owner. Activity is limited to fishermen, beachcombers, and occasionally surfers primarily in the 1km adjacent to the jetty. Though no birds from this study were detected on this stretch of Gulf beach both species are known to occur there.
PIPL		0 (0%)	0 (0%)
REKN		3 (0.4%) - exposed sand/mud flats	0 (0%)
2		**2B) *Corpus Christi Bay (north of JFK Causeway)*** – The Corpus Christi Bay shoreline consists of shell ridges, sand/mud flats and emergent marsh (including black mangrove). The southern edge of this area is more ecologically similar to the Upper Laguna Madre, with larger areas of flats that are more regularly exposed. Red Knots were relocated at several sites along the Corpus Christi Bay shoreline and associated sandbars and spoil islands. One Piping Plover from this study was detected several times in the southern part of this area, which is known to support a high density of this species in winter.	**2G) *Mustang Island*** – The north end of the island includes the beaches of Port Aransas south to Access Road 2, and these are often heavily trafficked by recreational visitors. They are also frequently "cleaned" of debris including *Sargassum* and other natural wrack with a grader, and the sand then graded and groomed. The middle of the island includes Mustang Island State Park which does not conduct removal of natural debris and flotsam. The southern end of the island also receives heavy recreational access and is mechanically managed similarly to the northern end.
PIPL		2 (0.6%) - one bird from North Padre Island, later relocated back on North Padre Island	0 (0%)

REKN		15 (2.1%) - several birds dispersed north in fall/winter 2012/13	9 (1.3%) - same birds as found in 2B
3	**3M)** ***Upper Laguna Madre (JFK Causeway to Bird Island Basin)*** - Throughout this area the current geology of the area is not conducive to the formation of broad unvegetated intertidal flats. However, there is a series of shallow basins immediately landward of the shoreline that become inundated during high seasonal water levels, storms, and sometimes from precipitation. Superficially, these resemble the types of algal and sandflat habitats that are frequently used by both species.	**3B)** ***Upper Laguna Madre (JFK Causeway to Bird Island Basin)*** – The Nighthawk Bay area is comprised of one extensive shallow flat and a series of smaller flats northward towards the undeveloped canals of Padre Isles subdivision. Depending on water levels, the edge of the water can vary by as much as 1.3km on the main flat. The flats show a typical pattern of zonation in the Laguna Madre – a rarely inundated upper sandflat, a more frequently inundated algal flat, and a less frequently exposed lower sandflat. While the main flat was the most commonly used feature, all of the smaller discontinuous flats to the north were also used by both species.	**3G)** ***North Padre Island (Packery Channel to Bird Island Basin)*** – The beaches from the southern jetty at Packery Channel south to Bob Hall Pier experience high recreational use. Natural debris/flotsam removal and beach sculpting is routine along this beach. Only one telemetry relocation in this study was recorded there. Birds were not trapped there, as the two focal species apparently only use these beaches very infrequently. From Bob Hall Pier south to an imaginary line extending from the Bird Island Basin Road on Padre Island National Seashore (PAIS), there is currently no beach manipulation. Some beach maintenance activity has occurred on the county-managed portions (north of PAIS) in the past, but for the duration of this project no maintenance activity was practiced. Driving is permitted on the gulf beach between Bob Hall Pier and the northern bollards of Malaquite Beach within the PAIS boundary.
PIPL	2 (0.6%) - two birds relocated on flats south of Pita Island on 2/23/13	99 (28.5%) - the majority of relocations were on the flats at the north end of Nighthawk Bay. Several relocations were on spoil islands along GIWW, including one island commonly used as a roost site in fall.	60 (17.3%) - all relocations were of birds captured in this segment or in Nighthawk Bay
REKN	0 (0%)	88 (12.2%) - nearly all relocations on flats at north end of Nighthawk Bay.	93 (12.9%) - many of the relocations were of birds that also used Nighthawk Bay.

