DOES BEACH NOURISHMENT AFFECT THE DISTRIBUTION OF SEA TURTLES:

THE SECOND POST-CONSTRUCTION ASSESSMENT OF JUVENILE GREEN TURTLES (*Chelonia mydas*) ON THE NEARSHORE REEFS OF BROWARD COUNTY, FL.

Christopher Makowski[1], Lou Fisher[2], & Craig J. Kruempel[3]

[1]Sr. Marine Biologist
Coastal Planning & Engineering, Inc.
Marine Science & Biological Research Department
2481 NW Boca Raton Blvd
Boca Raton, Florida, 33431

[2]Natural Resource Specialist III
Broward County Environmental Protection Department
1 N University Drive, Suite 301
Plantation, Florida, 33324

[3]Vice President
Coastal Planning & Engineering, Inc.
Marine Science & Biological Research Department
2481 NW Boca Raton Blvd
Boca Raton, Florida, 33431

Abstract

This study's objective was to provide the first surveying record of juvenile green turtle population density along the nearshore reefs of Broward County, Florida, after construction of the Broward County Shore Protection Program. The 'Shark Fishing' surveying technique is an effective, turtle-friendly approach for estimating juvenile green turtle populations over nearshore hardbottom habitats in Southeast Florida. The data obtained during our late spring/early summer surveys is timed to record observations and density estimates during that period of the year when juvenile green turtles establish strict home ranges (Mendonca, 1983; Wershoven and Wershoven, 1988; Makowski *et al.*, 2006). This hypothesis is supported by the similarity in the number of turtles observed during both the 2007 northward (43 observed turtles) and southward (37 observed turtles) directed efforts.

Previous sea turtle surveys recorded comparable results with annual variations. In 2003, the two directional surveys yielded an identical number of sightings (north to south, n = 48 turtles; south to north, n = 48 turtles) over Segment II and Segment III. In 2004, the two directional surveys yielded a similar number of sightings with decreased totals from the previous year (north to south, n = 35 turtles; south to north, n = 42 turtles). Surveys taking place at the same study site in 2005 again recorded a similar number of turtle sightings, however, with increased totals from the previous year (north to south, n = 57 turtles; south to north, n = 60 turtles) (Makowski *et al*., 2006). Last year, the 2006 surveys recorded a slight decrease in turtle sightings, which was determined to be a non- significant variation in the juvenile population that had occurred during pre-construction and post-construction events (ANOVA, df = 15, $P = 0.56$). Likewise, the 2007 turtle observations matched the estimated abundance totals from the previous year (Table 1), supporting the hypothesis that a stable population of juvenile green turtles resides along Broward County's nearshore reefs in the Summer months.

Within the Shore Protection Project area of Segment III, turtles were found to have no significant change in population abundance two years after construction (ANOVA; df = 9, $P = 0.84$). An average of one turtle was seen either swimming along the bottom, resting on the bottom, or breathing at the surface approximately every 1.2 km. The Segment II control site also found no significant change in turtle abundance after completion of the Shore Protection Project (ANOVA; df = 9, $P = 0.46$). An average of one turtle was seen either swimming along the bottom, resting on the bottom, or breathing at the surface approximately every 0.45 km. In-water surveys of adjacent nearshore reefs have revealed that no significant change in the juvenile green turtle population has occurred before, during, and after beach renourishment construction of the Broward County Shore Protection Project.

Introduction

Green turtle (*Chelonia mydas*) hatchlings migrate offshore and spend 3-5 years as pelagic stage juveniles, feeding and growing in the open ocean. They then return to shallow coastal waters as sexually immature "dinner-plate" sized (<65 cm SCL) turtles (Musick and Limpus, 1997). As juvenile green turtles aggregate along the southeastern coast of Florida, they gradually complete a dietary shift from omnivory to herbivory, feeding upon macroalgae and seagrass in the nearshore (Limpus and Walter, 1980; Limpus *et al.*, 1994). Recent studies have shown that juvenile greens exhibit home ranging behavior and foraging site fidelity, as they may be observed at any one site on a daily basis, and when displaced, return to the same site (Bresette *et al.*, 1998; Seminoff *et al.*, 2002; Makowski *et al.*, 2006). This feature of their ecological behavior suggests, at any one time and place, systematic observations will provide an accurate estimate of overall population size and its variation within a local region.

