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Movements and Habitat Use Locations of Manatees Within Kings Bay Florida During the Crystal River National Wildlife Refuge Winter Season (November 15–March 31)

By Daniel H. Slone, Susan M. Butler, and James P. Reid

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Datum

Horizontal coordinate information is referenced to the World Geodetic System 1984 (WGS 84).

Abbreviations

CRNWR	Crystal River National Wildlife Refuge
FLDEP	Florida Department of Environmental Protection
GIS	geographic information system
GPS	Global Positioning System
IACUC	Institutional Animal Care and Use Committee
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

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Abstract

Kings Bay, Florida, is one of the most important natural winter habitat locations for the federally threatened *Trichechus manatus latirostris* (Florida manatee). Crystal River National Wildlife Refuge was established in 1983 specifically to provide protection for manatees and their critical habitat. To aid managers at the refuge and other agencies with this task, spatial analyses of local habitat use locations and travel corridors of manatees in Kings Bay during manatee season (November 15–March 31) are presented based on Global Positioning System telemetry of 41 manatees over a 12-year timespan (2006−18). Local habitat use areas and travel corridors differed spatially when Gulf of Mexico water temperatures were cold (less than or equal to 17 degrees Celsius) versus when they were warm (greater than 17 degrees Celsius). During times of cold water, manatees were found in higher concentrations in the main springs and canals throughout the eastern side of the bay, whereas when waters were warm, they were found more generally throughout the bay and into Crystal River, except for the central open part of the bay and the southwest corner.

Introduction

Kings Bay Florida (fig. 1), is the winter home of the largest population of *Trichechus manatus latirostris* (Florida manatee) in northwest Florida and the largest population of manatees in a natural system anywhere in the world (Kleen and Breland, 2014). Their population numbers have been increasing for more than a decade (Sattelberger and others, 2017). The bay is also home to the U.S. Fish and Wildlife Service Crystal River National Wildlife Refuge (CRNWR), which was established in 1983 to provide protection for these federally threatened marine mammals (50 CFR 17.108).

To aid managers at CRNWR and other agencies responsible for protecting public land and natural resources, the U.S. Geological Survey (USGS) Sirenia Project, in cooperation with the U.S. Fish and Wildlife Service and the Bureau of Ocean Energy Management, has been documenting manatee movement and migration patterns by conducting tracking work with manatees in the northern Gulf of Mexico (hereafter, the Gulf) with Global Positioning System (GPS) telemetry since 2006. The accurate (generally less than 5-meter [m] error) recording of manatee locations in rapid (15-minute) succession allows us to determine where and when