4	**4M)** ***Upper Laguna Madre (Bird Island Basin to north end of Land Cut)*** – there are no broad flats extending from the shoreline in this area, though there are a series of saline wetlands just landward of shore.	**4B)** ***Upper Laguna Madre (Bird Island Basin to Yarborough Pass)*** – North of Baffin Bay, a long sandbar extends from the back of Padre Island out to the edge of the GIWW. This sandbar was frequently used by both species when emergent and sparse seagrass was exposed. The flats that extend continuously from here south to Yarborough Pass represent typical zonation of algal and lower sandflat habitats.	**4G)** ***North Padre Island (Bird Island Basin to Yarborough Pass)*** – This stretch includes the remainder of Malaquite Beach as well as the northern fifteen miles of South Beach within PAIS. Driving is not permitted on Malaquite Beach, though some limited flotsam removal is occasionally conducted to facilitate pedestrian access at two points. The southern edge of this area is marked by the 15 mile marker on the beach, which corresponds to the road through the dunes that allows vehicular access to the Laguna Madre. Recreational activity is generally light or moderate on the northern part of this section though can be high during holidays spring through fall, and decreases towards the southern part where driving conditions frequently necessitate four-wheel drive and most of the visitation is associated with fishing. Traffic is light in this stretch with the exception of a weekend-long beach fishing tournament usually held in October, when clustered encampments of multiple vehicles are scattered along the entire beach, each with many fishing lines in the water.
PIPL	2 (0.6%) - one of these relocations was on a small spoil in the Laguna Madre just west of GIWW.	57 (16.4%) - relocations were clustered around the sandbar at the north end, and near Yarborough Pass at the south end.	78 (22.5%) - very frequently used by birds which also used 4B.
REKN	1 (0.1%)	69 (8.3%) - relocations were dispersed throughout this area, with higher concentrations using the sandbar when exposed.	255 (35.4%) - the most heavily used stretch of gulf beach in the study.