Conservation efforts, such as the Florida SNBS (Statewide Nesting Beach Survey) and INBS (Index Nesting Beach Survey) programs, have been focused towards nesting females and hatchling success (NMFS and USFWS, 1991), however, little has been done to assess nearshore juvenile green turtle populations. Until recently, there have been no systematic or quantitative studies available to determine turtle abundance along any of the South Florida nearshore reef habitats. Makowski *et al.* (2005) describes the 'Shark Fishing' survey technique that can estimate the abundance and distribution of juvenile green turtles in shallow water developmental habitats. 'Shark Fishing' surveys aid in identifying juvenile turtles and their preferred range so conservation managers can take appropriate steps to protect endangered populations (Makowski *et al*., 2006).

In 2005/06, under Florida Department of Environmental Protection Permit No. 0163435-001-JC, the Broward County Shore Protection Project was conducted between Port Everglades and the Broward/Miami-Dade County line (Segment III). The project fill area was approximately 10.97 km in length and provided beach renourishment for the majority of the Segment III shoreline including John U. Lloyd State Park, Dania Beach, and Hollywood/Hallandale shorelines. The estimated sand fill volume for Segment III was approximately 1.92 million cubic yards of sand.

In response to specific conditions in the above referenced FDEP permit issued for the Broward County Shore Protection Project, the Broward County Environmental Protection Department (EPD) contracted Coastal Planning & Engineering, Inc. (CPE) to document the abundance of juvenile green sea turtles during the pre- and post-construction phase. CPE was also tasked with developing and updating a geographic information system (GIS) database of sea turtle sightings along the County's nearshore reef tracts. In this study, CPE applied the 'Shark Fishing' technique to obtain the second post-construction record of juvenile green turtle populations along shallow (≤ 10 m deep) reef habitats in Central and Southern Broward County, Florida (Eastern Atlantic coast, USA).

Juvenile population records incorporated into the Broward County's Sea Turtle GIS will assist conservation managers by providing data on turtle presence over specific hardbottom resources, and whether these juvenile populations are static or fluctuating on an annual basis. The annually updated GIS may allow Broward County to assess effects that beach renourishment activities

have on resident sea turtle populations, and to determine if these effects cause either temporary fluctuations or long-term variation in the population dynamic. With such knowledge, managers will be better positioned to protect specific hardbottom resources, and the juvenile sea turtles that depend upon them during this stage of their development.

Methods

Study Area

The Broward County shoreline is subdivided into three Segments (I, II, and III), for the purposes of the County's shore protection management program (Figure 1). Only Segments II and III are surveyed for juvenile sea turtle populations under this contract. Segment II is 18.3 km in length, and extends from Hillsboro Inlet to Port Everglades Inlet. Segment III is 13.3 km in length, and extends from Port Everglades Inlet to the Broward County/Miami Dade County Line. Surveys were conducted over nearshore hardbottom resources in shallow (≤ 10 m) coastal waters from June 19-22, 2007. Previous (pre-construction) investigations were conducted in May and June 2003, from July 6-9, 2004, and from April 25-28, 2005; last year's post-construction survey was carried out on June 15, 16, and 26, 2006.

Survey Procedures

The 'Shark Fishing' technique consists of a towed diver survey method that documents the abundance and distribution of sea turtle populations with no handling and minimal disturbance of individual turtles (Makowski *et al.*, 2005) (Figure 2). Single transects were located and plotted over the nearshore reef habitat, parallel to shore and adjacent to the Segment III beach construction area, and Segment II project control area located north of Port Everglades.