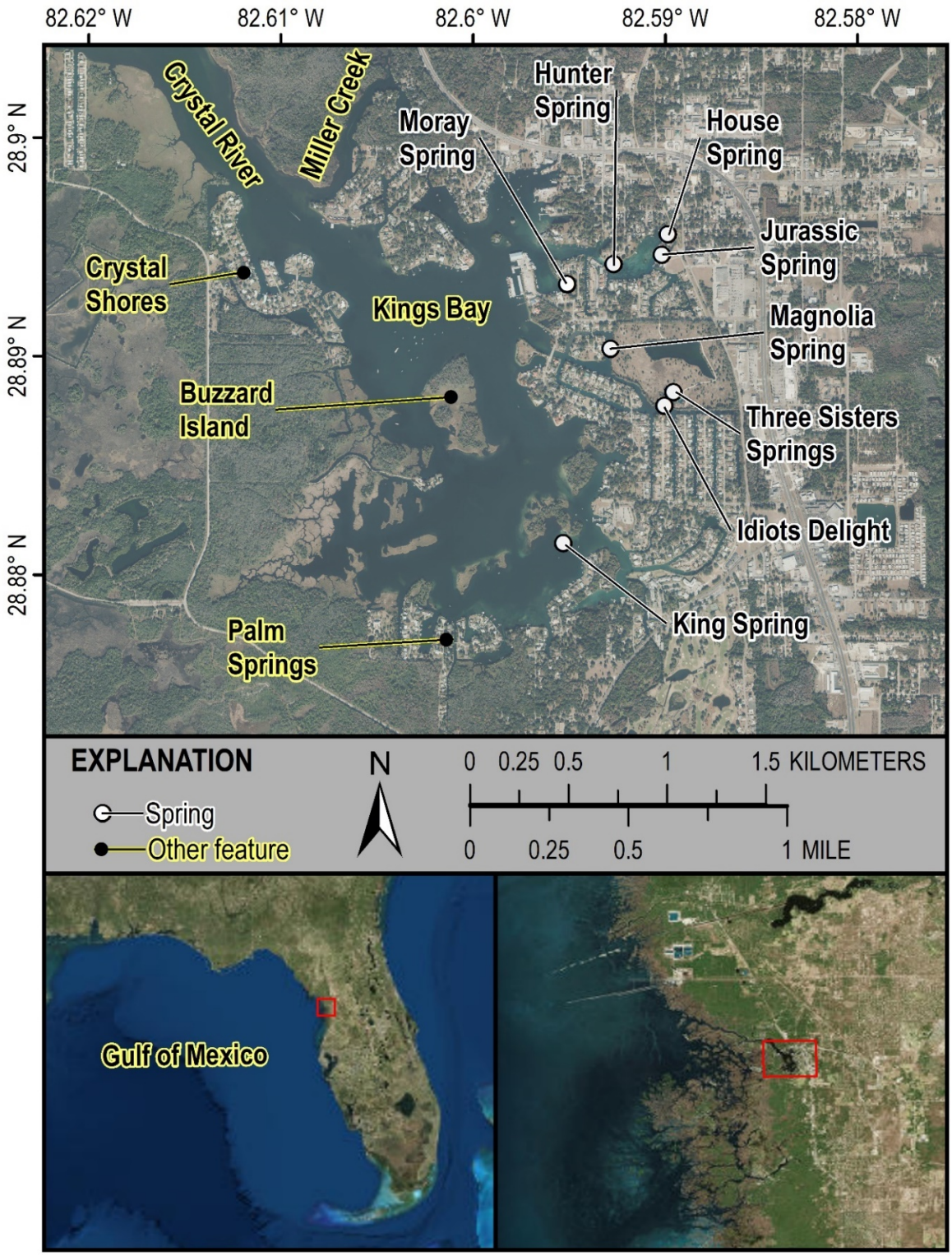

Figure 1. Map of Kings Bay, Florida, indicating locations of springs, neighborhoods (Crystal Shores and Palm Springs) and other physical features of the bay. (Aerial photo credits: Florida Department of Environmental Protection, top; Esri, bottom.)

manatees use local resources and how they move between them with much greater precision than was possible using earlier telemetry technology (Thomson and others 2017; Tomkiewicz and others, 2010). With accurate spatial and temporal habitat use data, information about the habitat preferences of individual manatees can be obtained, and then management decisions can be made with finer spatial accuracy, and in response to precise environmental, seasonal, and daily variation.

Methods and Data Collection

Manatee location data were collected from November 2006 to January 2018, with individual manatees tracked for a median of 18,000 locations over 6 months (further information in Slone and others, 2017). Because of the sensitivity of location data for federally listed species, contact the authors for more information about availability. Telemetry data were collected and maintained in the World Geodetic System 1984 (WGS 84 or EPSG4326) to match the native GPS datum.

Manatees were tracked by using a floating telemetry tag (TMT-462 and the smaller TMT-464, Telonics, Inc., Mesa, AZ; Marmontel and others, 2012; Slone and others, 2017) that contained GPS receivers coupled with satellite monitored Argos platform terminal transmitters. The tags were programmed to acquire GPS locations by using standard or quick-fix pseudoranging technology (Tomkiewicz and others, 2010) at 15-minute intervals, whenever the tag was at the surface.

