Characterizing Sea Turtle Nesting Behavior with Mobile GIS

Kirt Rusenko, PhD[1]
Jennifer Marangos[2]
Eric Householder[3]

ABSTRACT

The City of Boca Raton has monitored sea turtle nesting activity on its five miles of beach since 1976. Ten one-half mile zones locate the crawls and this activity is reported to the Florida Fish and Wildlife Conservation Commission. The zones generally do not provide biologists enough detail to locate problem areas where lighting or predators are adversely impacting nesting sea turtles.

In 2004 the Boca Raton Sea Turtle Conservation Program began recording nesting activity with handheld computers fitted with GPS receivers and ArcPad. The high resolution offered by GIS has shown that there is more nesting activity in front of condominiums and less in City Parks this season. The unexpected drop in nesting density is visualized with Spatial Analyst. City Glow may be responsible for this pattern and sea turtles are seeking the shaded areas in front of condominiums. This detailed information will help resolve this problem.

INTRODUCTION

During the 2004 nesting season in Boca Raton, female sea turtles avoided a City park area (South Beach Park) that contains no lighting. This park area has a low profile dune that appears flat when viewed from the ocean looking west whereas other City Parks have a high dune profile and tall Australian pine trees. Sea turtle crawls in the South Beach Park area decreased from a ten-year average of 0.074 crawls per foot (C/F) to an all time low of 0.022 C/F in 2004. When crawl locations were pinpointed by Mobile GIS using hand-held computers and ArcPad and ArcView software (ESRI, Inc.) sea turtle crawls were visualized as predominant in front of condominiums and City Parks with high dunes and/or Australian Pine Trees. This was reported by Salmon *et al.*, 1995 who also reported that more nests were found in front of taller condominiums. The loss of sea turtle nesting activity in South Beach Park can only be explained by the presence of City Glow, as that is the only light source in the area. In a study by Adamy *et al.*, 1997 South Beach Park was reported as being a "dark site".

Because the area was renourished (the beach was widened ten-fold by a dredge which pumped sand from the near-shore bottom to the shore) in 2004 it is important to demonstrate that city glow, not renourishment is responsible for the lack of nesting. As controls data from the renourished zone to the south showed normal crawl numbers and data from the north end of South Beach Park, which was not renourished shows a similar reduction in crawls as in the south end of the park. Although not measured, the intensity of the city glow does not appear to have increased based on photography taken during lighting surveys. In the past year, the City has installed metal halide street lighting fixtures and many businesses and residences are replacing high-pressure sodium fixtures with metal halide or halogen fixtures. The increased use of these "daylight" fixtures may be actually reducing the wavelength of the city glow so the glow is becoming more visible to nesting female sea turtles and their hatchlings. City glow disorientations now appear to have more impact on sea turtle nesting and hatchling disorientations in Boca Raton. Perhaps lighting ordinances need to extend beyond the beach such as the Model Lighting Ordinance proposed by the International Dark-Sky Association (www.darksky.org).