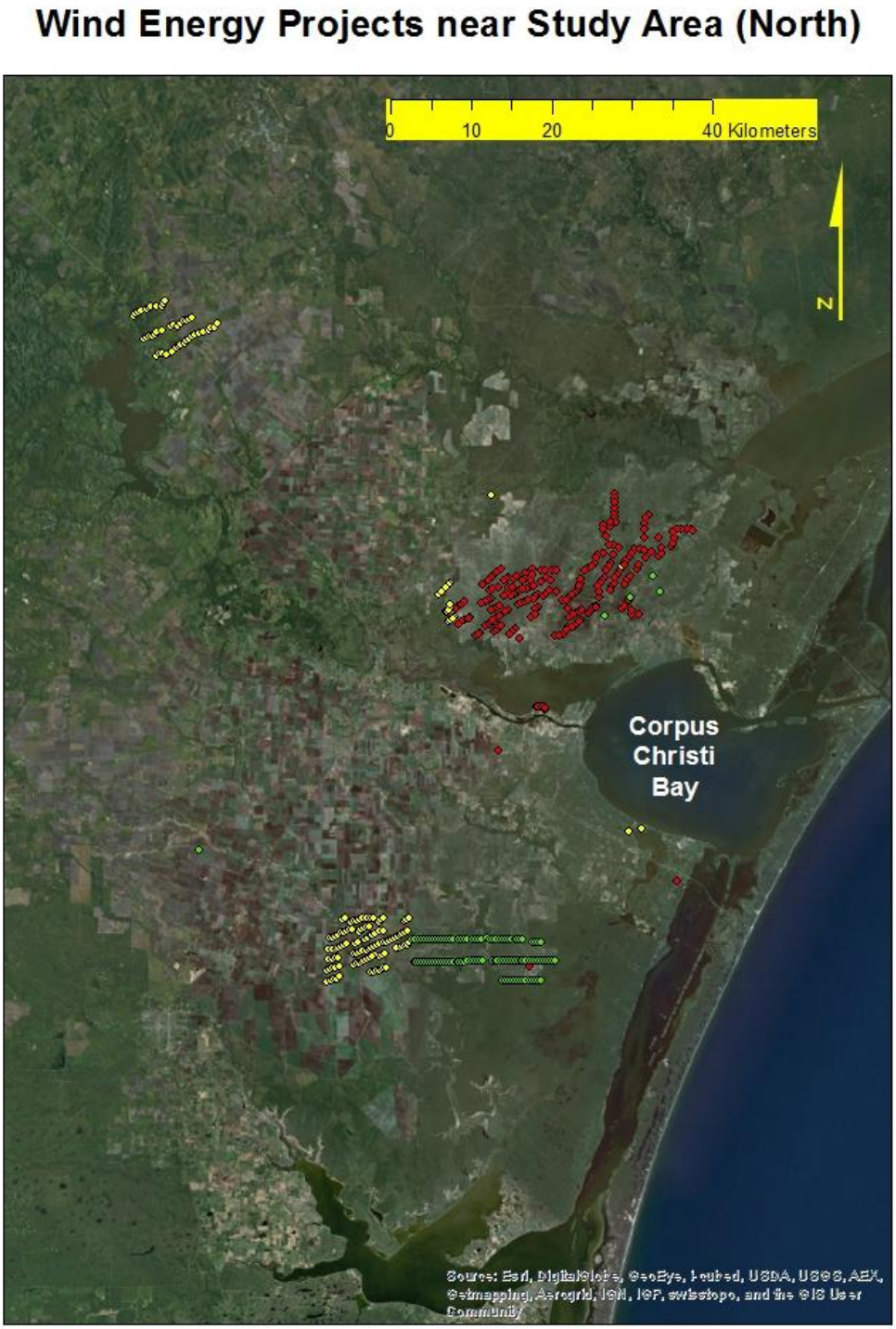
5	**5M)** ***Land Cut/West side of Nine Mile Hole*** – The eastern edge of the channel through the Land Cut provides only a narrow band of sandflat habitat; however, the western edge is bordered by some expansive sand and algal flats, and shallow seagrass beds that are occasionally exposed. These flats extend as much as 12km inland of the GIWW in some areas, though the more distant parts are only infrequently inundated by storms or wind-forcing events during times of seasonally high water.	**5B)** ***Upper Laguna Madre (Nine Mile Hole)*** – Nine Mile Hole is a shallow oblong basin between Padre Island and the spoils along the Land Cut of the GIWW. Depending on seasonal tides and especially winds, water can be driven as much as 15km south of the water line at mean water level. The west side is comprised mainly of mudflat and detritus (from decaying seagrass). The east side is primarily algal and sand flat, and additional sandflat habitat is associated with the series of spoils along a boat channel at the northern extent.	**5G)** ***North Padre Island (Yarborough Pass to Nine Mile Hole)*** – The southern end of this section is marked by a line corresponding to the southern edge of the Nine Mile Hole area of the Upper Laguna Madre. Beach conditions are often very rough in this stretch owing to the coarseness of substrate, which contains much shell material, and is locally known as Little Shell and Big Shell Beach.
PIPL	3 (0.9%) - all of these were in the northern part of the area up to 1 km west of the GIWW.	5 (1.4%) - all relocations were at the northern end of Nine Mile hole on the Padre Island shore	5 (1.4%)
REKN	0 (0%)	57 (7.9%) - relocations were clustered along the western shore of Nine Mile Hole, and along lower sandflat habitats throughout the north end especially in late spring and summer.	45 (6.3%) - many of these were the same birds that used Nine Mile Hole habitats in late spring.