Data from 153 GPS bouts were available for this project, defined as the time from when a GPS transmitter was attached to a manatee to the time when it was replaced with another tag, the tag detached due to entanglement, or the tag stopped functioning. Only records from healthy, wild caught or free-tagged manatees were used for this project. These bouts included 852,508 locations generated from 41 manatees tracked in the Gulf.

Water temperature in the Gulf was obtained from a publicly accessible environmental station maintained by the USGS (station 285531082412600 Crystal River at mouth near Shell Island (U.S. Geological Survey, 2018). Temperature data were reported every 15 minutes from the bottom of the water column and reported in degrees Celsius (°C). Locations of springs were obtained from a publicly accessible database maintained by the Florida Department of Environmental Protection (FLDEP) (Florida Department of Environmental Protection, 2016). Aerial photographs were obtained from publicly accessible databases maintained by FLDEP (Florida Department of Environmental Protection, 2011) or compiled by Esri (Esri, 2018).

Data Analysis

All data analyses were produced by using the statistical program R (Version 3.4.0; R Core Team, 2017) or ArcMap (Version 10.4.1.5686; Esri Inc., Redlands, CA). Maps were produced by using ArcMap. The purpose of these analyses was to illustrate patterns and trends and not to test any particular hypothesis. As such, the analyses included herein will be descriptive and graphical rather than quantitative (further information in Slone and others, 2017).

Manatee telemetry data points were paired by date and time to the closest Gulf water temperature record using the R package *data.table* (Dowle and Srinivasan, 2017) with parameter “roll = ‘nearest’” after standardizing time zones of the data sources. Any data that were not matched with a time difference of less than 1 hour were discarded.

Telemetry locations were converted to Universal Transverse Mercator (UTM) zone 17N (EPSG32617) using *spTransform* in the R package *sp*. (Pebesma and Bivand, 2005; Bivand and others, 2013). The point locations were then converted to movement lines by joining successive points with line segments using the *Lines* and *SpatialLines* functions in *sp*. The length of each line segment was calculated in meters by using the difference in UTM positions of the endpoints, the time to travel that distance was calculated as the difference between the GPS times of the endpoints, and travel speed was calculated by dividing a simple distance by time.

The manatee season for federal refuges is defined as November 15–March 31 by 50 CFR 17.108, which lists designated manatee protection areas and defines their regulations. Accordingly, the telemetry database was trimmed to only include records within these dates to assist refuge managers in understanding manatee habitat use and movements during these times when their sanctuaries are operational. Managers at CRNWR recently implemented a new management plan that closes public access to manatee sanctuaries when Gulf waters are less than 17 °C, so the database was also split into times when Gulf water was cold (less than or equal to 17 °C) and warm (greater than 17 °C).

To visualize local resource use areas and travel corridors, movement lines were categorized by speed into two movement rates (Slone and others, 2012, 2013). Movement paths slower than 0.2 kilometer per hour (km/h) and less than 200 m in length were assigned to the "local" use group. Movement paths faster than 0.4 km/h but slower than 0.8 km/h, and less than 1,200 m in length were assigned to the "travel" corridor group. Movement paths that were longer and faster than this were common but indicated long-distance, directed movements out of Kings Bay to the offshore seagrass beds and so were excluded from this study. The two movement rates being considered here can be considered short-range travel corridors and short distance/slow speed local use only.

The four groups of movement paths (cold/local; cold/travel; warm/local; warm/travel) were then aggregated, by means of kernel density analysis, to show areas of higher and lower densities of movement. The ArcMap tool *Line Density* in the Spatial Analyst Package was used (Silverman, 1986), with a cell size of 2 m and a search radius of 20 m. Results were standardized to movement lines per square kilometer. A lower cutoff density was chosen to exclude single paths and single path intersections, so only multiple pathways in the same location would be revealed. A higher line density was then chosen to show approximately the top 10 percent of use areas across the four groups. The lower density cutoff was specified as 200 movement lines per square kilometer, and higher density areas specified as greater than 2,000 movement lines per square kilometer.

