

Sea Turtles in Florida's Atlantic Waters

CAITLIN M. BOVERY and JEANETTE WYNEKEN

Introduction

Knowledge of a species' spatial and temporal movement patterns is essential to management and conservation strategies, especially for highly mobile wildlife species. This is particularly true for marine species that occupy multiple habitats throughout their lifetime. Each habitat can present dramatically different abiotic and biotic challenges (Balon, 1986; Crawford and Balon, 1994; Wainwright and Richard, 1995). Ontogenetic habitat shifts are particularly common in marine organisms and are widespread among a variety of vertebrates (Price and Grant, 1984; Fishelson et al., 1987; Lind and Welsh, 1994; Kitowski, 2003; Page et al., 2005). Marine turtles undergo multiple ontogenetic habitat shifts (Bolten, 2003b; McClellan and Read, 2007; Snover, 2008) as they migrate across ocean basins and along coastal zones (Dodd and Byles,

2003; Eckert et al., 2006; Foley et al., 2008; Girard et al., 2009). Various pelagic or benthic communities serve as temporary homes at different stages and within a single stage of their life cycle (Witzell, 2002; Bolten, 2003a; Polovina et al., 2006; Casale et al., 2008; Witherington et al., 2012). Documentation of where and when marine turtles move among habitats is scattered across both reviewed and gray literature. Consequently, such habitat shifts are poorly understood.

Although some species, such as the loggerhead, *Caretta caretta*, and green, *Chelonia mydas*, turtles may vary among populations and individuals in the details of their life history patterns (Hatase et al., 2006; McClellan and Read, 2007; Mansfield et al., 2009), all sea turtles begin life as terrestrial hatchlings. Hatchlings crawl to the sea, immediately transitioning to life in the marine environment as they swim offshore (Carr and Ogren, 1960). Some hatchlings and post-hatchling turtles then associate with flotsam, such as *Sargassum* communities and downwelling lines (Carr and Meylan, 1980; Witham, 1980; Carr,

1986; Coston-Clements et al., 1991; Witherington, 2002) in oceanic waters. They may remain in oceanic habitats for several years (Carr et al., 1966; Carr, 1987; Collard and Ogren, 1990; Musick and Limpus, 1997; Bjorndal et al., 2000b, 2003; Reich et al., 2007a).

After a variable amount of time in the epipelagic zone, many of these turtles return as juveniles and sub-adults (large juveniles) to nearshore waters and inhabit the neritic zone (Bjorndal et al., 2003), while others alternate between oceanic and neritic foraging grounds (Bolten, 2003a; McClellan and Read, 2007; Mansfield et al., 2009). Such habitat shifts reflect dietary shifts. However, the direction of the cause-effect relationship remains a point of discussion (Witzell, 2002; McClellan and Read, 2007; Casale et al., 2008).

As sea turtles approach maturity, they move to waters in closer proximity to nesting beaches (Bowen et al., 2005) and commence migratory breeding cycles every one to nine years depending on the species and ocean basin (Carr and Ogren, 1960; Miller, 1997). During nesting season, adult turtles temporarily reside in neritic waters along the continental shelf, just off nesting beaches (Stoneburner, 1982; Mortimer and Porter, 1989; TEWG, 2009). After depositing their last clutch of the season, adult females may migrate thousands of kilometers to foraging areas (Caldwell et al., 1959; Bell and Richardson, 1978; Meylan et al., 1983; Girard et al., 2009; Plotkin and Spotila, 2002).

All species of sea turtles in the western Atlantic Ocean occur in Florida's Atlantic waters (Caldwell and Carr, 1957), including loggerhead; green; leatherback, *Dermochelys coriacea*

The authors are with the Department of Biological Sciences, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431 (corresponding author email: cbovery@fau.edu).

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ABSTRACT—Management of marine turtles presents various challenges due to their highly migratory nature, which includes major ontogenetic habitat shifts, seasonal movements between feeding grounds, and migrations to and from breeding grounds. Further, sea turtle spatial distributions often differ in species-specific ways during similar temporal periods. Various approaches combine to give valuable insights into spatial and temporal distributions of sea turtles and provide critical knowledge for understanding and protecting these imperiled species. Here we summarize and synthesize available data that document sea turtle occurrences in waters from the Florida Straits

(lat. 24°28' N) north to the latitude of Jacksonville, Fla. (lat. 30°20' N), including waters up to 150 km offshore, termed Florida's Atlantic waters for this review. We summarize 951 satellite tracked sea turtles, 288 of which crossed into Florida's Atlantic waters. All species of sea turtles inhabiting the Atlantic Ocean were found to use Florida Atlantic waters. Sea turtles use Florida's Atlantic waters year-round, yet distributions of individual species vary seasonally. We provide a current synthesis describing the spatial and temporal distributions of the five sea turtles species using Florida's Atlantic waters and suggest areas where further study may be warranted.

cea; hawksbill, *Eretmochelys imbricata*; and Kemp's ridley, *Lepidochelys kempii*, turtles. Moreover, peninsular Florida supports one of the largest loggerhead rookeries in the world with an average of 65,460 nests from 1989 to 2006 (TEWG, 2009), constituting the majority (80%) of loggerhead nesting in the western Atlantic Ocean (Dodd, 1988; Ehrhart et al., 2003; TEWG, 2009). Florida's east coast beaches also support growing rookeries for green turtles (Witherington et al., 2006) and leatherbacks (TEWG, 2007; Stewart et al., 2011). Consequently, waters adjacent to Florida's east coast include increasing numbers of turtles during reproductive periods.

We summarize here available information describing sea turtle locations/distributions in Florida's Atlantic waters. We completed a thorough review

of available literature in the field and compiled a comprehensive assessment of sea turtles satellite tracked through these waters. With these assessments, we identified areas lacking data and suggest future directions for study of sea turtles in Florida's Atlantic waters.