6	**6M)** ***Lower Laguna Madre (Land Cut to Port Mansfield)*** – At the northern extreme of the Lower Laguna Madre, just south of the Land Cut, a kidney-shaped embayment locally known as Pintail Lake is surrounded by broad flats especially on the north side. Due to the geographical position, water is alternately driven up onto the flat by prevailing southerly winds, and quickly drawn off it during frontal passages. There are only small and scattered flats from there south to the town of Port Mansfield.	**6B)** ***Lower Laguna Madre (Land Cut to Mansfield Pass)*** – The typical zonation pattern of Laguna Madre flats is present along this entire stretch, and is interrupted only in two spots where dredged channels have created habitats that are oriented slightly differently from the adjacent natural shorelines. Bird usage was sporadic along this stretch, with a higher concentration of relocations detected closer to the Mansfield Cut.	**6G)** ***North Padre Island (Lower Laguna Madre to Port Mansfield)*** – this section corresponds to the northern reach of the Lower Laguna Madre on the west side of the island, south to the jettied pass at Mansfield, which is the southern boundary of PAIS.
PIPL	1 (0.3%)	3 (0.9%)	0 (0%)
REKN	34 (4.7%) - the Pintail Lake area accounts for all but one of these relocations, and this area was heavily used by nearly all birds in the oversummer 2012 study. Flocks of several hundred birds were seen here prior to spring migration, suggesting it may be an important staging area.	12 (1.7%) - there is typical algal and lower sandflat zonation on this stretch; relocations of knots are dispersed along this shoreline.	0 (0%)