Following along the transect, surveys were performed once in a north bound direction and once in a south bound direction, and always on different days. Two in-water observers were towed approximately 10 m behind a slowly moving (1.5-2.0 knots) research vessel. The in-water observers visually scanned the area directly below and to the left (port observer), and directly below and to the right (starboard observer), to the limit of underwater visibility (typically, ≤ 15 m to each side). Towed divers reported turtle sightings to on-vessel personnel, who then took a locational fix for that site. After being located, the turtles usually swam in a perpendicular direction away from the boat, decreasing the chances of being recounted. In addition, onboard observers recorded the positions of surfacing turtles. During all surveys, turtles are never touched or put at risk.

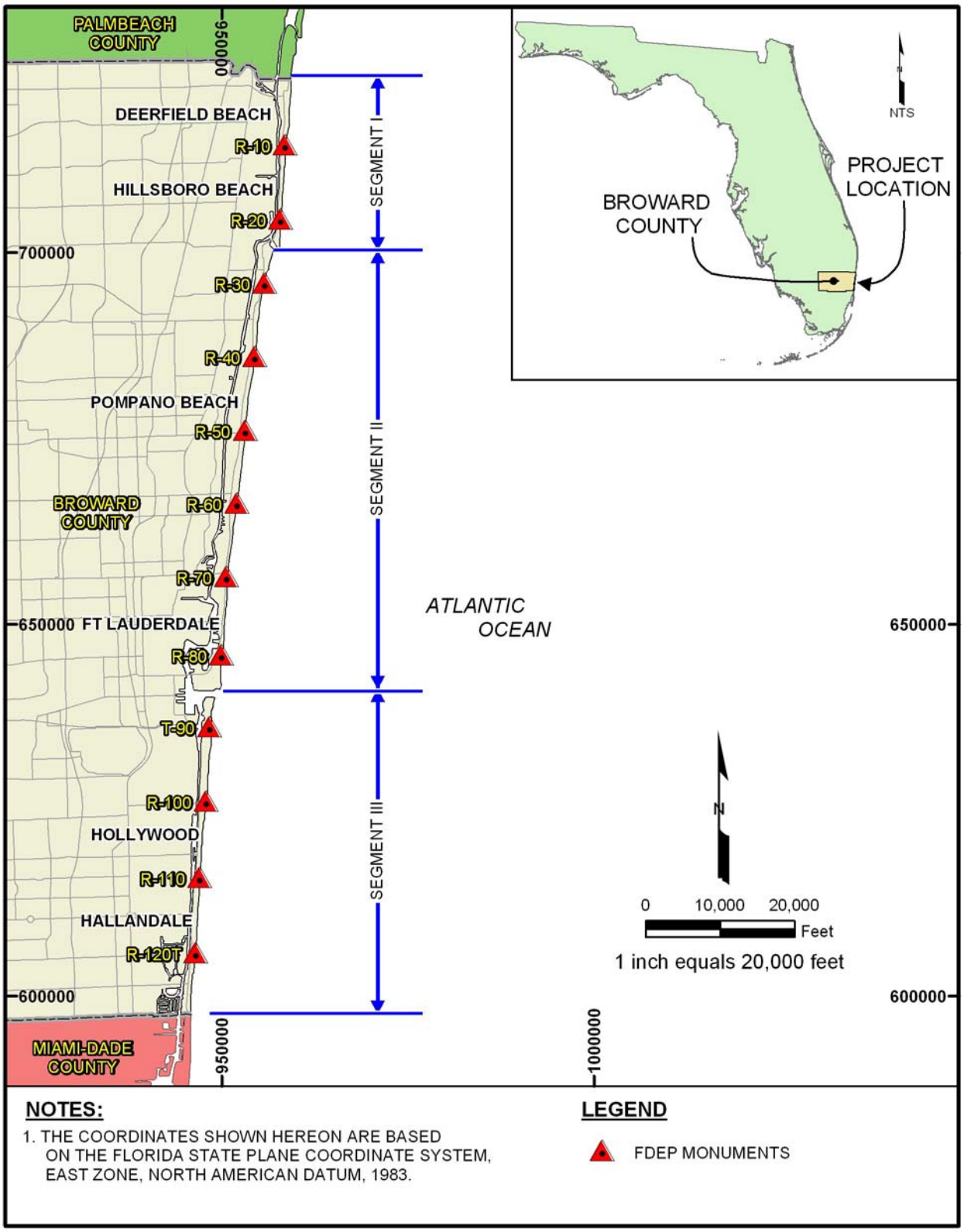

Figure 1. The Broward County Shoreline.

Figure 2. View from the stern of the research vessel showing the 'Shark Fishing' surveying technique. The circles mark where the 'in-water' observers are towed 10 m behind the vessel.

GIS & Statistical Analyses

The Broward County Sea Turtle GIS, a spatially-controlled interface, was developed to provide a platform for recorded turtle positional data. Turtle sightings were recorded on a lap-top computer that was simultaneously linked to satellites with a Trimble Differential Global Positioning System (DGPS) beacon. HYPACK® MAX software, a PC-based Windows software for planning, conducting, editing, and publishing hydrographic surveys, stored each turtle's positional data, as well as the date and time of the observation. An 'offset fish' mode allowed HYPACK® MAX to store the turtle's locational fix in relation to the in-water observers' position, which was 10 m behind the moving vessel. Other data (e.g., weather conditions, underwater visibility, activity of turtle) were added later to the GIS during data reduction and processed as descriptive identifications for each turtle sighting. All turtle sightings were then plotted on nearshore laser airborne depth sounder (LADS) contour maps, using ArcView version 9.2 GIS software.

