PART II

STOCK ASSESSMENT OF LEATHERBACK SEA TURTLES OF THE WESTERN NORTH ATLANTIC

Nancy B. Thompson
Jeffrey R. Schmid
Sheryan P. Epperly
Melissa L. Snover
Joanne Braun-McNeill
Wayne N. Witzell
Wendy G. Teas
Lisa A. Csuzdi
Ransom A. Myers

Table of Contents

PART II. STOCK ASSESSMENT OF LEATHERBACK SEA TURTLES OF THE WESTERN NORTH ATLANTIC

Geographic Range

The leatherback turtle, *Dermochelys coriacea*, is essentially pelagic, inhabiting the open ocean from hatchling through adulthood, but may venture into coastal waters to feed and reproduce. The broad thermal tolerance of this species allows for a greater geographic range than the cheloniid turtles (Paladino *et al.* 1990). Adult leatherbacks forage in temperate and subpolar regions from 71° N to 47° S latitude in all oceans (Pritchard and Trebbau 1984) and undergo extensive migrations to and from tropical nesting beaches between 30° N and 20° S (Starbird *et al.* 1993). Juvenile leatherback turtles have been observed from 57° N to 34° S, although turtles less than 100 cm CCL (curved carapace length) may be limited to regions with water temperatures above 26° C (Eckert 1999*a*).

In the Atlantic Ocean (Fig. 1), leatherbacks have been recorded as far north as Newfoundland and Labrador, Canada (Bleakney 1965, Goff and Lien 1988, James 2000) and Norway (Brongersma 1972, Willgohs 1957), and as far south as Uruguay and Argentina (Pritchard and Trebbau 1984) and South Africa (Hughes *et al.* 1998). Pelagic coelenterates (Scyphozoa and Siphonophora) are a major component in the diet of leatherback turtles (Den Hartog 1980, Den Hartog and Van Nierop 1984) and the occurrence of turtles often corresponds to concentrations of jellyfish (Leary 1957, Fritts *et al.* 1983, Collard 1990, Grant *et al.* 1996, James 2000).

Female leatherbacks nest from the southeastern United States to southern Brazil in the western Atlantic (Ruckdeschel and Shoop 1982, Soto *et al.* 1997) and from Mauritania to Angola in the eastern Atlantic (Brongersma 1982, Fretey and Malaussena 1991). With the exception of Gabon (Fretey and Girardin 1989), there is little information on leatherback nesting along the West African coast other than general descriptions of nesting beaches in Guinea-Bissau (Barbosa *et al.* 1998), Sierra Leone (Fretey and Malaussena 1991), Gulf of Guinea islands (Tomás *et al.* 1999, Graff 1995[1]), and Angola (Hughes *et al.* 1973, Carr and Carr 1991). The most significant nesting beaches in the Atlantic, and perhaps the most significant in the world, are in French Guiana and Suriname (Pritchard and Trebbau 1984). Relatively important nesting sites also occur in Guyana and Colombia in South America and in Panama and Costa Rica in Central America (Bacon 1981). Among the Caribbean Islands (Fig. 2), leatherbacks regularly nest on Dominican Republic, Puerto Rico and the accompanying islands of Culebra and Vieques, St. Croix in the U.S. Virgin Islands, Trinidad, and Tobago. Occasional to sporadic nesting occurs throughout the Caribbean, including the mainland countries of Honduras, Mexico, Nicaragua, and Venezuela and the islands of Barbados, Dominica, Grenada, Guadeloupe, Jamaica, Martinique, Saint Lucia, and Saint Vincent (*Ibid.*).

Female leatherbacks typically undergo trans-oceanic migrations after nesting. Tagging studies in French Guiana have demonstrated that nesting females travel eastward to Ghana, West

[1] Graff, D. 1995. Nesting and hunting survey of the turtles of the island of São Tomé. Progress Report July 1995, ECOFAC Componente de São Tomé e Príncipe, 33 pp.