Results and Discussion

There were 123,107 movement paths in the telemetry database that fell within manatee season (November 15–March 31) and intersected or were contained within the study area, which was the visible extent of the maps depicted herein. These included tracks from 34 manatees in the database. Of those tracks, 51,817 from 34 manatees were local-use movements from times when Gulf water was cold, and 4,328 tracks from 31 manatees were traveling movements. During times when Gulf waters were warmer, there were 38,308 local-use tracks from 32 manatees and 4,527 traveling movements from 34 manatees.

The lower density cutoff of the kernel density analyses excluded many single paths and intersections that were found throughout most of Kings Bay, including canals, coves, and the entrance to Crystal River. This indicates a possibility of encountering manatees in any of the

accessible waters of the bay during manatee season. The high-density manatee movements comprised approximately the top 10 percent of use areas and travel corridors.

During times of cold Gulf water, local use areas were concentrated mainly near springs, in residential canals, and in dead-end coves (fig. 2). There was little use near Buzzard Island. Most travel during cold periods was limited to the eastern side of the bay along the shoreline, and between springs (fig. 3); especially between Three Sisters Springs-Idiots Delight and the Magnolia Spring complex. Travel was also recorded within Miller Creek and from the northern springs to the Crystal Shores neighborhood.

During times of warm Gulf water, tagged manatees used most of Kings Bay, except for open-water areas in the center of the bay, and the southwest portion. There were high concentrations of local use in springs (fig. 4), but with a larger use area associated with each spring compared to times of cold Gulf water. The southwest portion of the bay, from King Spring to the Palm Springs neighborhood, showed local and traveling use (fig. 5) across nearly the entire area. Travel corridors were clearly delineated along both banks in the upper portion of Crystal River, along the western shore of the bay, and around Buzzard Island, in addition to high densities of movement paths between Three Sisters Springs-Idiots Delight and Magnolia Spring.

The spatial patterns described here can be compared to the analyses performed previously on an earlier version of the same telemetry dataset (Slone and others, 2017), where manatee use of Three Sisters Springs and Idiots Delight increased as Gulf water temperature decreased, and use of Kings Bay outside of springs was higher at warmer temperatures. A similar pattern of habitat use closer to springs during the winter and more dispersed during the summer was also observed in aerial survey data (Sattelberger and others, 2017). The patterns observed in the aerial survey analysis were similar, although not identical, to those described here and were not constant over years. Keeping in mind the differences in methodology and timing of the aerial surveys compared to our telemetry data, the patterns of local habitat use and travel corridors delineated here by the 34 manatees in our dataset may be representative of the several hundred manatees that use Kings Bay during the winter (Kleen and Breland, 2014). Because we could not track all manatees, the best interpretation of these maps is as confirmation of areas where manatees have routinely travelled and spent time rather than a delineation of areas where manatees have not been or will avoid in the future.