Single-factor ANOVAs were conducted to determine if the quantity of turtle observations had significantly varied within Segments II and III during pre-construction and post-construction monitoring events. In addition, a single-factor ANOVA was performed to determine if the overall abundance of turtle sightings in Broward County had significantly changed after construction of the Broward Shore Protection Project. Analyses were conducted with SPSS software, with significance based on $P \leq 0.01$.

Results

Based on external morphological appearance, observers identified all of the sea turtles sighted during the survey as juvenile green turtles (*Chelonia mydas* L); no other species, or size class, of sea turtles were observed during this investigation.

The two surveys yielded a similar number of sightings (north to south, n = 37 turtles; south to north, n = 43 turtles) over the nearshore hardbottom habitats of Central and Southern Broward County (Figure 3). The estimated density of turtles, based upon the length of survey area (31.6 km for both Segment II and III), totaled one turtle observation every 0.79 km. Turtles were observed as either resting on the bottom, swimming slowly over the reef, or breathing at the surface. None of the observed turtles appeared distressed by researcher presence; rather, they usually departed by slow, yet deliberate swimming, in a direction perpendicular to the boat's heading (transect vector).

During the north to south survey, most (26 out of 37, or 70%) juveniles green turtles were sighted within Segment II (Hillsboro Inlet to Port Everglades Inlet). The remaining 11 turtles (30%) were observed within Segment III (Port Everglades Inlet to Broward County/Miami-Dade County Line). During the south to north survey, the majority of juvenile turtles (31 out of 43, or 72%) were sighted within Segment II, while the remaining 12 turtles (28%) were observed within Segment III.

Statistical analyses showed that the overall turtle abundance along Broward County has not significantly differed during pre-construction and post-construction events (ANOVA; df = 19, P = 0.65). Specifically within the construction area of Segment III, turtle abundance did not significantly decrease after completion of the Broward County Shore Protection Project (ANOVA; df = 9, P = 0.84). Similarly, no significant variation in the turtle population was detected within the control area of Segment II post-construction (ANOVA; df = 9, P = 0.46). Mean summaries from all surveying years are provided in Table 1.