Africa (Pritchard 1976) and northward to Newfoundland, Canada (Goff *et al.* 1994). Female turtles tagged in the U.S. Virgin Islands, Columbia, French Guiana, and Costa Rica were found stranded along the Atlantic and Gulf coasts of the United States (W. Teas personal communication[2]). Satellite telemetry was used to track the post-nesting movements of two leatherbacks from Trinidad (Eckert 1998, Eckert 1999*b*). Both turtles traveled to approximately the 45° N latitude; one of which migrated eastward across the Atlantic Ocean before turning northward to waters off the coast of Spain and France, and the other migrated northward in the central Atlantic. Both turtles then began moving southward during the last week of November presumably to foraging areas off the African coast (Eckert 1999*b*). These migrating leatherbacks demonstrated a preference for waters between 16-18° C. A free-ranging male was captured and satellite-tagged off Nova Scotia in early September and traveled to the southern coast of Newfoundland before returning to Nova Scotian waters in mid-October[3]. This turtle then began moving rapidly southeastward through late October before contact was lost approximately 2,200 km east of Virginia, U.S.A.

Seasonal Distributions

Because leatherback turtles display some degree of endothermy (Paladino *et al.* 1990), their seasonal distributions extend latitudinally into the western North Atlantic as far north as Canadian waters. However, these turtles are not homeothermic and as reptiles do demonstrate some limitations to thermal tolerances as noted previously. As a result, seasonal movements would be expected and could be over a very large range, including trans-oceanic movements. It is also assumed that, when they leave the nesting beach as hatchlings, they move to offshore waters into the pelagia and upon reaching a certain size, utilize coastal and pelagic waters.

James (2000), after examining data from aerial surveys, observer records, and self reporting from both fishers and whale watchers, determined that leatherback turtles are found in Western Atlantic Canadian waters off of Nova Scotia and out beyond the 2000 m isobath from July through October, with a notable peak in August. While the majority of turtles were reported well within the 200 m isobath and would be considered coastal, sightings and interactions were reported by fishers out to and beyond the 2000 m isobath coincident with fishing activities. No size information is available for these turtles, however, photo documentation of turtles feeding at the surface would imply that these turtles were large, juvenile to adult sized turtles as they were easily visible from fishing vessels.

Summarizing three years of survey effort off the northeastern U.S. coastal waters, Shoop and Kenney (1992) described seasonal movements based on changes in turtle density from Cape Hatteras, N.C. to the Gulf of Maine, including Georges Bank out to the 2000 m isobath. Survey effort was primarily from seasonal random transect aerial surveys designed to develop density estimates for mammals and turtles conducted in the late 1970's, and included to a lesser extent, data collected by aircraft and ships while in transit for other data collection purposes and historical data from 1958 forward. Leatherback turtles were reported throughout the study area

[2] Wendy Teas, National Marine Fisheries Service, SEFSC, Miami, Fla., personal communication (E-mail) to Therese Conant, National Marine Fisheries Service, PR, Silver Spring, Md., January 14, 2000.

[3] Canadian Wildlife Federation. 2000. Tracking "Sherman" information. http://www.cwf-fcf.org/pages/sherman.htm

and included waters beyond the 2000 m isobath as reported by James (2000) for Canadian waters (Fig. 3). The authors describe a seasonal peak in turtle abundance throughout the study area in the summer with an increasing density of turtles southward from Maine to N.C. and a concentration south of Long Island. Fewer turtles were observed in both the spring and fall with turtles in the spring concentrating at the 2000 m isobath. No turtles were observed in the winter.

In July and August of 1995 and 1998, the NMFS Northeast Fisheries Science Center (NEFSC) conducted aerial surveys specifically designed to develop density estimates for leatherback turtles in waters from Maine to the Virginia/North Carolina border and including Chesapeake Bay and waters off the southeast coast of Nova Scotia and Newfoundland. The results from these surveys are very similar to those of Shoop and Kenney (1992) from 20 years earlier, although the NEFSC surveys were limited to the summer. Turtles were observed from Maine southward and were concentrated from Long Island southward in coastal waters, and out to the 2000 m isobath; no turtles were observed in Chesapeake Bay (Fig. 3). Turtles have been reported from the lower Chesapeake Bay as both live and stranded dead (Lutcavage and Musick 1985, Barnard *et al.* 1989).