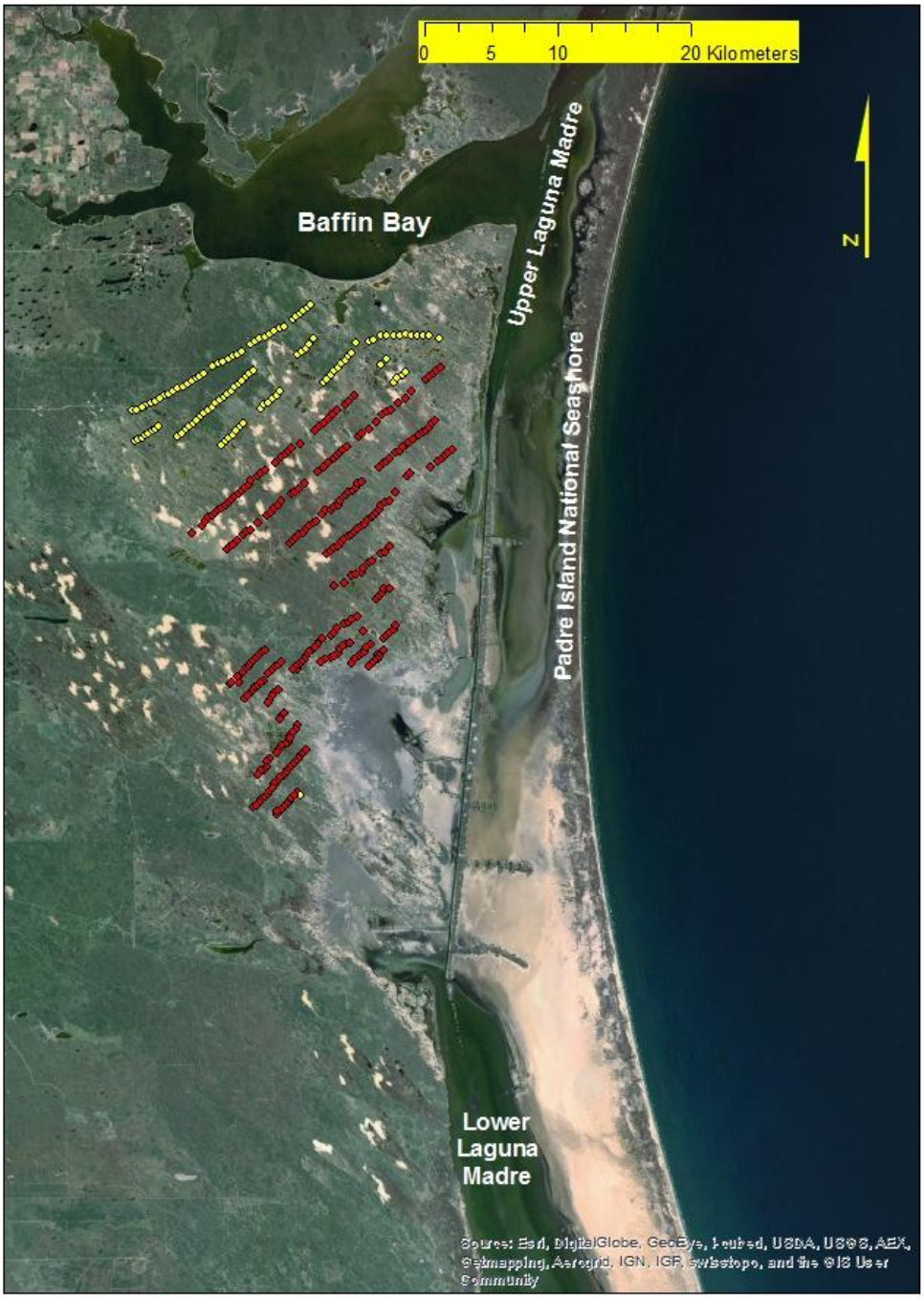
7	**7M)** ***Lower Laguna Madre (Port Mansfield to Port Isabel)*** – South of the town of Port Mansfield, an extensive system of shallow intertidal flats extends several kilometers inland, as well as some very broad shallow basins around the edge of Peyton's Bay, north of Arroyo Colorado. These habitats are also present south of Arroyo Colorado, along the shores of the Laguna Atascosa National Wildlife Refuge (LANWR), though the flats are broader here. Most relocations of birds on the Laguna Madre mainland shore were in this area.	**7B)** ***Lower Laguna Madre (Mansfield Pass to South Padre Island city limits)*** – This area is very similar to the area north of the Mansfield Cut, though the overall width of the flats is narrower towards the southern part of the island. Relocations in this area were concentrated around the expansive flat immediately south of the Mansfield cut (both species), along the seasonally exposed lower sandflats (REKN), and one small area of shoreline north of the town of South Padre Island (one PIPL).	**7G)** ***South Padre Island*** – The majority of the island north of the developed southern end is managed as a unit of Laguna Atascosa National Wildlife Refuge. Because of the difficulty of driving in this stretch, the beaches receive only light visitation usually by fishermen traveling north to the southern jetty at Mansfield Pass. In front of the developed parts of the island (town of South Padre Island), however, extensive beach raking and grooming occurs on the beaches as well as periodic beach replenishment projects, one of which was occurring during this project. Because of restrictions on flight time, some stretches of South Padre Island – in particular the northern part – were not covered during aerial surveys. Both Piping Plovers and Red Knots are known to use the beach north of the town of South Padre Island, but no birds in this study were relocated there.
PIPL	10 (2.9%) - most relocations associated with a single bird.	11 (3.2%) - relocations clustered around the flat south of the Mansfield Pass, and another cluster associated with a single bird that spent most of the winter there.	0 (0%)
REKN	35 (4.9%) - flats adjacent to LANWR frequently used by knots, and often in large flocks	27 (3.8%) - relocations scattered throughout the northern half of this segment.	0 (0%)

8	**8M/B)** ***Laguna Atascosa NWR Bahia Grande unit*** – Several broad intertidal basins comprise the Bahia Grande Unit of Laguna Atascosa NWR. In recent years hydrological connectivity has been restored to this area. Several radiomarked Red Knots were relocated in the Laguna Larga basin of this complex. ***South Bay/Boca Chica Flats*** – A wide variety of habitats are available in this area, including sand and algal flats that were used by both species (oversummering REKN, and one PIPL that resided there through the winter).		**8G)** ***Boca Chica Beach*** – Due to the remoteness of the access point to this stretch of beach, vehicular traffic is limited and recreational activity is concentrated near the base of the south jetty at Brazos Santiago Pass, or where State Highway 4 ends on the gulf beach. No relocations of birds were detected on this stretch of beach, though both species are known to use it.
PIPL	11 (3.2%) - all relocations of one bird that wintered in the flats around South Bay		0 (0%)
REKN	4 (0.6%) - all relocations of oversummering birds.		0 (0%)

Appendix 3. Proposed (green), scheduled (yellow) and built (red) wind turbines and associated meteorological towers near coast of the study area.