ANOVA- Segment II

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22.5	1	22.5	0.589005	0.46485	5.317655
Within Groups	305.6	8	38.2			
Total	328.1	9				

ANOVA- Segment III

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.4	1	0.4	0.041451	0.843754	5.317655
Within Groups	77.2	8	9.65			
Total	77.6	9				

All turtle sightings were incorporated into an ArcView 9.2 GIS template and archived into the Broward County Sea Turtle GIS (Figure 3). The GIS database allows a user to access information on any specific juvenile turtle sighting. Accurate Florida State Plane Coordinate (East Zone, NAD 83) locations and descriptive information for each observation (Figure 4) are available in the database for each of the surveys conducted by the CPE team.

Table 1. Results from all surveying years. Numbers listed under "Segments" are turtle sightings during the north to south (N-S) and south to north (S-N) surveys, and their actual mean. The two mean values, added together, yield an "estimated abundance" for the turtles in both Segments during the survey year.

Survey Year	Segment II N-S	Segment II S-N	Segment II **Mean**	Segment III N-S	Segment III S-N	Segment III **Mean**	**Estimated Abundance**
2003	34	32	**33**	14	16	**15**	**48**
2004	22	27	**25**	13	15	**14**	**39**
2005	38	43	**41**	19	17	**18**	**59**
2006	29	31	**30**	11	10	**11**	**41**
2007	26	31	**29**	11	12	**12**	**41**
	Column Totals:		**158**			**70**	**228**

A CD (included in this report) contains the following additional information:

- time and date of observation
- geographic position of each sea turtle observation in the water column
- sea state and underwater visibility
- activity of turtle
- previous pre- and post-construction survey results (2003 - 2006)

Discussion and Conclusions

This study's objective was to provide a second post-construction record of juvenile green turtle population density along the nearshore reefs of Broward County, Florida, after completion of the Broward County Shore Protection Project. The 'Shark Fishing' surveying technique is an effective, turtle-friendly approach for estimating turtle populations over nearshore hardbottom habitats in Southeast Florida. The data obtained during the late spring/early summer surveys is timed to record observations and density estimates during that period of the year when juvenile marine turtles establish strict home ranges (Mendonca, 1983; Wershoven and Wershoven, 1988; Makowski *et al.*, 2006). This hypothesis is supported by the similarity in the number of turtles observed during both the 2007 northward (43 observed turtles) and southward (37 observed turtles) directed efforts.

Previous sea turtle surveys documented comparable results with annual variations. In 2003, the two directional surveys yielded an identical number of sightings (north to south, n = 48 turtles; south to north, n = 48 turtles) over Segments II and III. In 2004, the two directional surveys yielded a similar number of sightings with decreased totals from the previous year (north to south, n = 35 turtles; south to north, n = 42 turtles). Surveys taking place at the same study site in 2005 again recorded a similar number of turtle sightings, however, with increased totals from the previous year (north to south, n = 57 turtles; south to north, n = 60 turtles) (Makowski *et al*., 2006). Last year, the 2006 surveys recorded a slight decrease in turtle sightings, which was determined to be a non-significant variation in the population that had occurred during pre-construction and post-construction events (ANOVA, df = 15, $P = 0.56$). Likewise, the 2007 turtle observations matched the estimated abundance totals from the previous year (Table 1), supporting the hypothesis that a stable population of juvenile green turtles resides along Broward County's nearshore reefs in the summer months.