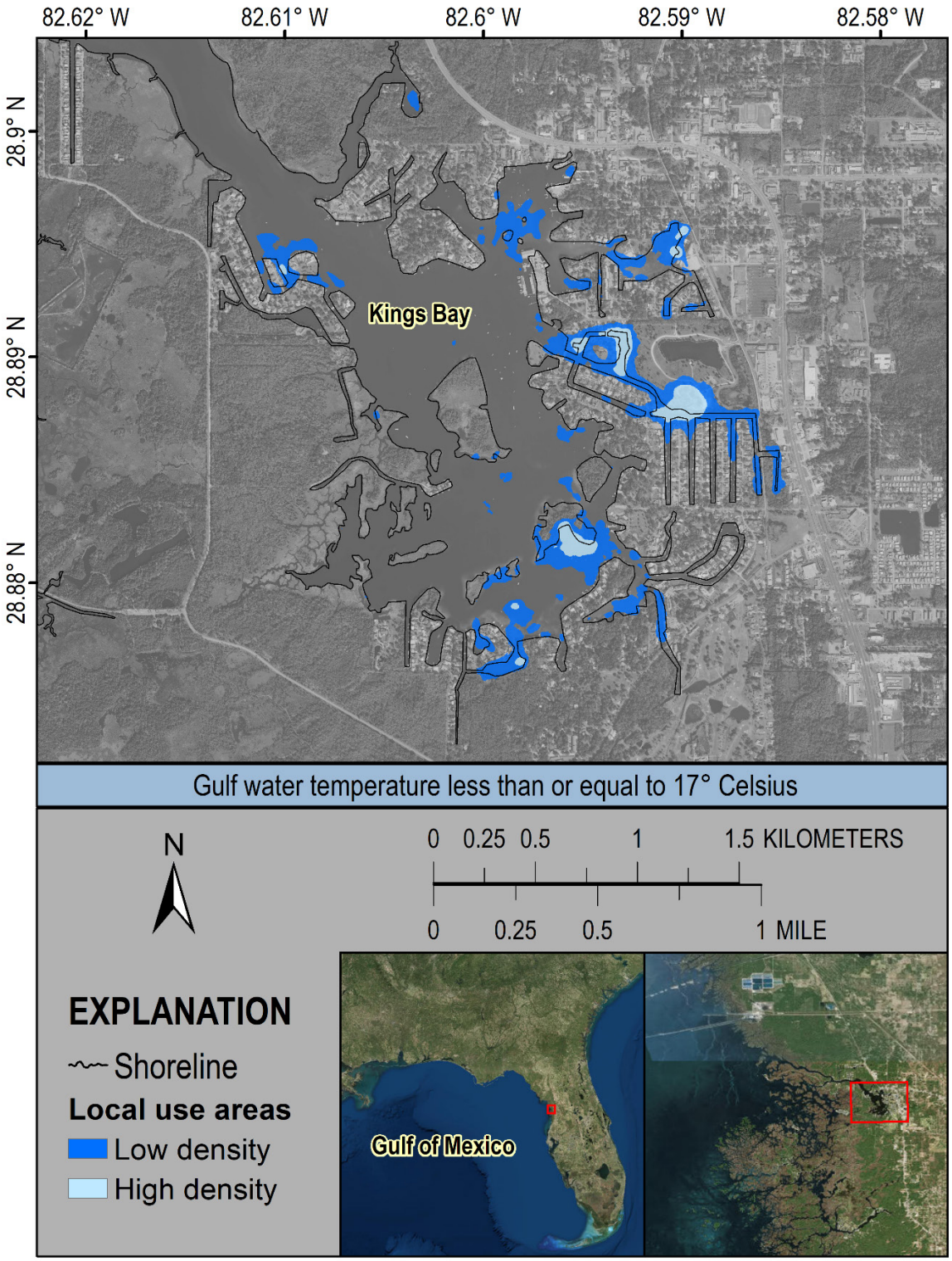

Figure 2. Map of Kings Bay, Florida, indicating local use areas of 34 manatees tracked from 2006 to 2018 during manatee season (November 15–March 31) when water in the Gulf of Mexico was less than or equal to 17 degrees Celsius. (Aerial photo credits: Esri.)