Wind Energy Projects near Study Area (Central)



Wind Energy Projects near Study Area (South)

Appendix 4. Zone and segment capture/relocation totals by individual and year. Italics indicate place of capture. Underlined values signify transmitter recovery.

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Piping	**13**									2	*1*												**3**	**0.63**
Plover	**20**							*3.0*		2													**5**	**1.77**
2011/12	**23**									1	*2*												**3**	**0.08**
	25									3	*6*		4										**13**	**107.41**
	26									1	*1*												**2**	**-**
	ALL	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**9**	**10**	**0**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**26**	
	%	***0***	***0***	***0***	***0***	***0***	***0***	***11.5***	***0***	***34.6***	***38.5***	***0***	***15.4***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***0***		

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Piping	**62**						11	*3*															**14**	**10.14**
Plover	**63**						7	*4*															**11**	**23.29**
2012/13	**64**							*2*	1														**3**	**0.37**
	67						2	*5*															**7**	**13.64**
	81						*1*																**1**	**-**
	95						7	*3*															**10**	**1.13**
	96						2	*4*															**6**	**2.32**
	97						2				*8*												**10**	**1.94**
	98						10	*4*															**14**	**21.35**
	99						4	*6*															**10**	**4.37**
	100											2		*1*				6	1				**10**	**600.75**
	101							1			*2*												**3**	**0.01**
	102									6	*6*												**12**	**16.82**
	103									8	*5*		1										**14**	**10.46**
	104													*1*					1		11		**13**	**391.36**
	105									2	*3*					2		1	2				**10**	**234.77**
	106										*2*				1			3	6				**12**	**2006.52**
	107											1		*3*		1							**5**	**155.67**
	109									1	*3*												**4**	**5.87**
	113									4	*5*												**9**	**42.33**
	114[a]									3	*6*												**9**	**1289.88**
	134			2			*6*	4															**12**	**40.24**
	137						*5*	3															**8**	**15.69**
	138					1	*8*	1															**10**	**9.13**
	140						10	*4*															**14**	**3.90**
	141									10	*4*												**14**	**48.27**

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Piping	**142**						4	*2*															**6**	**3.22**
Plover	**143**						9	*4*															**13**	**0.78**
2012/13	**144**[b]						*1*																**1**	**857.59**
(cont'd)	**145**						*2*																**2**	**-**
	146						*6*	7															**13**	**3.19**
	147									7	*6*								1				**14**	**173.38**
	148					1	*2*																**3**	**2.78**
	149								1	1	*7*												**9**	**47.55**
	151									2	*7*		2										**11**	**18.18**
	152									4	*4*		1										**9**	**18.89**
	ALL	**0**	**0**	**2**	**0**	**2**	**99**	**57**	**2**	**48**	**68**	**3**	**4**	**5**	**1**	**3**	**0**	**10**	**11**	**0**	**11**	**0**	**326**	
	%	***0***	***0***	***0.6***	***0***	***0.6***	***30.4***	***17.5***	***0.6***	***14.7***	***20.9***	***0.9***	***1.2***	***1.5***	***0.3***	***0.9***	***0***	***3.1***	***3.4***	***0***	***3.4***	***0***		
ALL PIPL	**ALL**	**0**	**0**	**2**	**0**	**2**	**99**	**60**	**2**	**57**	**78**	**3**	**8**	**5**	**1**	**3**	**0**	**10**	**11**	**0**	**11**	**0**	**352**	
	%	***0***	***0***	***0.6***	***0***	***0.6***	***28***	***17***	***0.6***	***16***	***22***	***0.9***	***2.3***	***1.4***	***0.3***	***0.9***	***0***	***2.8***	***3.1***	***0***	***3.1***	***0***		