Other studies (Bjorndal *et al.*, 2005; Makowski *et al.*, 2005) have also shown natural annual fluctuations in the nearshore aggregation of juvenile green turtle populations. Bjorndal *et al*. (2005) found that juvenile green turtle populations at Conception Creek and Union Creek, Great Inagua, Bahamas, had successive phases of increase, decrease, and stability. These annual changes were attributed to changes in immigration of juveniles, suggesting that migratory tendencies of immature greens lead to different aggregation patterns (Bjorndal *et al*., 2003; Bjorndal *et al*., 2005). Similarly, Makowski *et al.* (2005) reported the results from a 'Shark Fishing' survey over two consecutive summers along the nearshore reefs of Palm Beach County, Florida. During the summer of 2001, 62 juvenile green turtles were observed along an approximately 12 km length of reef habitat located in Central Palm Beach County adjacent to the Town of Palm Beach shoreline. A 2002 survey of these same Palm Beach County reefs resulted in higher (n = 79) observed turtle densities, with no sea turtles seen over sandy bottoms of equal depth. One possible reason for these changes in juvenile population abundance would be to allow for the benthic vegetation (i.e., macroalgae and seagrasses) to proliferate in the wake of heavy cropping from the past year (Goldberg, 1973).

Within the Broward County Shore Protection Project area of Segment III, turtles were found to have no significant change in population abundance two years after beach construction (ANOVA; df = 9, $P = 0.84$). An average of one turtle was seen either swimming along the

bottom, resting on the bottom, or at the surface approximately every 1.2 km. The Segment II control site also found no significant change in turtle abundance after completion of the Segment III Shore Protection Project (ANOVA; df = 9, $P = 0.46$). An average of one turtle was observed either swimming along the bottom, resting on the bottom, or at the surface approximately every 0.45 km.

For the past five years, juvenile green turtle estimates have been recorded within the nearshore waters of Broward County. These waters have been shown to be a habitat for the development of immature green turtles, and the monitoring of their population estimates allows County officials to better regulate for the protection of this endangered species (Wershoven and Wershoven, 1988). In conclusion, surveys of Broward County's nearshore reefs have revealed that no significant change in the juvenile green turtle population has occurred after beach renourishment construction of the Broward County Shore Protection Project.

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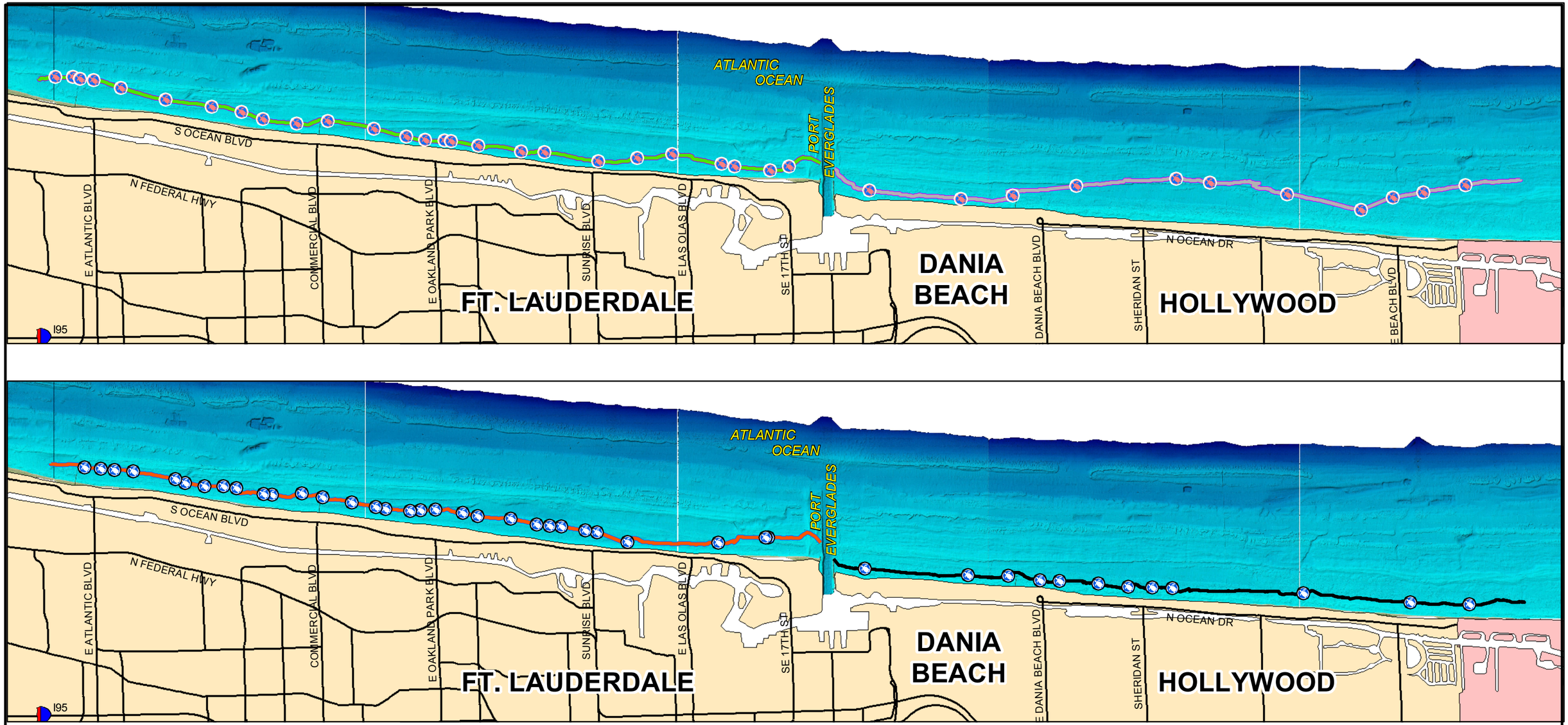