Methods

Literature Identification and Review

We draw data from several major methodologies to summarize our understanding of sea turtle distributions and movements throughout Florida's Atlantic waters (Fig. 1). Information about sea turtle distributions throughout Florida's coastal waters comes from in-water studies employing a wide range of methodologies, including direct capture (Henwood, 1987; Bresette et al., 1998;

Ehrhart et al., 2007; Hawkes et al., 2007, 2011; Arendt et al., 2012a,b,c), satellite telemetry (Blumenthal et al., 2006; Girard et al., 2009; Mansfield et al., 2009; Arendt et al., 2012a,b,c; Ceriani et al., 2012), shipboard surveys (Bresette et al., 2010), aerial surveys (Fritts et al., 1983; Schroeder and Thompson, 1987; Epperly et al., 1995, 2002; McClellan, 1996; Witzell and Azarovitz, 1996; Henwood and Epperly, 1999; Goodman et al., 2007), stable isotopes (Reich et al., 2007a, b; Ceriani et al., 2012), and bycatch records (Thompson et al., 1991; Epperly et al., 2002). Mark-recapture via flipper or pit tagging provides start and end point data demarking some travels (Meylan, 1995; Schmid and Witzell, 1997; Witzell, 1998; Williams and Frick, 2008). The results of these and other studies indicate a widespread distribution of marine turtles in Florida's Atlantic waters.

Literature for this review was compiled using the following databases: Sea Turtle Online Bibliography (st.cits.fcla.edu/st.jsp), seaturtle.org document library (www.seaturtle.org/tracking), NOAA Southeast Fisheries Science Center Sea Turtle Publications (www.sefsc.noaa.gov/species/turtles/publications.htm), and Google Scholar. Search terms used to identify relevant literature included the scientific and common name of each turtle species found in Florida and combinations of the following: sea turtle, marine turtle, turtle, seaturtle, tracking, migration, swimming, distribution, satellite tracking, radio tracking, acoustic tracking, telemetry, tracking, Southern Gulf Stream, and Florida Current.

From the literature identified, publications were reviewed to determine if the turtles studied were present in Florida's Atlantic waters. Both gray and white literature was examined during the review process. Literature was excluded if positions of tracked turtles were not rigorously filtered or if interpretations extended beyond the scope of the data collected. Additionally, geographic constraints were applied limiting the literature incorporated to studies in which turtles were found in

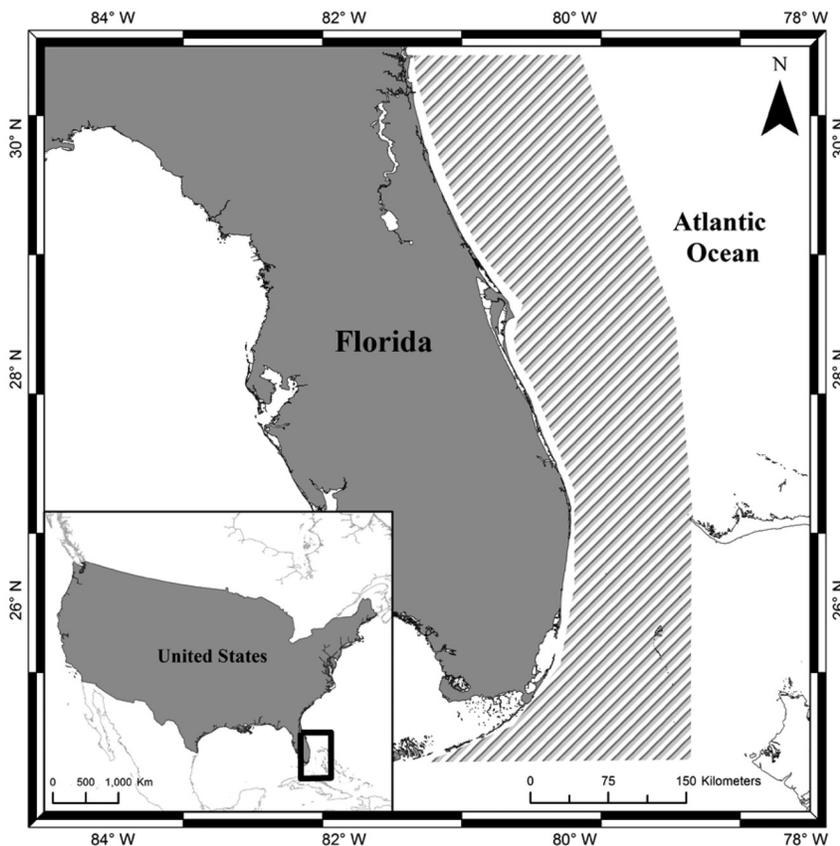


Figure 1.—Atlantic coast of Florida. Gray hatched area indicates the Florida's Atlantic waters included in this review, from the Florida Straits north to Jacksonville, Fla., including waters up to 150 km offshore.

the southern extent of the Gulf Stream, the Florida Current, nearshore waters along the southeast coast of Florida, or waters abutting the western Bahamas Banks. The study area that we used for the geographic limitation extended from lat. 30°20'N south to lat. 24°28'N and out to 150 km from the Florida coastline (Fig. 1). Where turtle locations were not tracks or direct sightings, for example mark-recapture (tag returns), we included only turtles whose locations could be interpolated in a realistic time frame. We cross-referenced publications to prevent the use of double-reported data.

Spatial Distribution Summarization

To complement our literature review, we compiled a summary of all available satellite telemetry studies that occurred within the spatial confines of our review. Archived and active

sea turtle tracking programs of study hosted by seaturtle.org and conserve-turtles.org were surveyed for turtles tracked through Florida's Atlantic waters. Visual and qualitative screening excluded erroneous sea turtle tracks. Once relevant tracks were identified, data owners were contacted to request permission to include sea turtle tracks in species-specific tabulations. We did not request permission to include track details. The unpublished studies were tabulated with relevant satellite tracking literature results to establish tallies of all available data documenting turtle species, as well as when and where they are present, throughout Florida's Atlantic waters.

Summary Metrics

When we identified turtles which used our study area, we tallied the (1) total number of sea turtles tracked by

those various research programs, (2) number tracked through Florida's Atlantic waters, and (3) calculated percentages of tracked turtles that used Florida's Atlantic waters. Additionally, we acquired maps representing aerial and vessel survey sightings of loggerhead turtles to illustrate the spatial distribution of the most common species found in Florida's Atlantic waters. Results were summarized and analyzed to identify data gaps in the understanding of sea turtles in Florida's Atlantic waters.