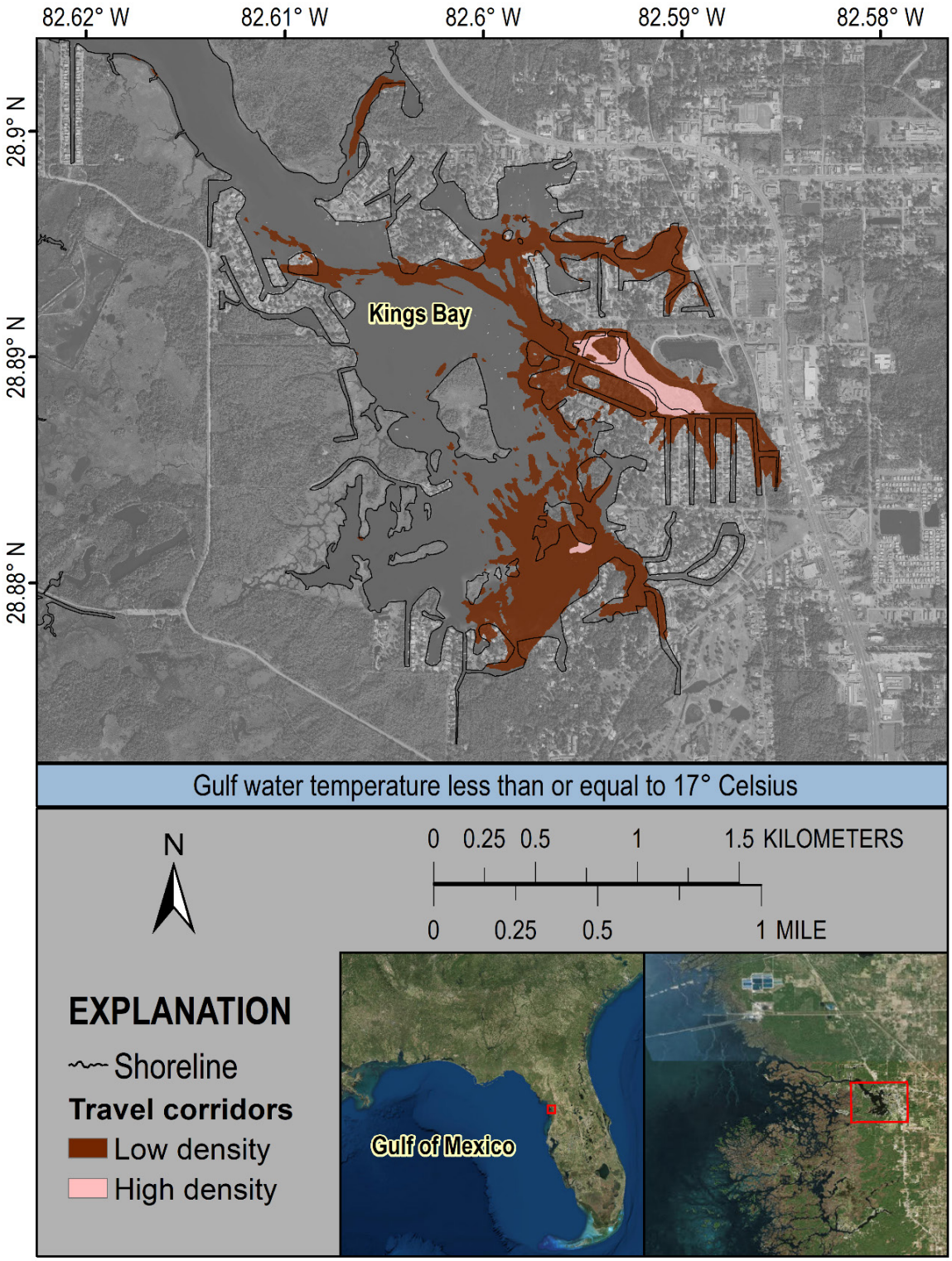

Figure 3. Map of Kings Bay, Florida, indicating travel corridors of 34 manatees tracked from 2006 to 2018 during manatee season (November 15–March 31) when water in the Gulf of Mexico was less than or equal to 17 degrees Celsius. (Aerial photo credits: Esri.)