NOTES

1. SEGMENT II (NORTH OF PORT EVERGLADES) AND SEGMENT III (SOUTH OF PORT EVERGLADES) OF BROWARD COUNTY, SHOWING VESSEL TRANSECT PATH AND EACH TURTLE SIGHTING (FILLED CIRCLE).
2. SURVEY DATE: JUNE 19 - 22, 2007.
3. NORTH TO SOUTH SURVEY, TOP OF SHEET.
4. SOUTH TO NORTH SURVEY, BOTTOM OF SHEET.

LEGEND

2007 TURTLE SIGHTINGS

- DIRECTION NORTH TO SOUTH
- DIRECTION SOUTH TO NORTH

2007 VESSEL TRANSECTS

- SEGMENT II NORTH TO SOUTH
- SEGMENT III NORTH TO SOUTH
- SEGMENT II SOUTH TO NORTH
- SEGMENT III SOUTH TO NORTH

N

0 1,000 2,000 3,000 Meters

1 centimeter equals 800 meters

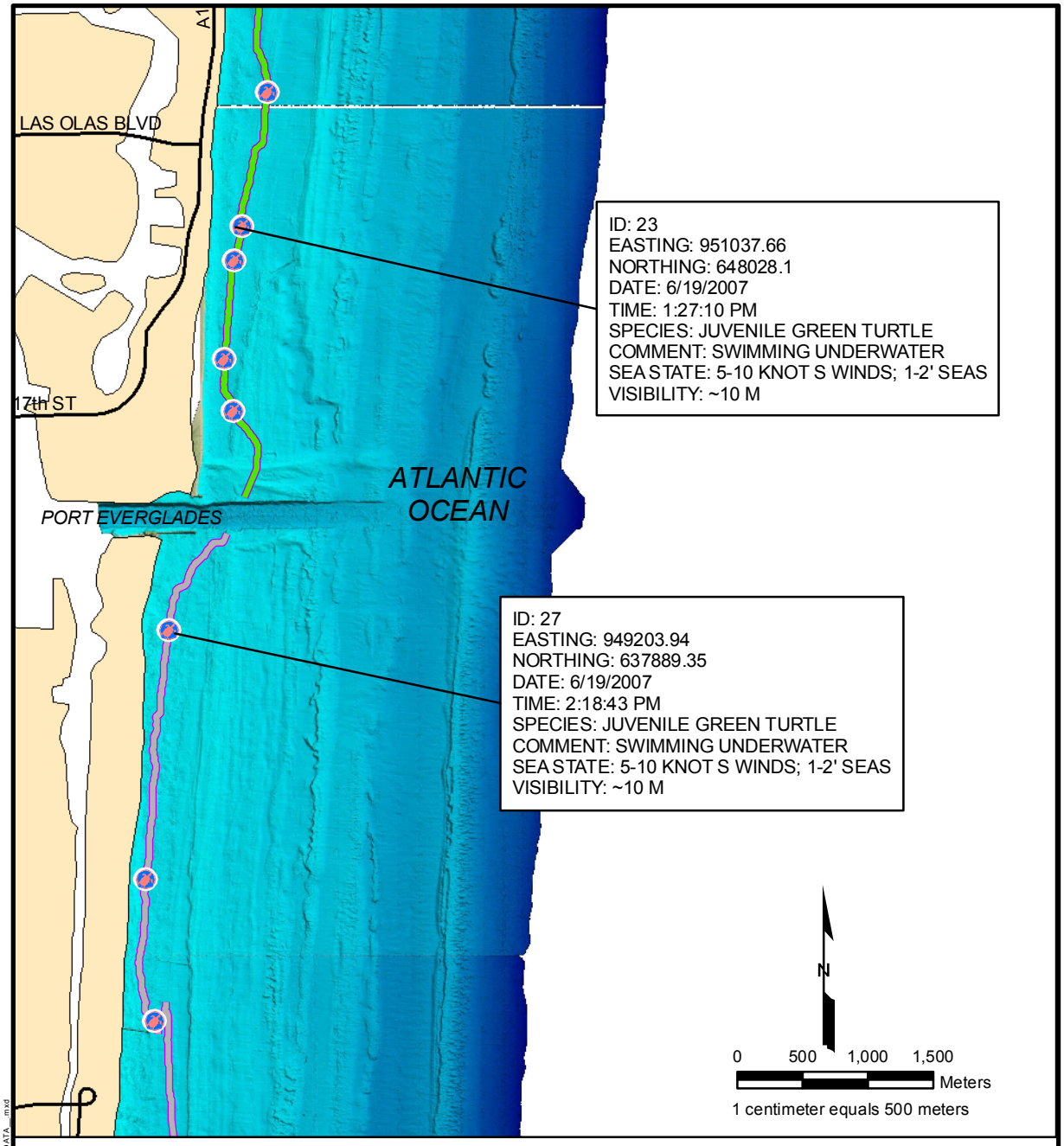
TITLE:

BROWARD COUNTY, FLORIDA
2007 SEA TURTLE SURVEY
SEGMENTS II & III

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BLVD.
BOCA RATON, FL 33431
PH.(561)391-8102