Results

Thirty-three sources of sea turtle satellite tracking data were identified for use in this study. A total of 951 sea turtles were tracked using satellite telemetry, including 578 loggerhead, 109 leatherback, 92 green, 159 Kemp's Ridley, and 13 hawksbill tur-

Table 1.—Summary of sea turtle satellite tracking programs that observed turtles within Florida's Atlantic waters.

Species	Total no. tracked			No. tracked in Florida's Atlantic waters			Percentage tracked in Florida's Atlantic waters			Citations
	Adult	Sub-adult	Juvenile	Adult	Sub-adult	Juvenile	Adult	Sub-adult	Juvenile	
Loggerhead	337	93	148	105	59	19	31.2%	63.4%	12.8%	1, 2, 4, 6, 7, 8, 9, 10, 12, 13, 16, 17, 21, 22, 23, 24, 25, 28, 31
Leatherback	109	0	0	48	0	0	44.0%	—*	—*	3, 11, 13, 14, 26
Green	31	44	17	3	31	9	9.7%	70.5%	52.9%	3, 5, 12, 15, 18, 22, 23, 24, 27
Kemp's Ridley	4	55	100	1	2	6	25.0%	3.6%	6.0%	18, 19, 20, 21, 23, 24, 25, 29, 30
Hawksbill	5	8	0	0	5	0	0.0%	62.5%	—*	12, 27, 32
Totals	486	200	265	157	97	34	32.3%	48.5%	12.8%	

*No turtles of this size class were tracked using satellite telemetry in Florida's Atlantic waters.

- ¹ Arendt et al., 2012b.
- ² Arendt et al., 2012c.
- ³ Bagley, D. A., Research Associate, University of Central Florida, Orlando, Fla. Personal commun., 2013.
- ⁴ Dodd and Byles, 2003.
- ⁵ Shaver, D. J., Chief, Division of Sea Turtle Science and Recovery, National Park Service, Padre Island National Seashore, Corpus Christi, Tex. Personal commun., 2012.
- ⁶ Foley et al., 2008.
- ⁷ Girard et al., 2009.
- ⁸ Gumbo Limbo Nature Center, Boca Raton, Fla.
- ⁹ Hawkes et al., 2007.
- ¹⁰ Hawkes et al., 2011.
- ¹¹ James et al., 2005.
- ¹² Hart, K. M., Research Ecologist, U.S. Geological Survey, Southeast Ecological Science Center, Davie, Fla. Personal commun., 2013.
- ¹³ Loggerhead Marinelifelife Center, Juno Beach, Fla., 2002–2011, unpubl. data.
- ¹⁴ Eckert et al., 2006.
- ¹⁵ Makowski et al., 2006.
- ¹⁶ McClellan and Read, 2007.
- ¹⁷ Phillips, 2011.
- ¹⁸ Read, A., B. Foster, C. McClellan, and D. Waples. 2004. Habitat use of sea turtles in relation to fisheries interactions. Final Rep. N.C. Sea Grant Fish. Resour. Grant Prog., 02–FEG–05, Raleigh, N.C., 121 p. (unpubl.).
- ¹⁹ Renaud and Williams, 2005.
- ²⁰ Renaud, 1995.
- ²¹ Sasso, C. R. Research fisheries biologist, NMFS SEFSC, Miami, Fla. Personal commun., 2013.
- ²² The Georgia Sea Turtle Center, Jekyll Island, Ga.
- ²³ Tucker 2012. www.mote.org/seaturtles.
- ²⁴ Virginia Aquarium and Marine Science Center, Virginia Beach, Va.
- ²⁵ Godfrey, M. H. Biologist, N.C. Wildl. Resour. Comm., Beaufort, N.C. Personal commun., 2013.
- ²⁶ Canadian Sea Turtle Network, Nova Scotia, Canada
- ²⁷ Richardson, P. Biodiversity programme manager, Mar. Conserv. Society, Ross on Wye, Hereford HR9 5NB, U.K. Personal commun., 2013.
- ²⁸ Ceriani et al., 2012
- ²⁹ Keinath, 1993
- ³⁰ Mansfield, 2006
- ³¹ Mansfield, 2009
- ³² Wood, L. Biologist, Palm Beach Zoo, West Palm Beach, Fla. Personal commun., 2013.

tles (Table 1). Of those turtles tracked by data contributors, a total of 299 sea turtles were observed in Florida's Atlantic waters in the duration of their track, including 183 loggerhead, 48 leatherback, 43 green, 9 Kemp's ridley, and 5 hawksbill turtles (Table 1). Percentage of the sea turtles tracked that crossed into Florida's Atlantic waters is summarized in Table 1. The seasonal changes in loggerhead movements are illustrated in Figure 2 to supplement the satellite tracking information and review of loggerhead presence in Florida's Atlantic waters.

The literature review identified a variety of habitats along Florida's Atlantic coast that host sea turtles. Drifting *Sargassum* communities support early stages of loggerhead, green, hawksbill, and Kemp's ridley sea turtles. Neritic zones of Florida's Atlantic waters provide habitat for a variety of life stages of loggerhead, green, hawksbill, and Kemp's ridley sea turtles that rely on nearshore reefs, coastal lagoons, and shorelines for developmental, breeding, and nesting grounds. Neritic waters also serve as access to nesting beaches for loggerhead, green, leatherback, hawksbill, and occasionally Kemp's ridley turtles. Additionally, pelagic zones of Florida's Atlantic waters are used by loggerhead, green, hawksbill, Kemp's ridley, and leatherback turtles as migratory pathways.

Discussion

All five species of sea turtles use Florida's Atlantic waters. There are species-specific differences in the relative abundances associated with seasons and with movements to and from rookeries. Here we discuss each species' use of Florida's Atlantic waters and highlight the trends in size class occurrence relative to the 200 m isobath. We end with a discussion of the satellite track data.