In the early 1980's (1982-1984) the NMFS Southeast Fisheries Science Center (SEFSC) conducted seasonal aerial surveys to census turtles and mammals from the western boundary of the Gulf Stream to coastal waters from Cape Hatteras, N.C. to Key West, Florida (Thompson 1984[4], Schroeder and Thompson 1987) (Fig. 4). Leatherbacks were observed in all seasons with a notable peak in observations beginning in the spring and continuing through the summer. In the spring, leatherbacks were evenly distributed throughout the sampling area, including out to the western boundary of the Gulf Stream, but were more concentrated along the coast. During the summer, a concentration of sightings off the central east coast of Florida, similar to that for loggerhead turtles, suggested a concentration of resources in this area. In looking specifically in this area off the Florida east coast, Schroeder and Thompson (1987) noted that turtles were more abundant in the summer and tended to concentrate between 20 m and 40 m of depth. Similar distributions by depth are described by Hoffman and Fritts (1982) from an aerial survey conducted off the east coast of Florida in August 1980. Thompson and Huang (1993) suggested that waters at this depth were cooler than nearshore waters and that turtles may in fact use thermal cues to identify thermal fronts which would concentrate resources. The use of thermal cues would explain the high densities of leatherbacks that have been observed on occasion (Knowlton and Weigle 1989).

Bi-monthly aerial surveys conducted in the Gulf of Mexico are described by Fritts *et al.* (1983). Sampling areas were approximately 25,000 km^2 blocks off of Brownsville, Texas; Marsh Island, Louisiana; and Naples, Florida. In the Texas block, sampling was completed out to about 2000 m and for the two other areas, sampling was completed out to about 200 m. No turtles were observed off of Texas during any survey month. While few turtles were observed in the other areas, turtles were observed generally in waters less than 100 m off of Louisiana in the

[4] Thompson, N.B. 1984. Progress report on estimating density and abundance of marine turtles: results of first year pelagic surveys in the southeast U.S., unpublished report for stock assessment workshop MMT/7, National Marine Fisheries Service, SEFSC, Miami, Fla., 59pp.

fall only. Turtles were observed in waters off the Florida west coast during the spring, summer, and winter months.

From 1983-1986, the NMFS Southeast Fisheries Science Center completed seasonal aerial surveys in coastal waters of the Gulf of Mexico from inshore waters out to the 100 fathom isobath (Scott *et al.* 1989[5]). Leatherback turtles were observed in the Gulf of Mexico in the summer and fall and most were observed east of the Mississippi River delta. This is consistent with the distribution in the Gulf of Mexico described by Hildebrand (1982) and Fritts *et al.* (1983).

From 1996 to 1998, the SEFSC conducted seasonal shipboard and aerial surveys to census marine mammals and turtles in the Gulf of Mexico (Mullin and Hoggard 2000[6]). Most of the ship board survey effort was on the continental slope directed at depths between 100 m to 1000 m from Texas to Florida. The focus of the aerial effort was the northeastern Gulf of Mexico, resulting in the continental shelf off the Florida panhandle being sampled as well as the slope waters. Leatherback turtles were observed during aerial surveys in both the summer and winter. In the summer, turtles were observed from the coast to deeper waters slope waters in excess of 100 m, and in the winter, turtles were concentrated in slope waters from 100 m outward. Sightings from these surveys and those by Scott *et al.* (1989)[5] are compiled and presented in Figure 4.

In general, since aerial surveys are limited to observations of large juvenile, subadult and adult turtles only, any discussion of hypothesized seasonal movement is limited to the larger life history stages. Aerial survey results suggest that along the Western North Atlantic coast of North America and within the Gulf of Mexico there are seasonal movements of large juvenile to adult sized leatherback turtles from the southeastern coast in the spring to the mid-Atlantic and New England coasts to Canadian waters in the summer. The decrease in sightings in the winter and fall suggest that turtles may move even further south or farther offshore. In the Gulf of Mexico, while sightings are infrequent as compared to the Atlantic Ocean, there appears to be a peak in abundance of turtles in the warmer months, suggesting movement from the Gulf of Mexico in the colder months, perhaps southward.