FAX. (561)391-9116

DATE: 07/31/07	BY: DNR	COMM NO: 5353.24	FIGURE 3

G:\Broward\d535011_2009_SEA_TURTLE_SURVEY_MXD\2006_BROWARD_TURTLE_11x17_081406.mxd



NOTES

1. INFORMATION STORED FOR EACH TURTLE ON ENCLOSED CD.
2. THIS MAP SHOWS THE PARTICULARS FOR 2 OF 40 TURTLE SIGHTINGS, DURING THE NORTH TO SOUTH SURVEY.
3. SURVEY DATE: JUNE 19 - 22, 2007

LEGEND

2007 SEA TURTLE SIGHTINGS

2007 VESSEL TRANSECTS (N TO S)

2007 SEGMENT II NORTH TO SOUTH

2007 SEGMENT III NORTH TO SOUTH

COASTAL PLANNING & ENGINEERING, INC.

2481 N.W. BOCA RATON BLVD.
BOCA RATON, FL 33431
PH.(561)391-8102
FAX. (561)391-9116

TITLE:

BROWARD COUNTY, FLORIDA
2007 SEA TURTLE SURVEY
SURVEY POINT DATA

DATE: 08/21/07	BY: DNR	COMM NO: 5350.24	**FIGURE 4**

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