Loggerhead Turtles

U.S. beaches along peninsular Florida, as well as Florida's Atlantic waters adjacent to the coastline, provide essential habitat for one of the world's largest loggerhead sea turtle rookeries.

A significant portion of the world's population of loggerhead turtles, up to 80% of the North Atlantic population, nests on peninsular Florida's beaches and produce ~90% of all hatchlings in the western North Atlantic Ocean (TEWG, 2009). Hatchling and small juvenile loggerhead turtles (mean \pm standard deviation = 46.9 ± 3.2 mm straight carapace length (SCL), range = 40.9–78.4 mm) from Florida's east coast beaches have been observed in *Sargassum* lines and frontal zones along the east coast of Florida (Witherington, 2002; Witherington et al., 2012) and so transit Florida's Atlantic waters. Direct observations show that these turtles then move to forage and grow in oceanic waters in the eastern North Atlantic (Bolten et al., 1998; Monzón-Argüello et al., 2009).

After an estimated 6.5–11.5 years as oceanic juveniles, loggerheads (SCL = 46–64 cm) return to developmental habitats within neritic waters, including Florida's east coast (Bjorndal et al., 2000b; Bolten, 2003b; Snover et al., 2010). These waters provide important developmental habitats for juvenile loggerheads originating from Florida, Mexico, the U.S. eastern seaboard, and other Atlantic nesting beaches (Witzell et al., 2002). Additionally, waters along the east coast of Florida provide seasonal overwintering habitats and year-round foraging grounds for loggerhead turtles (Henwood, 1987; Keinath, 1993; Ehrhart et al., 2007; McClellan and Read, 2007; TEWG, 2009; Arendt et al., 2012b).

Some juvenile loggerheads along Florida's east coast undergo seasonal migrations northward in warmer months and migrate south when water temperatures decline in the fall (Lutcavage and Musick, 1985; Carr, 1987; Musick and Limpus, 1997; TEWG, 2009). Mansfield et al. (2009) documented seasonal movements of juvenile loggerheads from the Chesapeake Bay to areas off of North Carolina, with two turtles moving as far south as Florida's east coast. Large juvenile loggerheads ($\bar{x} = 62.6 \pm 4.9$ cm SCL, range = 57.5–75.8 cm) caught in North Carolina were also tracked into

Florida's Atlantic waters (McClellan and Reed, 2007).

Juvenile loggerheads as small as 45 cm SCL are captured in coastal waters between St. Augustine, Fla. (lat. 29°53'N), and Brunswick, Ga. (lat. 31°09'N), during the spring and summer months (Arendt et al., 2012c; Table 1) and near Cape Canaveral (lat. 28°23'N) during winter months (Ogren and McVea, 1995). Juvenile loggerheads have been captured throughout the Indian River Lagoon (Ehrhart et al., 2007), indicating their arrival from oceanic habitats, although their routes to the coastal lagoons are poorly documented. Juvenile and adult loggerheads also use coastal bays and inlets as feeding and wintering habitats. For example, loggerhead turtles captured ($\bar{x} = 80.1$ cm SCL, range = 48.9–98.7 cm) year round within Florida Bay in the Florida Keys range from juvenile to near mature size classes (Schroeder et al., 1998).

The Port Canaveral Shipping Channel is an important area for adult loggerhead turtles (Carr et al., 1980). Results from five trawling studies in this area documented the capture of 3,132 individuals, 83% of which were juveniles (mean total carapace length = 69 cm, $n = 2,546$) while 17% were adults (mean total carapace length = 92 cm, $n = 586$) (Henwood, 1987). Of the adults captured, 271 were female and 315 were males. Adult males were captured primarily during March through May, while adult females were mostly captured from April through August (Henwood, 1987). Henwood (1987) suggested that these adults display short-term residency in this area before moving to other foraging habitats after the nesting season ends. Moreover, Henwood (1987) noted that adult male migrations differed from those of adult females in that males entered the area prior to the arrival of females, with peak densities from April to May.

Juvenile loggerhead turtles are present year-round in the Port Canaveral Shipping Channel with greater abundances in the winter, suggesting a northward migration during spring and