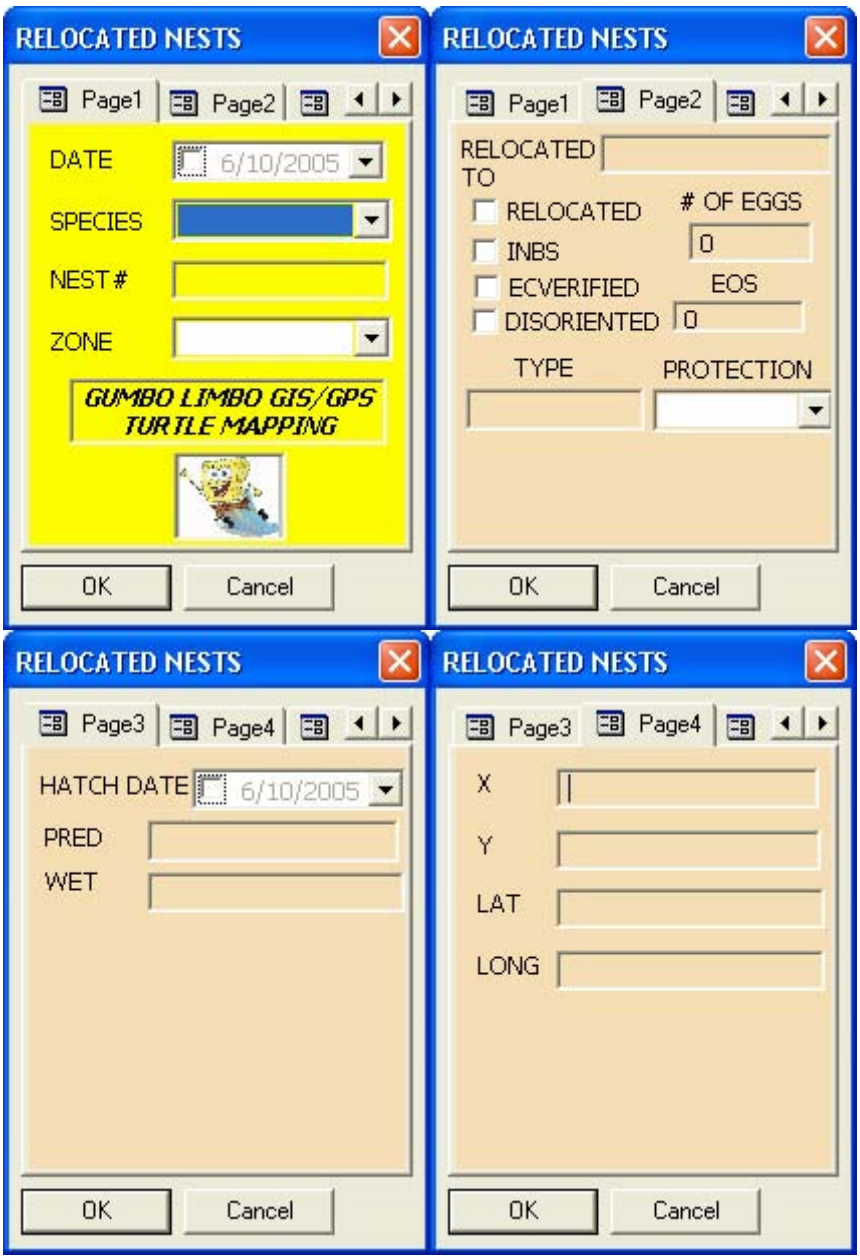
MATERIALS AND METHODS

Sea turtle nesting data was collected according to the Florida Fish and Wildlife Conservation Commission's (FWC) Guidelines. Because some of the South Beach Park area has been renourished before the 2004-nesting season, the false crawls (non-nesting emergences) are recorded for both above and below the high-tide line. Each crawl in the Boca Raton City limits was recorded using an HP Compaq IPAQ 2215 or a Compaq IPAQ 3850 hand-held computer fitted with a Compact flash GPS receiver. The hand-held computer utilized ArcPad 6.0.3 Mobile GIS

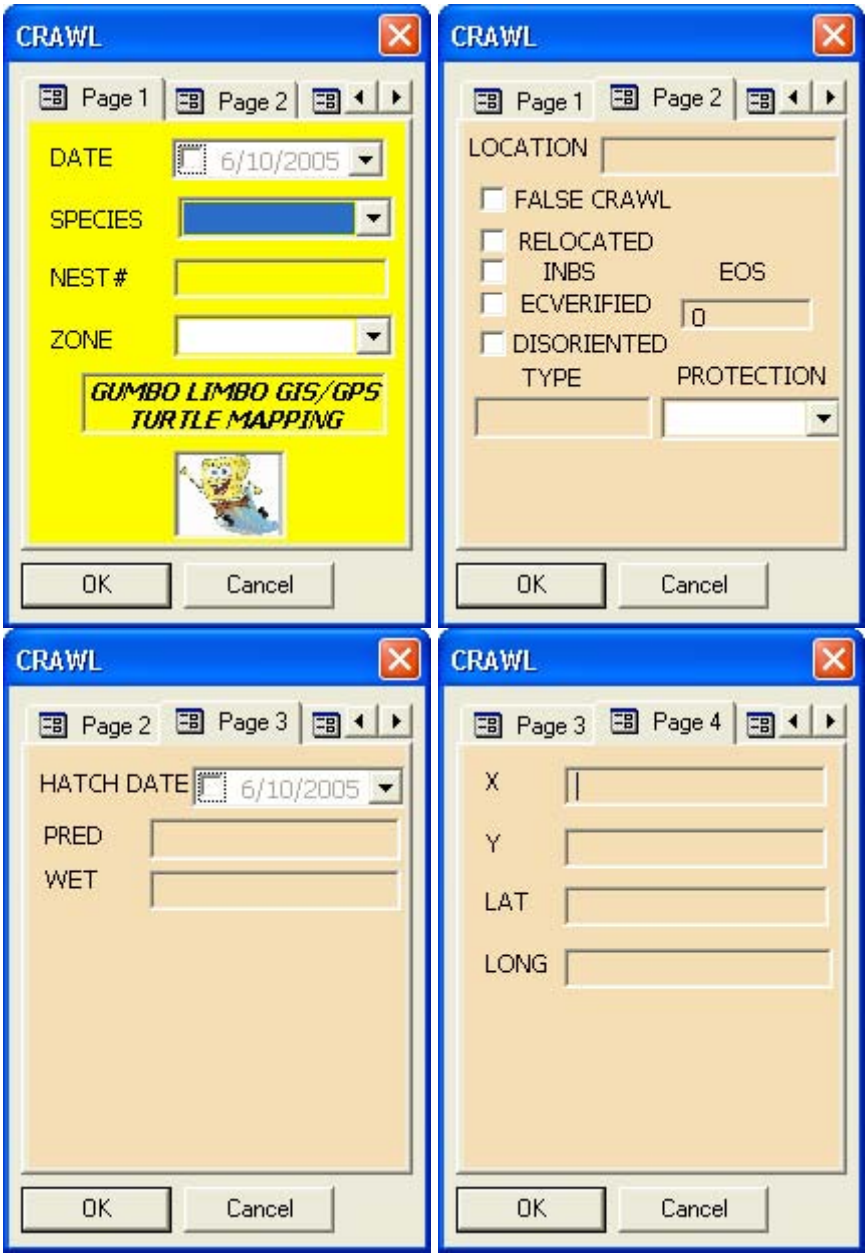
software (ESRI. Inc., WWW.ESRI.com). Sea turtle crawl data was evaluated with ArcView 3.2 and ArcGIS 9.0 software (ESRI, Inc.) on desktop computers. Beach photography was standardized by using Kodak Gold 400 print film in a 35 mm camera fitted with a 24 mm f/2.8 lens. The film was exposed for 1 second at f/2.8.