Eckert (1999*a*) suggests that turtles smaller than 100 cm length are restricted to waters of at least 26°C. This is supported by strandings, turtle carcasses that wash up dead along the coast. The Sea Turtle Stranding and Salvage Network (STSSN) database[7] was examined from 1986-1999. While turtles less than 100 cm curved carapace length have been reported throughout the

---

[5] Scott, G.P., D.M. Burn, L.J. Hansen and R.E. Owen. 1989. Estimates of bottlenose dolphin abundance in the Gulf of Mexico from regional aerial surveys. Unpublished report. NMFS-SEFSC-Miami Laboratory – CRD-88/89-07, Miami, Fla., 59 pp.

[6] Mullin, K.D. and W. Hoggard. 2000. Visual surveys of cetaceans and sea turtles from aircraft and ships, p.111-322. In R.W. Davis, W.E. Evans, and B. Wursig, eds. Cetaceans, sea turtles and seabirds in northern Gulf of Mexico: distribution, abundance and habitat associations. Unpublished report. USGS/BRD/CR-1999-0006, OCS Study MMS 2002-002. Department of Marine Biology, Texas A&M University, Galveston, Texas.

[7] Unpublished data. The Sea Turtle Stranding and Salvage Network is a cooperative endeavor between NMFS, other federal agencies, the states, many academic and private entities, and innumerable volunteers. Data are archived at the National Marine Fisheries Service Southeast Fisheries Science Center in Miami, Fla.

southeast U.S. and Gulf of Mexico, no turtle smaller than 100 cm length has been reported north of North Carolina (Fig. 5). Seasonally, strandings are higher along the northeast U.S. coast in the summer and fall, in the winter and spring along the southeast U.S. coast, in the spring along the western Gulf of Mexico coast, and in the summer along the eastern Gulf of Mexico (Fig. 6). The strandings data indicate that leatherback turtles are found in the Gulf of Mexico primarily in the spring and summer which is consistent with results from aerial surveys.

Stock Definition

A primary goal in marine turtle research during recent years has been stock identification, whereby regional population structures, in terms of nesting females, are characterized by fixed differences in mitochondrial DNA (mtDNA) haplotypes (Dutton 1996). For leatherbacks, however, analyses of mtDNA revealed far less structuring of nesting populations on a global scale than has been observed in cheloniid turtles (Dutton *et al.* 1999). Nonetheless, a high degree of genetic subdivision was observed among rookeries in the Pacific, Indian, and Atlantic Oceans. (Dutton *et al.* 1999) In the Atlantic, nesting populations on St. Croix and Trinidad exhibited significantly different haplotype frequencies between each other and among those for mainland populations in Florida, Costa Rica, and Suriname/French Guiana. (*Ibid.*) This observation provides support that nesting females return to their natal beach on these Caribbean islands. However, rookeries in Florida and Suriname/French Guiana were indistinguishable, and these Atlantic populations were indistinguishable from a South African nesting colony in the Indian Ocean, based on mtDNA. (*Ibid.*)

It is, as for all turtles, impossible in the field to distinguish animals by nesting population. The presence of some rare haplotypes identified from leatherback strandings in Georgia suggests that some are animals from Costa Rica or Trinidad (P. Dutton personal communication[8]). Preliminary results of analysis using new nuclear DNA (nDNA:microsatellites) markers reveals that the South African populations are distinct from the Caribbean, suggesting that the lack of differentiation with mtDNA is due to recent shared ancestry, rather than ongoing gene flow (*Ibid.*). On a regional scale, microsatellite data show that the Trinidad and French Guiana/Suriname populations are homogeneous, in contrast to the mtDNA data. This indicates that despite their relative proximity, mtDNA gene flow may be restricted by natal homing on the part of females, while at the nuclear level, gene-flow is facilitated by males who most likely encounter and mate with females from both populations (*Ibid.*). Genetic analysis of samples from the West African populations is ongoing, with preliminary data suggesting that (like the South Africa rookery) they are indistinguishable at the mtDNA level from some Caribbean populations, but distinct at the nuclear level (*Ibid.*). The loss of nesting populations in the St. Croix region and Trinidad would eliminate most of the detected mtDNA variation in the Atlantic, although these populations represent less than 10% of nestings in this region (Dutton *et al.* 1999).