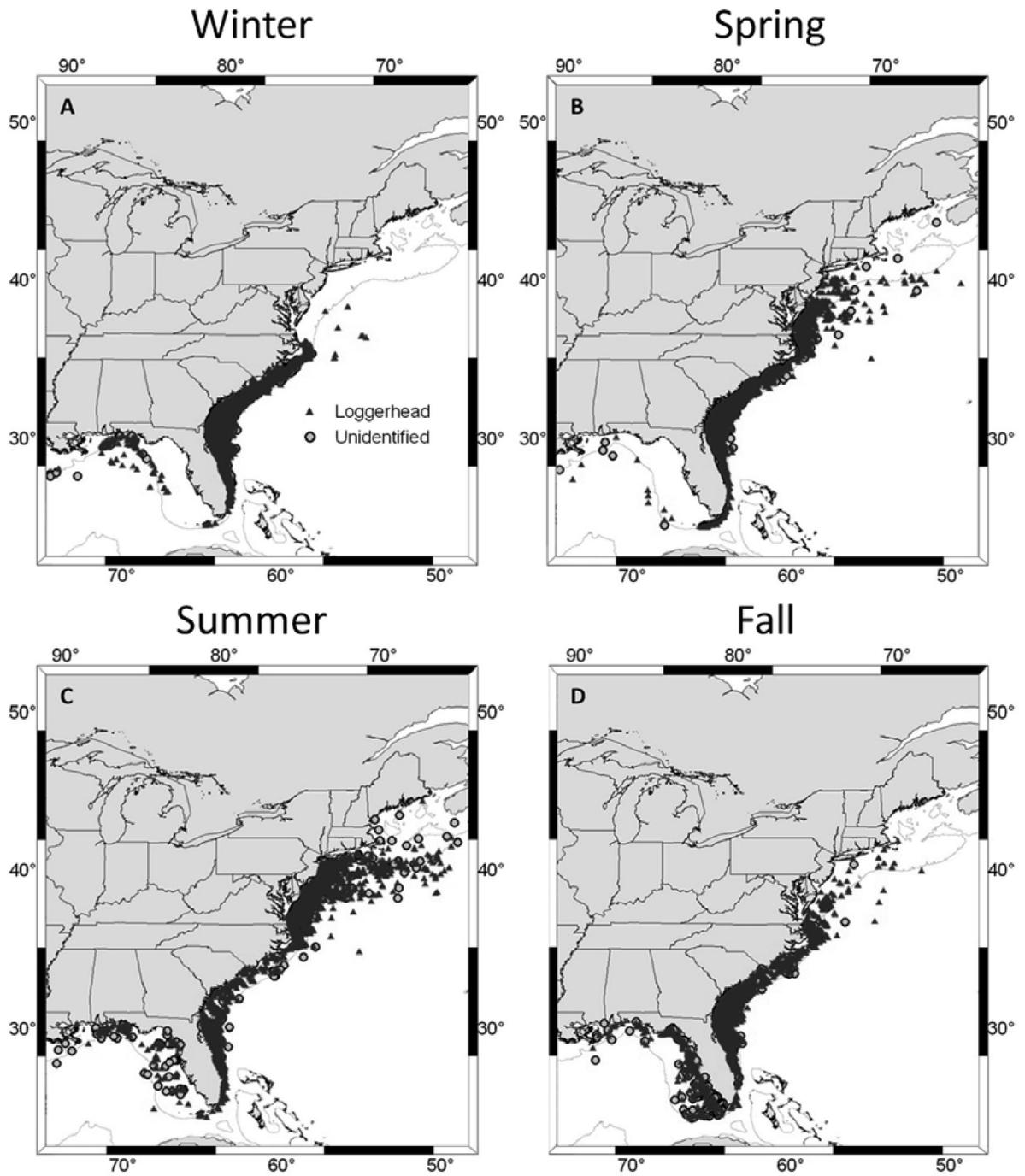


Figure 2.—Seasonal composites of loggerhead turtle, *Caretta caretta*, distributions from aerial and shipboard surveys conducted from the late 1970's to 2002: A) Winter (January–March), B) Spring (April–June), C) Summer (July–September), D) Fall (October–December). Reproduced with permission from Turtle Expert Working Group (2009).

summer that coincides with warmer temperatures in higher latitudes (Hennwood, 1987; Schmid, 1995). During trawling surveys conducted in 2006 and 2007 adjacent to Cape Canaveral, 158 loggerheads were captured, including 42 adult males, 9 adult females, and 107 juveniles; the smaller loggerheads were captured closer to shore (Arendt et al.¹).

Mark-recapture studies indicate that post-nesting loggerhead females from the central east coast of Florida disperse to areas along the U.S. Atlantic Coast, Gulf of Mexico, and Caribbean (Meylan et al., 1983). Tracking studies have identified diverse routes between nesting, feeding, and overwintering grounds. Some loggerhead turtles tracked by satellite telemetry (Table 1) use Florida's Atlantic waters for varying amounts of time; others cross the Florida Current and move into Bahamian or Cuban waters, while others move north along Florida's east coast and the edges of the Gulf Stream (Caldwell et al., 1959; Meylan, 1995; Foley et al., 2008; Godley et al., 2008; Girard et al., 2009; Mansfield et al., 2009). Occasionally, post-nesting loggerhead turtles migrate from Florida's Atlantic waters to outer continental waters off of southwest Florida and into the Gulf of Mexico (Foley et al., 2008; TEWG, 2009).

Florida's Atlantic waters are important migratory pathways for turtles tagged elsewhere (TEWG, 2009), including those found nesting along North Carolina beaches (Hawkes et al., 2007) and in southwest Florida (Girard et al., 2009). Some post-nesting loggerheads travel along coastal routes, while others cross deep oceanic waters (Foley et al., 2008). Adult female loggerheads use waters near nesting beaches (<50 km) as well as areas distant from nesting beaches (>700 km, Foley et al., 2008). Post-nesting

¹Arendt, M., J. Byrd, A. Segars, P. Maier, J. Schwenter, D. Burgess, J. Boynton, D. Whitaker, L. Liguori, L. Parker, D. Owens, and G. Blainvillain. 2009. Unpubl. Examination of local movement and migratory behavior during spring and summer along the Atlantic coast off the southeastern United States. Final report. Natl. Mar. Fish. Serv., 177 p. (avail. at http://www.sefsc.noaa.gov/turtle/docs/CR_Arendt_et_al_2009.pdf).

loggerheads tracked from the southwest coast of Florida show both localized and long-distance movements (Girard et al., 2009). Upon reaching overwintering habitats, females reside in well-defined, relatively small areas on the continental shelf off Florida, Texas, Mexico, and Bahamas (TEWG, 2009).

In the winter and spring, adult loggerheads are found north of Florida's central east coast, and in southern Floridian and Cuban waters (Fig. 2A, B; TEWG, 2009). In summer and fall, adult loggerhead turtles are more widely spread throughout coastal waters west of the 200 m isobath (Fig. 2C, D; TEWG, 2009).

Additional tracking studies indicate that adult male loggerheads utilize continental shelf waters throughout most of Florida (Arendt et al., 2012a, c). In spring (April–June), adult males are more evenly distributed throughout all continental shelf waters. In the summer (July–September), adult males aggregate along the west and east central coast of Florida, similar to fall (October–December). Resident males remained in the Port Canaveral area, moving further offshore after breeding, while migrant turtles dispersed to foraging grounds north and south of Port Canaveral (Arendt et al., 2012a, c).

Aerial surveys have increased our knowledge of the distribution and abundance of some marine turtles. Generally, larger individuals are more easily identified to species and more information on the at-sea distribution and abundance of these turtles is available (Epperly et al., 2002). Loggerhead sea turtles are often the most commonly observed species during aerial surveys (Hoffman and Fritts, 1982; Fritts, 1983; Thompson²) and have been observed throughout Florida's Atlantic waters (Fig. 2A–D; McClellan, 1996; TEWG, 2009). Aerial

²Thompson, T. J., and C. R. Shoop. 1983. Southeast Turtle Surveys (SETS), Pelagic surveys. Final report. Natl. Mar. Fish. Serv., Miami, Fla. NA82-GA-C-00012. Aero-Marine Surveys, Inc., Groton, Conn., 76 p. (avail. at http://www.sefsc.noaa.gov/turtle/docs/CR_Shoop_Thompson_1983.pdf).

surveys indicate that loggerheads are distributed along the entire southeast coast of Florida with greater abundances in the spring and summer (McClellan, 1996), coinciding with nesting season.