The Mobile GIS portion of the project used Compaq IPAQ Pocket PCs running the MS Pocket PC (CE) operating system and used an Ambicon GPS Navigation compact flash card model GPS-Cfpro. The units were loaded with ESRI's ArcPad Mobile GIS/GPS software, which was used for data gathering and mobile mapping. The Turtle Nest Team used a customized version of ArcPad to conduct their field surveys. For the turtle mapping project, numerous forms and custom toolbars were created in ArcPad Studio (Application Builder) (ESRI, Inc.) to facilitate rapid field data entry. Three separate sets of ESRI Shapefiles (Relocated, Crawl and Other) and corresponding custom input form were created in ArcPad Application Builder to facilitate rapid data entry during a survey. To provide a friendly interface for the survey teams, each set was based on a separate ***Spongebob*** character (Spongebob, Plankton and Patrick) and placed on the individual IPAQ units. The custom forms for the Spongebob set are shown below.

Relocated Nests Forms:

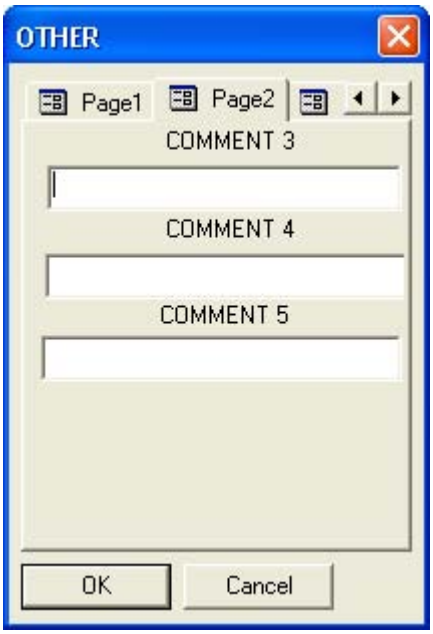


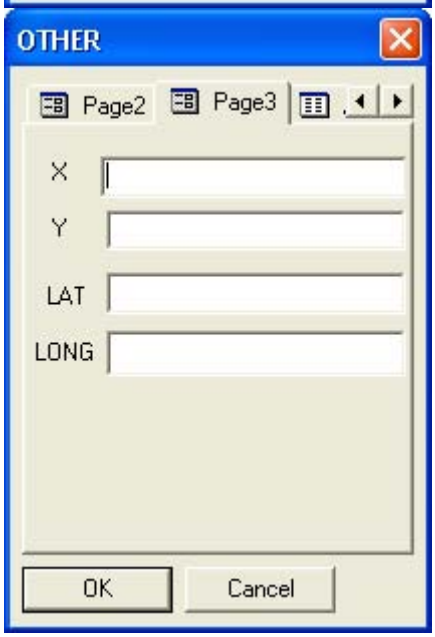
Crawl Forms:


CRAWL
Page 1
Page 2
DATE
6/10/2005
SPECIES
NEST #
ZONE
GUMBO LIMBO GIS/GPS
TURTLE MAPPING
OK
Cancel
CRAWL
Page 1
Page 2
LOCATION
FALSE CRAWL
RELOCATED
INBS
EOS
ECVERIFIED
0
DISORIENTED
TYPE
PROTECTION
OK
Cancel
CRAWL
Page 2
Page 3
HATCH DATE
6/10/2005
PRED
WET
OK
Cancel
CRAWL
Page 3
Page 4
X
Y
LAT
LONG
OK
Cancel

Other Forms:


OTHER
Page1
Page2
6/10/2005
COMMENT 1
COMMENT 2
GUMBO LIMBO GIS/GPS
TURTLE MAPPING
OK
Cancel


OTHER
Page1
Page2
COMMENT 3
COMMENT 4
COMMENT 5
OK
Cancel


OTHER
Page2
Page3
X
Y
LAT
LONG
OK
Cancel

The custom tool bars were created in ArcPad Application Builder to provide quick and efficient data entry. To the left of the ***Activity*** label, a separate flag was used to activate each individual shape file and form. The yellow flag is tapped to activate and edit the Crawl shapefile, the Green flag is tapped to activate and edit the Relocated shapefile and the blue flag is tapped to activate and edit the other shapefile. The Satellite icon to the right of the flags is used to gather the coordinate and invoke the custom forms. Below is an example of the Spongebob custom toolbar, which was loaded on the designated IPAQ and used with the Spongebob shapefile set.