---

[8] Peter Dutton, National Marine Fisheries Service, SWFSC, La Jolla, Ca., personal communication (phone) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla.

Population Size and Status

Since nesting females are the most accessible stage in the marine turtle life history, counts of females or their nests provide the best available index for the status of marine turtle populations (National Research Council 1990). Other methods for censusing marine turtle populations include counts from aerial surveys, carcass strandings, and catch per unit effort in fishing gear, but counts of females and their nests are most commonly used to delineate long-term (*e.g.*, longer than a decade) population trends.

Pritchard (1971) first estimated the worldwide leatherback population to be between 29,000 and 40,000 breeding females, but later refined his estimate to approximately 115,000 (Pritchard 1982). Ross (1982) provided a much more conservative estimate of 14,325 nesting females. Spotila *et al.* (1996) estimated a global population of 34,500 females, with a lower limit of about 26,200 and an upper limit of about 42,900. These latter authors also suggested that the species as a whole was declining and that local populations were in danger of extirpation. Pritchard (1996) cautioned that the conclusions of Spotila *et al.* (1996) were based on unproven assumptions and short-term trends at nesting beaches that are now protected. Nonetheless, all aforementioned authors have noted dramatic declines in nesting populations of leatherbacks in the Pacific Ocean, but apparently stable or increasing nesting populations in the Atlantic. Dutton *et al.* (1999) have interpreted genetic results from mtDNA sequences to indicate an evolutionary history of global extinction followed by relative rapid recolonization in terms of geological time scales.

Spotila *et al.* (1996) provided the most recent summary of the status of nesting leatherback turtles in the Atlantic Ocean. The largest nesting colonies of leatherbacks occur on the coasts of French Guiana (4,500-7,500 females per year) and Suriname, South America (600-2,000 females per year) and Gabon, West Africa (1,276-2,553 females per year. Smaller colonies occur among the Caribbean Islands, but constitute a significant aggregation when considered collectively (1,437-1,780 females per year).

Data collected at St. Croix and southeast Florida clearly indicate increasing numbers of nests for the past twenty years, though it should be noted that there was also an increase in the survey area in Florida over time (Boulon et al. 1996, Meylan et al. 1995, Florida Fish and Wildlife Conservation Commission 2000[9]) (Figs. 7, 8). There was an annual increase in the number of leatherback nests for all Suriname beaches during the early to mid-1980's with a subsequent annual decline since then to the present (Fig. 7). It is not known if there is a natural cycle in annual nesting. Schulz (1975) describes cycles of 10 years in the accretion and erosion of Guyana beaches which might explain the cycle observed in nesting over the past 30 years. Analysis of annual trends in numbers of nests is further complicated by the fact that, in the absence of data for a given year, the number of nests were estimated from one nesting beach to another giving a correlation in the number of nests among the three localities. Ya:lima:po and Galibi beaches are separated by the estuary of the Marowijne River (approximate width of 8 km), and it has been suggested that leatherback females may shift their nesting efforts to Suriname beaches owing to erosion at those in French Guiana (Pritchard and Trebbau 1984, Reichart and

[9] Florida Fish and Wildlife Commission. 2000. Southeast Florida Nesting Activity of the Leatherback Turtle. Florida Marine Research Institute. www.fmri.usf.edu/turtle/nesting/seleath.htm

Fretey 1993). Data collected at Ya:lima:po during 1992-97 suggest a steady decline in the number of nests, and, if turtles are shifting their nesting efforts, one would expect a comparable number of nests to occur elsewhere during this period. Such a trend is not apparent, but the data for Galibi during 1990-1994 and 1996-1997 were estimated. A decline in leatherback nests was also observed from 1985 to 1992 at the beaches of Matapica, located west of Galibi. Therefore, given these data, it is not clear whether the recent decline recorded at Ya:lima:po represents a real decrease in the nesting population or a possible shift to other beaches that somehow has not been observed or reported.