Aerial surveys conducted from the late 1970's to 2002 found that the majority of turtle sightings occurred along the continental shelf out to the 200 m isobath (Fig. 2A–D; TEWG, 2009). In the summer, loggerheads utilize coastal waters east to the edge of the continental shelf with few turtles extending into deep waters of the shelf (Witzell and Azarovitz, 1996). In general, sea turtles primarily use mid-shelf waters during fall and winter and they are more uniformly distributed over the continental shelf in the spring and summer (Schroeder and Thompson, 1987), with the majority of loggerhead sightings occurring in waters <100 m, west of the Florida Current (Hoffman and Fritts, 1982; Schroeder and Thompson, 1987).

Leatherback Turtles

The leatherback turtle is the widest ranging reptile in the world, found in the Pacific, Atlantic, and Indian Oceans (Mrosovsky, 1987). Leatherbacks have been observed throughout Florida's nearshore and offshore waters (Stewart and Johnson, 2006). In contrast to other marine turtle species, leatherbacks are primarily pelagic (Musick and Limpus, 1997). Most of what is known about leatherbacks in Florida's Atlantic waters is derived from adult turtles.

Leatherback turtles nesting in Florida are considered a separate stock from the six other stocks in the Atlantic Ocean (TEWG, 2007). Peak leatherback nesting in Florida occurs along the Atlantic coast (Stewart et al., 2011). Leatherback nesting in Florida has increased by 10.2% since 1979 (Stewart et al., 2011). Few in-water observations of juvenile or adult leatherbacks have been documented in Florida waters (Bresette et al., 1998; Eckert, 2002), though records of nesting (Stewart et al., 2011) and worldwide juvenile sightings (<145cm;

Eckert, 2002) indicate that leatherbacks may utilize these waters. Muck and Limpus (1997) noted that the fate of leatherback hatchlings after they leave nesting beaches is unknown and little is known about pelagic juveniles. Eckert (2002) concluded that juvenile leatherback turtles reside primarily in warmer waters, transitioning to colder waters as they grow. Nevertheless, leatherbacks nest on Florida's east coast beaches and their hatchlings use Florida's Atlantic waters.

Leatherbacks primarily inhabit pelagic waters, make annual north-south migrations in the North Atlantic (Eckert, 1998; James et al., 2005; Eckert et al., 2006), and can swim over 10,000 km/yr often across entire ocean basins (Eckert, 1998; Hughes et al., 1998; Eckert et al., 2006). Post-nesting adult females were tracked from Florida's Atlantic beaches for durations of 38 to over 454 days (Eckert et al., 2006). During the internesting period, these turtles moved north, occasionally remaining in waters over the continental shelf before returning to nest. Eckert et al. (2006) determined that the home-range of these animals was primarily along the continental shelf extending out to Gulf Stream waters east-southeast of Cape Canaveral and just off their nesting beaches. Adult female, adult male, and juvenile leatherback turtles tagged in waters off Nova Scotia, Canada, exhibited widely varied migration patterns throughout the western Atlantic Ocean (James et al., 2005). Individuals migrated to waters off nesting beaches as far south as the northeast coast of South America, Antilles, Panama, and Costa Rica, as well as continental shelf waters off the coast of the southeastern United States (James et al., 2005).

Data from aerial surveys and bycatch information provide much of our understanding of the distribution and abundance of leatherback turtles in waters bordering the entire southeastern United States. Their density is greatest along the east coast of central Florida where they primarily use mid-shelf waters throughout the year (Schroeder and Thompson, 1987; Ep-

perly et al., 2002; TEWG, 2007). Here, most sightings of leatherbacks occur in summer, east of the 20 m isobath (Schroeder and Thompson, 1987). In addition, bycatch rates in the commercial shrimp industry are greatest in nearshore waters where fishing effort is concentrated (Epperly et al., 2002). Incidental capture of leatherback turtles in long-line fisheries suggest that relatively large numbers of leatherback turtles inhabit deep waters extending beyond the edge of the continental shelf, outside the 200 m isobath, especially during summer and fall months (Witzell and Cramer, 1995; Witzell, 1999). In general, aerial sightings indicate that leatherbacks are more abundant off the U.S. Atlantic coast during the summer than during the winter and sighted less frequently in nearshore waters (TEWG, 2007).

Fritts et al. (1983) reported sightings of leatherback turtles off the central east coast of Florida in spring and summer in mostly shallow continental shelf waters <72 km from shore. Seasonal aerial surveys conducted from 1982 to 1984 observed leatherbacks during all seasons, with numbers peaking in summer months (Schroeder and Thompson, 1987). Hoffman and Fritts (1982) and Schroeder and Thompson (1987) found that leatherbacks were more abundant in the summer along Florida's central east coast and were concentrated at depths between 20 and 40 m.

Green Turtles

Florida's Atlantic waters are important feeding grounds and migratory pathways for green turtles. Atlantic green turtles nest throughout Florida with peak nesting occurring along the east coast from approximately lat. 29°25'N to lat. 27°50'N (NMFS and USFWS, 2007). Annual nesting in Florida has steadily increased over the past several decades (Meylan et al., 2006; Witherington et al., 2006). Hatchlings depart the nesting beaches and are dispersed by ocean currents as they begin the oceanic phase of their life cycle (Carr and Meylan, 1980; Witham, 1980; Meylan et al., 2006).