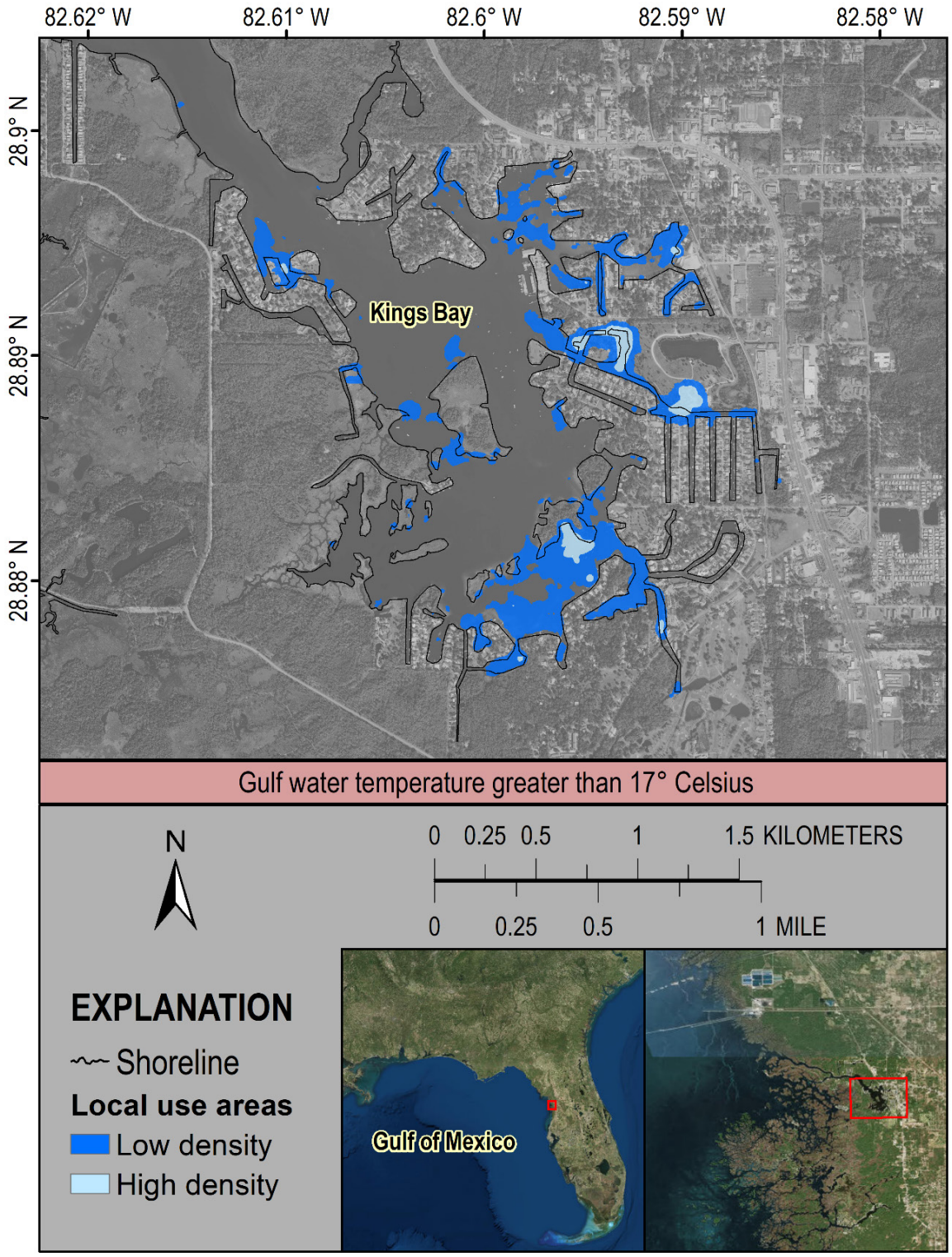

Figure 4. Map of Kings Bay, Florida, indicating local use areas of 34 manatees tracked from 2006 to 2018 during manatee season (November 15–March 31) when water in the Gulf of Mexico was greater than 17 degrees Celsius. (Aerial photo credits: Esri.)