Two sets of density maps were created of the raw sea turtle crawl data using ArcGIS Spatial Analyst 9.0 (ESRI, Inc.) The first set was of layers that were used to show the concentrations of turtles along the Boca Raton shoreline respective to their Florida Fish and Wildlife Conservation Commission (FFWCC) Zones. These density layers were produced using kernel calculations with a search distance of 800 ft and a cell size of 250 ft. The second set of density maps were choropleth maps that symbolized the magnitude of the raw crawl data within the FFWCC Zones. The choropleth density maps of the turtle crawls were calculated per square foot and as a count within each FFWCC Zone.

RESULTS

Historically sea turtle activity in Florida is located in _ mile or 1 Km zones within a county or municipality. Boca Raton has 10 one-half mile zones labeled A through J from north to south (Figure 1). Within each zone, nests were more specifically located by which condominium or lifeguard tower they were near. False crawls (or non-nesting emergences) were rarely located by more than the zone so accuracy was guaranteed only within a _ mile area. With mobile and desktop GIS, crawl patterns were visible in real time with accuracy that transcended condominium or lifeguard tower locations. With GIS, it is possible to detect and view problems with nesting sea turtles in front of a particular condominium, which was not possible previously.

Figure 1- Zone map of Boca Raton's beaches. This figure shows the _ mile zones that located sea turtle crawls in Boca Raton since 1988. The zones involved in this study (E, and F) are shown in this figure. These zones which encompass the city parks of Red Reef, Red Reef Municipal Golf Course, and South Beach Park from north to south.

The crawl patterns for South Beach Park and the surrounding areas are shown in Figure 2. Crawl density is clearly low compared to the surrounding area in the South Beach Park area. The renourished area begins just north of the Zone F marker (yellow/red star) and continues south to the Boca Raton Inlet. The south end of Zone E is primarily outside the renourished area. See the figure legend for an explanation of the symbols.

FIGURE 2- Arc**GIS 9.0 Map of South Beach Park and Surrounding Areas.** Sea turtle activity is represented by the following symbology: red= false crawl; green= nest; triangle= Loggerhead crawl; cross= Green crawl; yellow/red star= Zone marker. Using this technology, the reduced crawl density in South Beach Park is clearly visible whereas crawl density outside this area is higher. Tall condominiums are present in Zone G and high dunes are present in Red Reef Park.

Figure 3 shows the crawl density for all species by zone in the 2003-2004 nesting seasons. Even though 2004 was a record low nesting year, the pattern of densities is similar each year except for Zone F (South Beach Park). The density in 2003 is almost identical to the 10-year average for Zone F (0.074 crawls/ft) whereas in 2004 the density is nearly 4 times less (0.02 crawls/ft). In 2004 Zone E had a crawl density of 0.045 crawls/ft, which is twice the density in an area that was not renourished. When the zone is broken down into South Beach Park (E South) and Red Reef Park (E North) (Figure 4) it can be seen that E South has a similar crawl density as Zone F (0.026 c/ft) whereas E North has nearly three times more crawls (0.074 c/ft). The dune line in Red Reef Park is higher and more uneven than that of South Beach Park. In 2003 there is little difference in the crawl densities of Zone E (Figure 4).

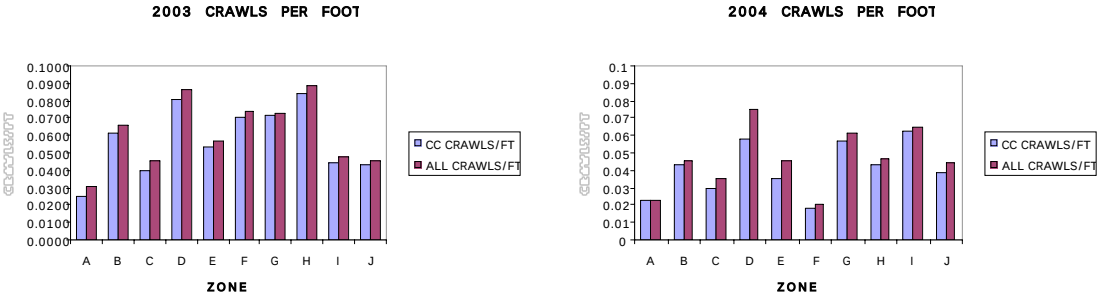


FIGURE 3- Crawl Densities by Zone in 2003 and 2004. A) Crawl densities for Loggerhead (CC) and all species combined for 2003. B) Crawl densities for Loggerhead and all species combined for 2004. The quantity for each zone is similar in each year except for Zone F (South Beach Park). For all species, Zone F has a ten-year average crawl density of 0.074 crawls/ft.