During their oceanic phase, post-hatchling turtles often associate with *Sargassum* and other flotsam accumulated along convergence zones caused by downwelling (Carr, 1987; Witherington et al., 2006; Witherington et al., 2012). In the Caribbean, Carr and Meylan (1980) documented neonate green turtles in *Sargassum* off the coast of Costa Rica. Large numbers of post-hatchlings commonly strand along Florida's central and northern east coast with *Sargassum* following fall and winter storm events (Carr and Meylan, 1980; Witherington et al., 2006). These turtles are presumed to have been residing along a front that forms along the continental edge of the Gulf Stream off central Florida's east coast (Witherington, 2002). Recently, young green turtles have been observed residing in *Sargassum* habitat in the Atlantic Ocean (Witherington et al., 2012).

After an average 2.8–4.6 years (Zug and Glor, 1998; Reich et al., 2007a), green turtles return to developmental habitats within neritic waters, including Florida's east coast (SCL = 20–25 cm, Bjorndal and Bolten, 1988; Bjorndal et al., 2000a; Reich et al., 2007a). Juvenile green turtles are found in Florida's Atlantic waters along nearshore reefs (Wershoven and Wershoven, 1991; Makowski et al., 2006), in coastal lagoons (Mendonça and Ehrhart, 1982; Ehrhart et al., 2007), and to a lesser extent in shipping channels (Henwood and Ogren, 1987). The small sizes of green turtles captured in these studies indicate that turtles may be new recruits to nearshore habitats, vacating the oceanic zone to become inhabitants of coastal waters.

Juvenile green turtles are captured in the Cape Canaveral Shipping Channel throughout the year except in August and November, suggesting a lack of seasonal changes in abundance (Henwood and Ogren, 1987). However, Schmid (1995) reported that juvenile green turtles in the Cape Canaveral Shipping Channel were seasonally most abundant between November and January. Near Marquesas Keys, Fla.,

juvenile and adult green turtles forage in shallow seagrass habitats (Bresette et al., 2010). Results from these surveys suggest that size partitioning of feeding areas occurs, with large juveniles and adult turtles using deeper water foraging habitats (Bresette et al., 2010). Once reaching a certain size (>70 cm SCL), large juvenile (sub-adult) green turtles depart coastal developmental habitats along Florida's central east coast and move to foraging grounds in the Florida Keys, Bahamas, and the Caribbean (Ehrhart et al., 2007; Bagley et al., 2008).

Traditional flipper tagging and more modern satellite telemetry techniques have indicated that the majority of adult females in Florida reside in nearshore foraging areas throughout the Florida Keys (NMFS and USFWS, 2007). Nesting females tracked from the east coast of Florida exhibited different post-nesting migrations to foraging areas near the Dry Tortugas, the southwestern coast of Florida, and across the Florida Current to the Bahamas (Witherington et al., 2006). Green turtles of various size classes tagged in coastal Florida waters have been recaptured in Cuban waters (Moncada et al., 2006) suggesting their movement likely includes Florida's Atlantic waters. Florida waters are also important migratory pathways for green turtles tagged elsewhere, including turtles from Costa Rica (Troëng et al., 2005), the Cayman Islands (Blumenthal et al., 2006), and Cuba (Moncada et al., 2006).

Green turtles have been sighted in aerial surveys along the entire east coast of Florida and are most common in nearshore waters (McClellan, 1996). In other aerial surveys, green turtles were sighted along the central east coast of Florida, west of the Gulf Stream Current (Hoffman and Fritts, 1982) and throughout the Florida Gulf Stream itself, up to 79 km from shore (Fritts et al., 1983).

Kemp's Ridley Turtles

Although it is believed that Kemp's ridley turtles also have an oceanic stage (Musick and Limpus, 1997; Bol-

ten, 2003a), there are few such records of these turtles (Henwood and Ogren, 1987; Collard and Ogren, 1990). Manzella et al. (2001) and Witherington et al. (2012) reported on the sighting of Kemp's ridley turtles in *Sargassum* in the Gulf of Mexico. Stranding of small juvenile Kemp's ridleys along the southeast Florida coast also indicates their use of these waters (TEWG, 2000). Kemp's ridley turtles return to neritic benthic habitats as early as one year after hatching (Snover et al., 2007). During the juvenile stage, turtles reside within neritic foraging grounds along Florida's east coast (Henwood and Ogren, 1987).

While most Kemp's ridley turtles originate from their primary rookery in Tamaulipas, Mexico (Carr, 1963; Hildebrand, 1963, 1982), what path these turtles take to reach Florida's coastal waters is uncertain. Various scenarios for dispersal of post-hatchling Kemp's ridley turtles indicate the potential for transport through the Florida Straits and into waters along the Florida coast (Collard and Ogren, 1990; Putman et al., 2010). Sub-adult Kemp's ridleys have been captured in Cape Canaveral, Fla. (Schmid and Witzell, 1997), while juvenile Kemp's ridley turtles have been captured at Hutchinson Island, Fla. (Bresette et al., 1998), from benthic habitats consisting of sand and hard-bottom reefs. Kemp's ridley turtles have also been captured in coastal lagoons along Florida's central east coast (Ehrhart, 1983).

The greatest abundance of Kemp's ridley turtles along Florida's Atlantic waters occurs in the Port Canaveral Shipping Channel. Although turtles here range in size from 21.5–60.3 cm SCL, the majority of turtles captured are juveniles (Henwood and Ogren, 1987). Along the U.S. east coast, juvenile Kemp's ridley turtles often exhibit north-south seasonal migrations (Henwood and Ogren, 1987; Keinath, 1993). Mark-recapture studies in the area indicate juvenile Kemp's ridleys likely undergo seasonal migrations, with the greatest abundance of Kemp's ridleys occurring in the winter from December to March (\bar{x} = 38.6

cm SCL, range = 24.1–66.0 cm SCL; Henwood and Ogren, 1987). Kemp's ridley turtles from this area were also subsequently captured in South Carolina and Georgia in the summer and fall (Henwood and Ogren, 1987), confirming the north-south migration cycle of Kemp's ridleys.