Nesting data from selected beaches were analyzed to estimate changes in nesting activity over time for leatherbacks (Appendix 1). The data were limited to sites where surveys were believed to have been relatively constant over time. It is an unweighted analysis and does not consider the beaches' relative contribution to the total nesting activity of the subpopulation and must be interpreted with some caution. This analysis treats nesting beaches as random samples from the total. For analysis of regional trends, nesting data from leatherbacks was separated into three areas: South America, St. Croix (U.S. Virgin Islands), and Florida.

For data from 1979 on from St. Croix the trend is increasing at 7.5% per year ($r = 0.078$; SE = 0.014). For data from 1979 on from Florida, several models were applied and the resulting trends ranged from 9.1% per year ($r = 0.095$; SE = 0.049) to 11.5% per year ($r = 0.122$; SE = 0.053). Only data from 1987 and on were used for South America. Depending on how the error variance was handled in the model, results here showed declining trends at –17.3% per year ($r = -0.190$; SE = 0.06) and –15.0% per year ($r = -0.163$; SE = 0.041). See Appendix 1 for details of the analyses and specific beach site used.

It is important to note that nesting trends may reflect trends in adult females in a population however it may not predict overall population trends well as adult females may account for only a small proportion of the population.

Age and Growth

The duration between hatchling and adulthood is unknown for leatherback turtles. The only information on the growth of leatherback turtles is from captive juvenile specimens, but none have been raised to maturity as captive leatherbacks experience high mortality. The limited data available for captive specimens suggest the leatherback grows much more rapidly than the cheloniid turtles and sexual maturity may therefore be obtained in a relatively short time (2-3 years; (Pritchard and Trebbau 1984). Patterns of skeletal growth support this hypothesized duration, prompting Rhodin (1985) to propose that leatherback turtles may attain sexual maturity in 3-6 years. Zug and Parham (1996) conducted a skeletochronological analysis of specimens collected from the eastern Pacific and calculated an average age to maturity of 13-14 years. For conservation management purposes, the authors indicated that 9 years is a likely minimum age to maturity for leatherback turtles based on the youngest adult in their sample. Zug and Parham (1996) also noted that the carapace lengths of their east Pacific samples were significantly smaller than those from the Atlantic, as suggested by Pritchard and Trebbau (1984), but emphasized the difficulties in comparing different populations owing to the variety of measuring techniques used by different investigators and the lack of conversions between techniques. A short generation time suggests that declines in population should be measurable on nesting beaches relatively rapidly. The shorter the generation time, the more likely protective measures will quickly stabilize and reverse declines in populations.

Population Analysis and Vital Rates

In an analysis of the literature, there is a reasonable amount of information on leatherback sea turtle fecundity (Table 1) and an estimate of this value could be made for incorporation into a population model. However, in previous sea turtle models, fecundity and the egg/hatchling stage typically have low elasticities, in other words, changes in these values has little impact on population trends (Crouse *et al*. 1987, Crowder *et al*. 1994). Juvenile and adult survival rates and age-at-maturity are the important parameters and as yet there is little information for these vital rates. As discussed in the section on Age and Growth, there is a great deal of uncertainty about individual leatherback growth rates. Estimates span from as little as 3-6 years (Rhodin 1985) to 13-14 years (Zug and Parham 1996). For survival rates, Dutton *et al.* (1999) provide an estimate of adult mortality based on whether or not a tagged female returned to nest within 5 years (considered the maximum remigration interval). The range in their estimates is extreme, 19 to 49%. We have no information on any other vital rates, particularly lacking is any information about the in-water juvenile stages.

Given the degree of uncertainty in what information there is, combined with a lack of any information about the in-water stages, and what is not yet known about the life history of the leatherback sea turtle, it is not possible to proceed with a stock assessment based on a quantitative population model. Specific directions of research needed are:

- Further studies on age and growth with emphasis on the juvenile stage/s.
- A comprehensive analysis of adult mortality based on nesting beach surveys.
- An understanding of habitat utilization by all stages with consideration of the habitat specific mortality factors.