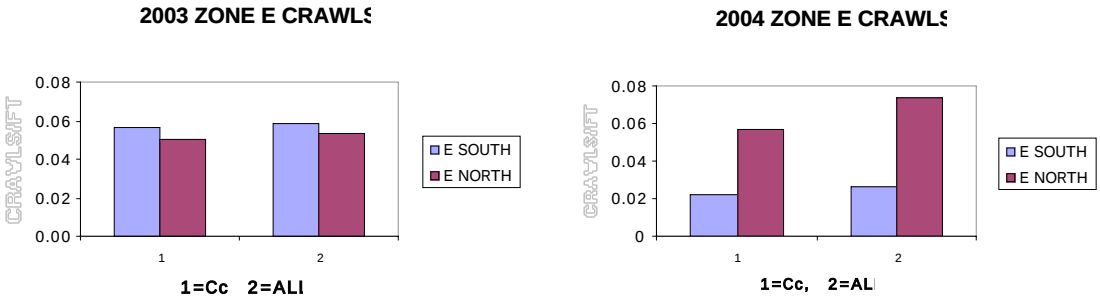


FIGURE 4- Crawl densities in Zone E (Separating South Beach Park from Red Reef Park). A) Crawl densities in Zone E, 2003. B) Crawl densities in Zone E, 2004. Zone E contains both Red Reef and South Beach Parks. The use of GIS allows the nesting activity in these two areas to be accurately quantified. In 2003, crawl densities are nearly equal in both areas of Zone E. In 2004, crawl densities differ significantly with the southern portion of Zone E (South Beach Park) showing a crawl density similar to Zone F. Zone E was not involved in the renourishment project of 2004.

Figure 5 is a satellite view of Florida at night showing a slightly dimmer Boca Raton.

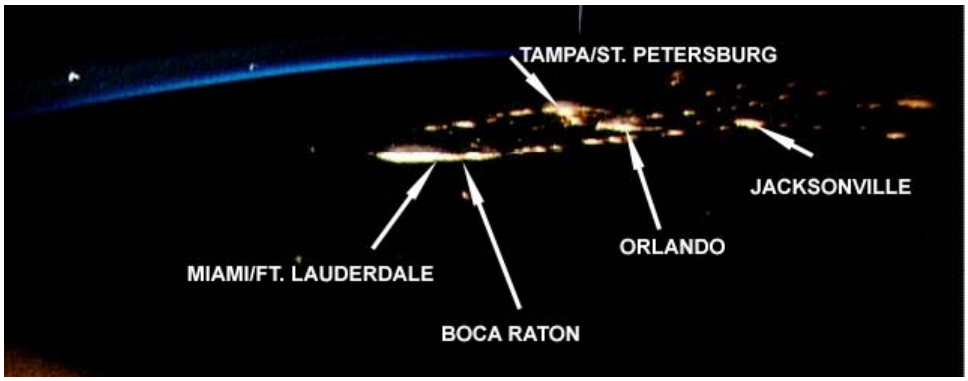


FIGURE 5- Satellite Photograph of Florida at Night. Even at this oblique angle, cities in Florida are clearly visible. Because Boca Raton has codes restricting light encroachment on neighboring structures and "up-lights" the amount of glow the City contributes to the atmosphere is apparently less than other municipalities. Boca Raton is somewhat dimmer in this photograph with a brighter West Palm Beach north of Boca. Photograph courtesy International Dark Sky Association.

After the raw data had been collected, projected, and brought into an ArcMap session, the patterns of turtle nesting began to appear. Traditional statistic performed by Dr. Rusenko provided further evidence of the effects of the city glow on the turtle nesting habits. When the raw data was manipulated by Spatial Analyst 9.0 (ESRI, Inc.) those statistical patterns presented themselves geographically. In the first set of density maps there are clear "hot spots" and "cold spots" of turtle nesting relative to the locations of taller dunes and condo buildings. (Figure 6) .

Figure 6 – 2004 Turtle Crawl Densities Zone C low density indicated an over cropped patch of Sea Grape trees while high densities are exhibited at the Spanish River & Red Reef Parks and South of the Boca Raton Inlet.