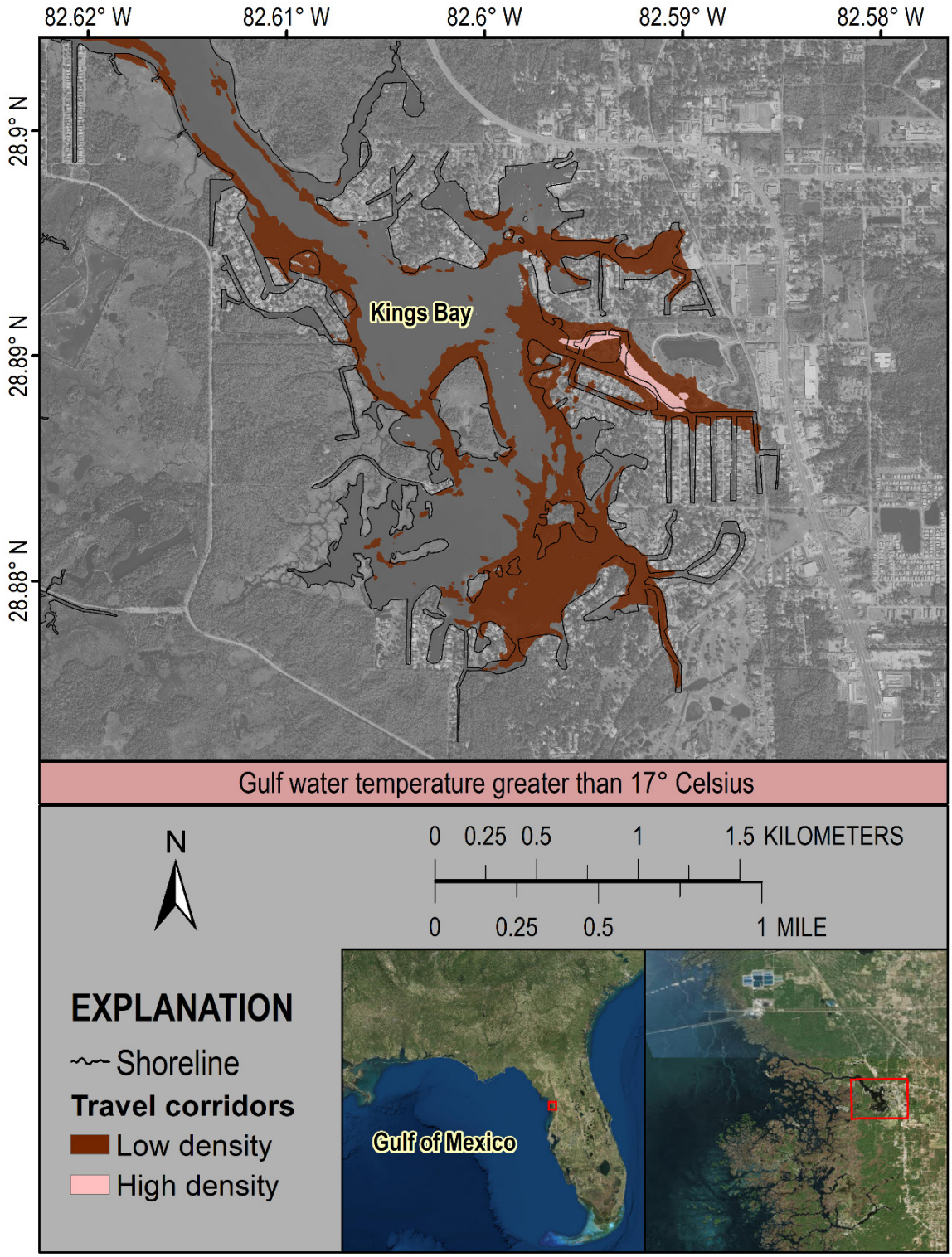

Figure 5. Map of Kings Bay, Florida, indicating travel corridors of 34 manatees tracked from 2006 to 2018, during manatee season (November 15–March 31) when water in the Gulf of Mexico was greater than 17 degrees Celsius. (Aerial photo credits: Esri.)

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