Sex Ratios

Studies at nesting beaches have shown that the sex ratio for hatchling leatherback turtles varies with location, season, and year (Leslie *et al.* 1996). In Suriname, Mrosovsky *et al.* (1984) determined that more males were produced at the beginning of the nesting season during the wetter, cooler months and more females at the end during the drier, warmer months. An overall sex ratio of 49% female was calculated, but the authors cautioned that sand temperatures on the beach and distribution of the nests might vary from year to year. Dutton *et al.* (1992)[10] proposed a similar seasonal shift in the sex ratio of hatchlings at St. Croix and estimated an overall sex ratio of 60-70% female. Perhaps this female biased ratio has resulted in the increased numbers of adult females nesting at this locality as illustrated in the previous section on Population Size and Status. Leslie *et al.* (1996) estimated male biased sex ratios for leatherback nests at Tortuguero, Costa Rica, but predicted a shift to female biased ratios when considering metabolic heating within the nest.

[10] Dutton, P.H., D.L. McDonald, and R.H. Boulon. 1992. Tagging and nesting research on leatherback sea turtles (Dermochelys coriacea) on Sandy Point, St. Croix, U.S. Virgin Islands. Annual Report to the U.S. Fish and Wildlife Service, 26pp.

The Sea Turtle Stranding and Salvage Network database[7] was examined to determine the sex ratio of leatherback sea turtles found in the waters off of the U.S. Gulf of Mexico and Atlantic coasts. It is possible that adult females utilize nearshore habitats in greater proportion than adult males due to the necessity of coming ashore to nest, whereas juvenile habitat utilization is not likely to be sex dependent. To obtain an unbiased estimate, only records for juveniles were included in the analysis where sex was determined via examination of the gonads. An animal was considered a juvenile if it was less than 145 cm CCL (Eckert 1999*a*), and records were excluded for animals greater than or equal to this size. In addition, many of the STSSN records for leatherback turtles list only straight-line carapace length (SCL) and many of these are known to be inaccurate owing to the limited size range of measuring calipers. To be conservative, records greater than or equal to 80 cm SCL (80 cm being the maximum length measured by most calipers available to stranding observers) were excluded when only a SCL was recorded. Of the juvenile leatherback sea turtles that stranded along the U.S. Gulf of Mexico and Atlantic coasts between 1980 and 1999, 28 were identified by necropsy as female and 20 as male giving a sex ratio of 1.4F:1.0M (or 58.3% female).

Strandings

Complete strandings information for leatherback sea turtles are provided in Table 2. As with the analysis of strandings of loggerhead sea turtles (TEWG 1998, 2000), the leatherback strandings used excluded incidental captures, post-hatchlings, or cold-stunned animals. Figure 9 depicts the leatherback strandings reported by area and season, 1986-1999. Figure 10 shows the statistical zones for which sea turtle strandings are reported. Monitoring effort is not directly comparable between zones but has been reasonably consistent over this period. There is no survey effort in zones 15 and 16, due to inaccessibility of shoreline, and coverage is low in zones 13 and 14. In the eastern Gulf of Mexico (zones 1-12, partial 24-25), survey coverage is low in zones 1, 3, 6, and 7 due to inaccessibility and zone 2 has very little land mass. The lack of data from these zones may or may not reflect a lack of strandings. Along the southeast U.S. Atlantic coast, coverage is also low in zones 24 and 25. In the northeastern U.S. Atlantic, survey coverage is less rigorous. However, high human densities along the coast in this area suggests most strandings will get reported. This is not true for inshore waters, such as the Chesapeake Bay and Pamlico and Core Sounds of North Carolina, where many strandings likely go unreported.

Trends

Table 2 shows leatherback strandings by region for the years 1986-1999. Over this 14-year period, the northeast (45%) and the southeast (42%) accounted for the majority of the strandings totals, with 13% of the strandings occurring in the Gulf of Mexico. In the northeast, strandings peaked in 1987 (80), 1993 (80) and again in 1995 (117 - a 46% increase over the 1987 and 1993 strandings' peaks). Most of the leatherback strandings (95%) in the northeast occurred in the summer and fall, with fewer strandings in the winter (3%) and spring (2%). Strandings in the southeast increased from 1986-1991, then began a gradual decrease until 1999 when levels were elevated again. Leatherback strandings in the southeast were highest during the spring (45%) and somewhat equally represented during the summer (15%), fall (21%), and winter (19%). Strandings in the Gulf of Mexico remained relatively low throughout the time period with only minor peaks in strandings in 1989 in the eastern Gulf and 1995 and 1999 in the western Gulf. Overall strandings in the Gulf were much higher in the spring and summer, accounting for 88% of the total number of strandings in that area.