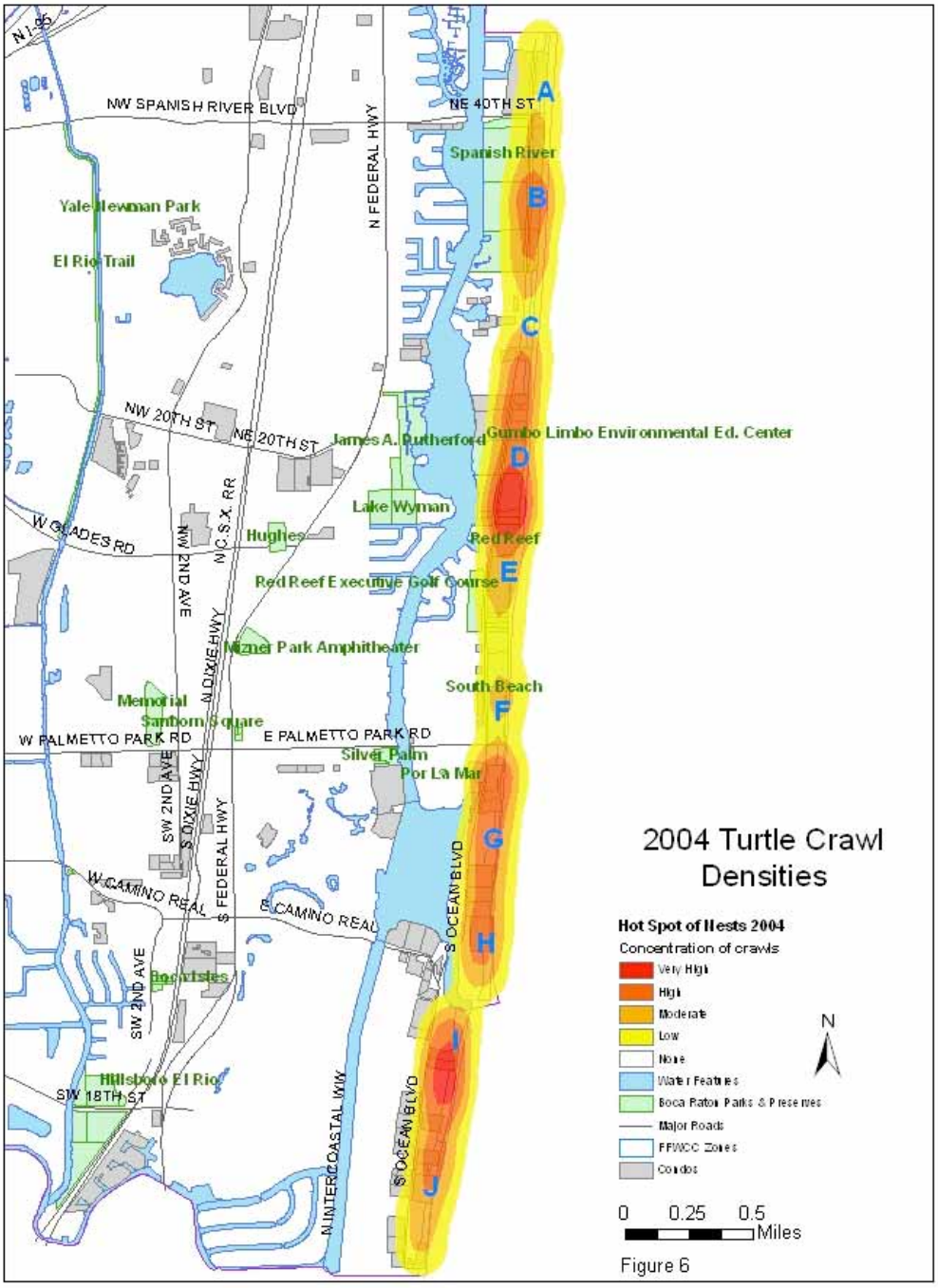


Figure 7 – 2004 Turtle Crawl Densities – Zones E & F South Beach Park & the Golf course show low nesting. The orange patch in Zone F represents the location of a tall stand of Australian Pines Trees.