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Red	**10**													*1*					2				**3**	**37.53**
Knot	**11**										*2*							2	1				**5**	**1030.40**
2011/12	**12**						7	1	1		*6*								1				**16**	**968.73**
	14										*1*				1								**2**	**-**
	15										*6*												**6**	**0.50**
	16										*4*		1										**5**	**9.94**
	17									2	*6*							5					**13**	**812.82**
	18										*3*		1						1				**5**	**525.73**
	19									*1*					1								**2**	**-**
	21									*1*													**1**	**-**
	22									*1*													**1**	**-**
	24									2	*1*												**3**	**1.55**
	ALL	*0*	*0*	*0*	*0*	*0*	*7*	*1*	*1*	*7*	*29*	*0*	*2*	*1*	*2*	*0*	*0*	*7*	*5*	*0*	*0*	*0*	**62**	
	%	***0***	***0***	***0***	***0***	***0***	***11***	***1.6***	***1.6***	***11.3***	***46.8***	***0.0***	***3.2***	***1.6***	***3.2***	***0***	***0***	***11***	***8.1***	***0***	***0***	***0***		

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Red Knot	**60**				1			*1*			1							1					**4**	**1142.66**
2012/13	**61**							*1*															**1**	**-**
	65							*1*															**1**	**-**
	66							*1*						1				1	3				**6**	**1620.88**
	68							*1*										5	1				**7**	**542.48**
	69						1	*1*			2			1				1					**6**	**1249.80**
	70							*2*					1		1	1							**5**	**1379.89**
	71						1	*3*		1	4			1									**10**	**566.57**
	73							*1*															**1**	**-**
	74							*2*			4			2									**8**	**192.95**
	93	1		5	*2*		1																**9**	**114.35**
	75										*2*												**2**	**-**
	80										*4*												**4**	**0.15**
	82										*2*												**2**	**-**
	84										*4*			3									**7**	**4.59**
	85							3			*7*					1			1				**12**	**603.90**
	86						1				*2*							7					**10**	**800.77**
	87										*1*												**1**	**-**
	88										*1*												**1**	**-**
	89	1		1	4			1			*1*												**8**	**250.22**
	90										*2*			4									**6**	**20.35**
	91				1						1												**2**	**-**
	92										2												**2**	**-**
	94							4			*3*			5									**12**	**140.31**
	76							2		1	*7*		1										**11**	**207.94**
	77										*10*												**10**	**3.88**
	78							1		1	9								1				**12**	**728.60**
	79							8			*2*												**10**	**54.60**
	83							3			*2*			5									**10**	**130.62**
	161										*3*												**3**	**0.05**
	163										*3*												**3**	**0.22**
	165										*3*			1		1		2	1				**8**	**826.00**
	168	1									2								1				**4**	**1931.79**
	160			1				*3*															**4**	**39.82**
	162							*3*		4	5					2			4				**18**	**2330.43**
	164							*1*															**1**	**-**
	166							*3*															**3**	**0.31**