Renaud (1995) tracked Kemp's ridley turtles along the east coast of Florida and observed nearshore coastal movements. A tracking study of juvenile Kemp's ridley turtles along the east coast of Florida indicates seasonal migrations to more northern waters in the spring (Gitschlag, 1996). Satellite tracked juvenile, sub-adult, and adult Kemp's ridley turtles from the western Gulf of Mexico displayed seasonal migrations along the west and east coasts of Florida (Renaud and Williams, 2005). In general, Kemp's ridleys inhabited waters <20 m in depth but moved to deeper waters in cooler winter months followed by a return to nearshore waters in the spring (Renaud, 1995; Renaud and Williams, 2005). Some Kemp's ridley turtles were observed migrating around the southern tip of Florida and into Florida's Atlantic waters (Renaud and Williams, 2005).

Aerial surveys have provided little information on the distribution and abundance of Kemp's ridley turtles, despite their documentation throughout Florida's Atlantic waters (Epperly et al., 2002). Fritts et al. (1983) reported limited sightings of Kemp's ridley turtles ($n = 2$) during aerial surveys off the east coast of Florida, noting a higher frequency of observation along southwestern Florida.

Hawksbill Turtles

Hawksbill turtles are found throughout the Gulf of Mexico, Caribbean Sea, and in the western Atlantic. In Florida, hawksbills are relatively rare though all life stages can be found in Florida's Atlantic waters (Meylan and Redlow, 2006). Similar to other sea turtle species, the hawksbill turtle hatchling oceanic stage is associated with *Sargassum* (Witherington et al., 2012) for one or more years, followed

by a neritic stage associated with hard-bottom reefs, and finally a reef dwelling adult stage.

Hawksbill nesting is rare in Florida. From 1979 to 2003, only four nests per year were recorded along Florida's beaches (Meylan et al., 1995). Nesting occurs primarily from June to December with most nests documented from August to October (Meylan and Redlow, 2006). Nesting has primarily been documented along the east and southeast coast (Carr et al., 1966; Meylan and Redlow, 2006). There are no studies that examine the interesting or post-nesting movements of hawksbills along Florida's beaches, although hawksbills from Florida have been recaptured in the Bahamas and Texas (Meylan and Redlow, 2006). Stranded hawksbills have been found primarily in the Florida Keys or along the east coast of Florida and occur throughout the year with the greatest number of strandings in March and June (Meylan and Redlow, 2006).

Hawksbills are known to inhabit nearshore reefs along the central east coast of Florida (Meylan and Redlow, 2006). Juvenile hawksbill turtles are captured year-round along hard-bottom reefs off the coast of Palm Beach County, Florida (Wood, 2006). In addition, juvenile hawksbills have been captured at the St. Lucie Power Plant (Bresette et al., 1998) in all months except January and February and from benthic habitats consisting of sand, and hard-bottom reefs. Wershoven (1989) captured three juvenile hawksbill turtles from hard-bottom reefs off Broward County from 1986 to 1988, with seven recaptures of one juvenile. It may be that juvenile hawksbills inhabiting waters off the southeast coast of Florida waters forgo migration due to less severe seasonal changes in water temperature. However, further studies are needed to assess year-round abundance. Hawksbill turtles have been sighted during aerial surveys off the southwest coast of Florida, yet few sightings have occurred along the east coast (Epperly et al., 2002). Despite significant effort, little evidence is available regarding

their marine distributions offshore in Florida's Atlantic waters (Meylan and Redlow, 2006).

Satellite Telemetry Data

Exploration of available satellite tracks identified an abundance of programs that tracked sea turtles throughout the northeast Atlantic Ocean. All species of sea turtle tracked were observed in Florida's Atlantic waters, though not all age classes were observed in these waters. Loggerheads composed the majority of the turtles tracked by the compiled research programs and accounted for the majority of sea turtles in tracked Florida's Atlantic waters (Table 1). Movements of adults, primarily females tagged at nesting beaches, formed the majority of loggerhead tracks in our study area. Leatherback and green turtles were the next most common species to be tracked through Florida Atlantic waters. Sub-adult loggerhead and green turtles formed the highest percentage of sea turtles crossing into Florida's Atlantic waters (63.4% and 70.5%, respectively), indicating the importance of this area for those species and age classes. The high percentage of hawksbill sub-adults observed in Florida's Atlantic waters, represents relatively few turtles, all tagged in Florida's east coast or Turks and Caicos. Relatively few adult Kemp's ridleys were tracked and those tracked in Florida's Atlantic waters were likely transients moving between summer and winter habitats.

The compilation of the data summarized here highlights data gaps in the satellite tracking of sea turtles that may use Florida's Atlantic waters. There are no available track data for adult hawksbills, yet some nesting occurs along Florida's east coast so they clearly transit the area. There is a deficiency of tracks for sub-adult and juvenile leatherbacks, adult and juvenile green turtles, as well as adult Kemp's ridleys. Because other data sources have identified these stage classes in Florida's Atlantic waters, tracking data would help address where in these waters the turtles occur.

Conclusions

Because one or more life stages of most sea turtle species are present in Florida's Atlantic waters, the importance of these waters cannot be overstated. In synthesizing the available information on sea turtle occurrence in the coastal and offshore waters east of Florida, we identified spatial and temporal concentrations of turtles, and persistent obvious gaps that exist in our understanding of their spatial and temporal distributional patterns. Despite the differences among the distributional patterns of sea turtle species in Florida's Atlantic waters, all species exhibit distinct habitat shifts and seasonal variation within study waters. Three species (loggerhead, green, and leatherback) transit coastal and offshore waters in considerable numbers when females come to nest and when hatchlings disperse away from shore. Few hawksbills and Kemp's ridleys use Florida's coastal zones for reproduction, yet they use Florida's Atlantic waters either as residents (juvenile and sub-adult hawksbills) or as migrants (Kemp's ridleys). Numerous studies focus efforts on establishing interesting and post-nesting movements of nesting female turtles, yet few have focused on the immature stages, non-nesting adults, or adult male turtles. Greater effort should be undertaken to document spatial and temporal use of the waters by juvenile turtles in nearshore and offshore habitats, adult male migratory and movement patterns, and include focus on hawksbill and Kemp's ridley activity in the Atlantic waters between Florida and the Bahamas. Such movement and habitat data are relevant to fisheries management to avoid bycatch, offshore energy development, and marine industries throughout Florida's Atlantic waters.

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