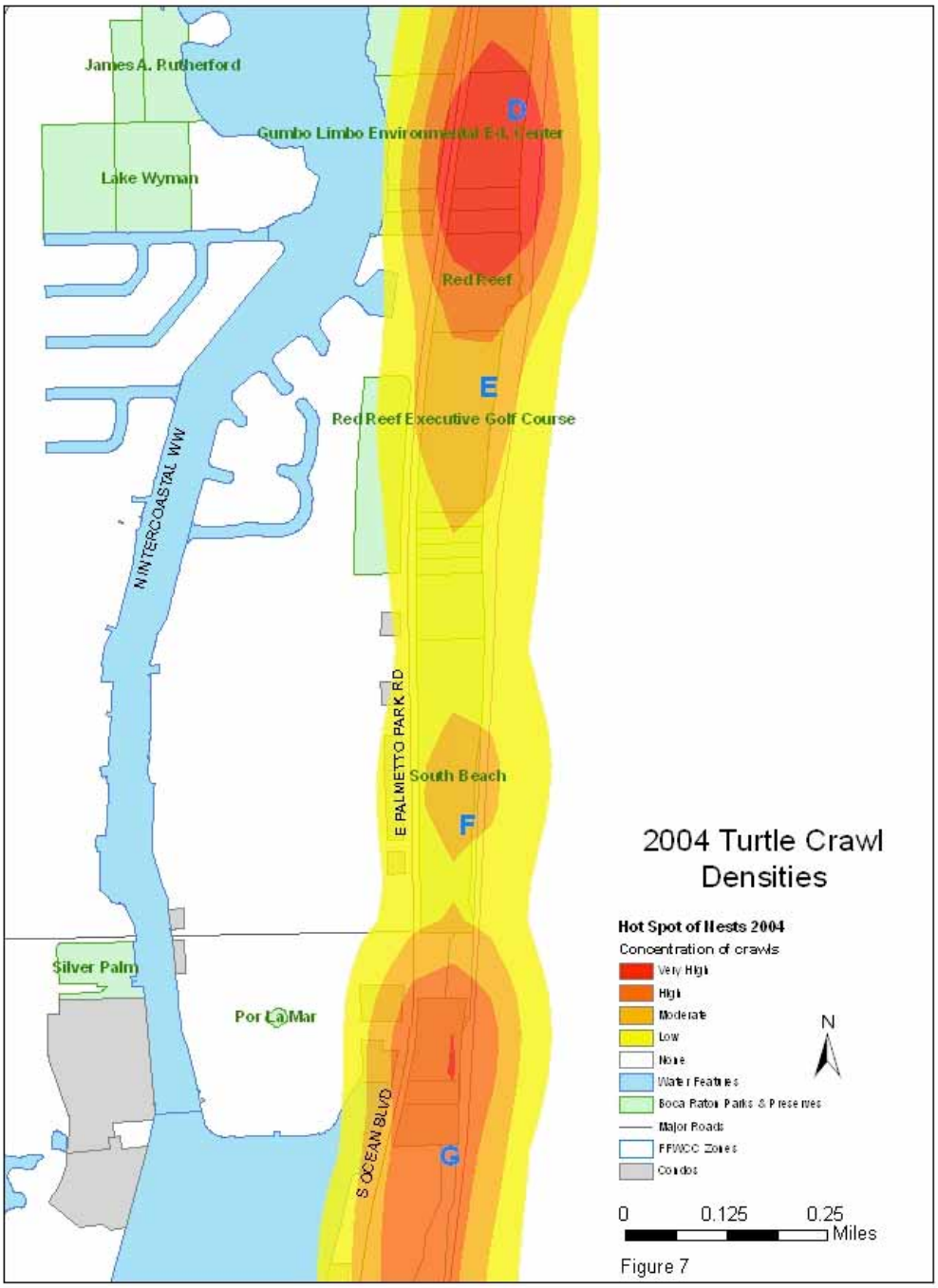
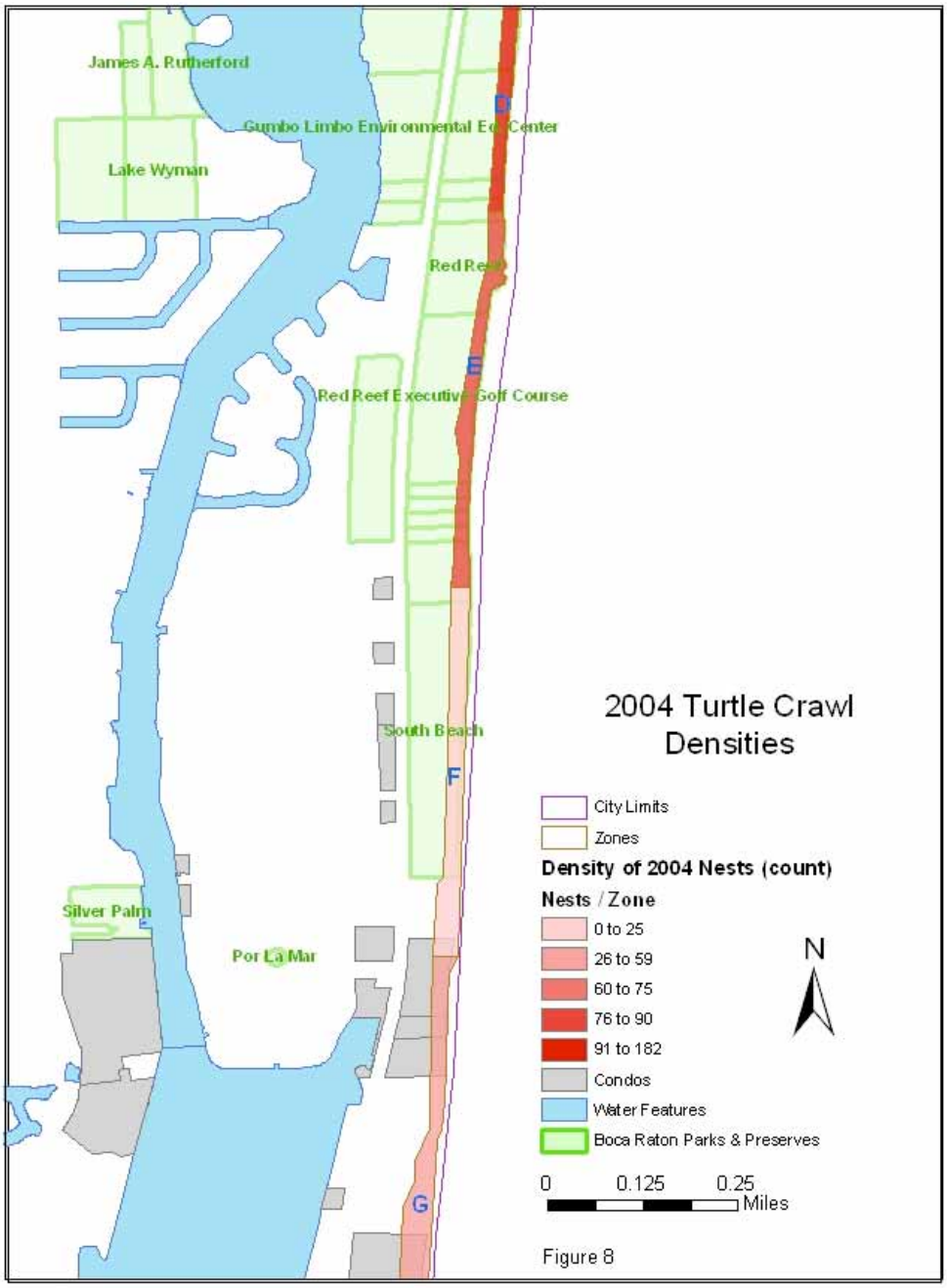