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Red Knot	**167[c]**													*1*									**1**	**123.01**
2012/13	**169**						8	*4*		1													**13**	**52.18**
(cont'd)	**170**				1			*1*											1				**3**	**1200.26**
	171													*1*					1				**2**	**-**
	172							*1*															**1**	**-**
	173						1	*1*		2													**4**	**29.47**
	175						2	*3*			1												**6**	**23.12**
	176							*1*															**1**	**-**
	177						15	*5*		1	2			2		1							**26**	**849.39**
	178						3	*2*															**5**	**14.29**
	179			1				*1*															**2**	**-**
	180						9	*4*		1													**14**	**76.06**
	181						3	*2*			1												**6**	**37.95**
	182			5				*2*			1												**8**	**23.17**
	183						6	*5*															**11**	**14.11**
	184							*1*															**1**	**-**
	174						14	3			*4*												**21**	**39.55**
	187							2			*1*												**3**	**0.55**
	194						5	3			*1*												**9**	**27.70**
	189										2												**2**	**-**
	191										1							3	1				**5**	**1313.26**
	193						8	2			*3*												**13**	**59.82**
	195										1												**1**	**-**
	196									4	*8*					1							**13**	**317.48**
	197						1			2	*8*												**11**	**107.02**
	198									6	*10*							1					**17**	**492.85**
	199									2	*3*												**5**	**16.05**
	186									1	*1*					1			3				**6**	**500.97**
	188						1			2	*2*												**5**	**103.18**
	190									2	*8*			2		1							**13**	**198.19**
	201									1	*3*												**4**	**7.81**
	203									4	*3*		1										**8**	**65.43**
	208									3	*6*												**9**	**28.14**
	200										*1*												**1**	**-**
	202									5	*6*												**11**	**51.58**
	204									4	*5*												**9**	**38.14**
	206									2	*9*			1									**12**	**124.05**

Red Knot	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
2012/13	207			2			2	1			2							1					8	1188.86
(cont'd)	209									5	2							1					8	420.51
	ALL	3	0	15	9	0	82	90	0	55	184	0	3	30	1	9	0	23	18	0	0	0	522	
	%	0.6	0	2.9	1.7	0	16	17.2	0	10.5	35.2	0	0.6	5.7	0.2	1.7	0	4.4	3.4	0	0	0		

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
Red	36										1		2		5								8	150.36
Knot	37										1		1					2	3		2		9	1520.93
summer	38										1		1										2	-
2012	39										1		1										2	-
	40										3		5		1			1			1		11	1869.40
	41										4		5										9	54.44
	42										1		1										2	-
	43										3		5	3									11	136.54
	44										1		2	1	2	1			1				8	818.51
	45										2		2										4	7.98
	46										2		1	1	5								9	242.84
	47										1												1	-
	48										3		2	1	3								9	192.19
	49										1		1										2	-
	50										1												1	-
	51										3		5	1	2				1		1		13	1587.08
	53										1		2	1	6			1					11	1166.55
	54										2		1										3	4.18
	55									1	3		4		1	1							10	270.10
	56										1		4	3	2	1							11	517.22
	57										3		5	1				1					10	495.56
	59										2		2	2	4								10	293.00
	ALL	0	0	0	0	0	0	0	0	1	41	0	52	14	31	3	0	5	5	0	4	0	156	
	%	0	0	0	0	0	0	0	0	0.6	26.3	0	33	9	20	1.9	0	3.2	3.2	0	2.6	0		

ALL REKN	ALL	3	0	15	9	0	89	91	1	63	254	0	57	45	34	12	0	35	28	0	4	0	740	
	%	0.4	0	2	1.2	0	12	12	0.1	8.5	34	0	7.7	6.1	4.6	1.6	0	4.7	3.8	0	0.5	0		

REKN WINTER	ALL	3	0	15	9	0	89	91	1	62	213	0	5	31	3	9	0	30	23	0	0	0	584	
	%	0.5	0	2.6	1.5	0	15	16	0.2	11	36	0	0.9	5.3	0.5	1.5	0	5.1	3.9	0	0	0		

	ID	1B	1G	2M/B	2G	3M	3B	3G	4M	4B	4G	5M	5B	5G	6M	6B	6G	7M	7B	7G	8M/B	8G	TOTAL	MCP (sq km)
ALL BIRDS	**ALL**	**3**	**0**	**17**	**9**	**2**	**188**	**151**	**3**	**120**	**332**	**3**	**65**	**50**	**35**	**15**	**0**	**45**	**39**	**0**	**15**	**0**	**1092**	
	%	***0.3***	***0***	***1.6***	***0.8***	***0.2***	***17***	***14***	***0.3***	***11***	***30***	***0.3***	***6***	***4.6***	***3.2***	***1.4***	***0***	***4.1***	***3.6***	***0***	***1.4***	***0***		