Figure 8 – 2004 Turtle Crawl Choropleth Density Map FFWCC Zones D – G



DISCUSSION

In the past, light from city glow has been responsible for hatchling disorientations on rainy nights when the clouds are low and reflect the glow onto the beach. In 2004 city glow was reported to be involved with 42 of 56 hatchling disorientation events (nests) whereas 2003 reported sky glow in 24 of 54 reports. Significantly, in 2004, there were 10 hatchling disorientation reports in City parks, including for the first time, disorientations reported in Red Reef Park on rainless nights. The loss of nesting activity in South Beach Park is likely due to its lower dune capped with seagrapes resulting in what may appear to be a bright horizon to a near-sighted female at the water's edge. Salmon *et al.*, 1995 report silhouette cues such as condominiums and tall trees are important factors in nest site selection. Red Reef Park has a very high dune (10-14 m) capped with Australian Pines and Spanish River Park has a dense stand of Australian Pines throughout the park.

Renourishment generally causes increased false crawl to nest ratios, which is why total crawls were reported. Zones G, and H an area of condominiums just south of South Beach Park had similar numbers of crawls before renourishment as it did after but there were fewer nests following renourishment. Renourishment is not responsible for the loss of activity in South Beach Park.

Boca Raton has stricter lighting guidelines than most municipalities, which is why nighttime photos of Florida show Boca as visibly dimmer (Figure 5). In order to preserve nesting in urban areas it may be necessary to move beyond the beach and enact a citywide ordinance to reduce sky glow. A Model Ordinance to reduce city glow is available on the International Dark Sky Association' website (www.darksky.org).

Before mobile GIS was available, such nesting patterns were difficult to visualize in real time because the locations were referenced to half-mile zones, condominiums, and lifeguard towers. These locations were accurate to no more than 200 feet while mobile GIS reduced this accuracy by almost an order of magnitude (20 feet or less). Because the GIS data contains detailed information about the sea turtle nests and false crawls, more intricate wildlife management plans can be applied in real time as the GIS data is reviewed daily. Before GIS data such as the number of hatchlings that emerged from the nest, the number of infertile eggs, and whether the nest was disoriented by lights or was predated by raccoons was reviewed at the end of the nesting season, which offered no protection for the season in which data was collected.

REFERENCES

Adamany, S. L., M. Salmon, and B. Witherington (1997) "Behavior of Sea Turtles at an Urban Beach. III. Costs and Benefits of Nest Caging as a Management Strategy" *Florida Scientist* 60:239-253

Salmon, M., R. Reiners, C. Lavin, and J. Wyneken (1995) "Behavior of Loggerhead Sea Turtles on an Urban Beach. I. Correlates of Nest Placement. *J. Herpetology* 29:560-567

AUTHOR INFORMATION

1 City of Boca Raton, Gumbo Limbo Nature Center, 1801 N. Ocean Blvd., Boca Raton, FL 33432
2 City of Boca Raton, GIS Services, 201 W. Palmetto Park Rd., Boca Raton, FL 33432
3 Xpedition Geo Services,