Hot Spots

The majority of leatherback strandings were about equally divided between the northeast (45%) and the southeast (42%). One potential source for the strandings in the northeast might be entanglement in fishing gear which seems to pose more of a problem in the northeast than in other states. According to STSSN strandings data[7] for 1980-1999, 62% (N=48) of stranded leatherback sea turtles which had evidence of entanglement in fishing gear, occurred in northern states (Virginia to Maine) while 18% (N=14) occurred in southern states (Florida's east coast to North Carolina) and 19% (N=15) occurred in Gulf states (Florida's west coast to Texas). Entanglement was cited as the major cause of leatherback strandings in Massachusetts (Prescott 1988; R. Prescott personal communication[11]) and New York (S. Sadove personal communication[12]) (See entanglement under Anthropogenic Impacts section). Likewise, ingestion of marine debris may pose more of a threat to leatherbacks in the northeast than anywhere else in the United States. An analysis of the STSSN strandings data[7] from 1980-1999 revealed a majority (72%) (N=26) of stranded leatherback sea turtles which had ingested marine debris or fishing gear occurred in northern states (Virginia to Maine) than in southern (Florida's east coast to North Carolina)(25%) (N=9) or Gulf states (Florida's west coast to Texas) (3%) (N=1). (See marine debris ingestion under Anthropogenic Impacts section) Most of the leatherback strandings in the southeast (66%) (N=435) occurred during the spring and fall while relatively high strandings in the western Gulf (76%) (N=97) occurred during the spring, coinciding with nearshore shrimp trawling activity. In 1995, the NMFS, in cooperation with the U.S. Fish and Wildlife Service, Florida, Georgia and South Carolina, developed the Leatherback Contingency Plan in order to reduce leatherback mortality in shrimp trawls. This plan enabled the NMFS to establish leatherback conservation zone regulations (50 CFR 223.206) in 1995 which stipulated the use of weekly aerial surveys to enumerate concentrations of leatherback sea turtles along the coast from Cape Canaveral, Florida to the N.C./Va. border. If concentrations of leatherbacks were high (10 sea turtles/50 nautical miles), then the area was closed to shrimp trawlers not using a TED modified with the leatherback exit opening. Although the Leatherback Contingency Plan was developed in order to prevent leatherback sea turtles migrating northward from becoming incidentally captured in shrimp trawlers, high strandings of leatherbacks in Florida and Texas have prompted the NMFS to impose emergency measures to protect leatherback sea turtles in additional areas and times. From October 28 to November 29, 1999, a total of 15 leatherback turtles washed ashore in southern Florida (statewide annual number of leatherbacks strandings has averaged 23 over the past 10 years). Consequently, the NMFS imposed a 30 day restriction requiring all shrimp vessels operating in the area to use a TED with an escape opening large enough to exclude leatherback turtles (64 FR 69416-69418, December

[11] Robert Prescott, Massachusetts Audubon Society's Wellfleet Bay Wildlife Sanctuary, South Wellfleet, Mass., personal communication (E-mail) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 1, 2000.

[12] Sam Sadove, Long Island University, Southampton College, Southampton, NY, personal communication (phone) to Joanne Braun-McNeill, December 6, 2000.

13, 1999). Likewise, during the spring of 2000, after a record 9 leatherbacks stranded along the Texas coast in a 6 week period (statewide annual number of leatherbacks strandings has averaged 12 over the past 6 years), the NMFS required shrimpers trawling off the coast of Texas to use a TED with an escape opening large enough to exclude leatherbacks for a 30 day period (65 FR 24132-24134, April 25, 2000).

Anthropogenic Impacts

Pelagic Longline Fisheries

See Part III.

Marine Debris Ingestion

Leatherback sea turtles might be more susceptible to marine debris ingestion than other species due to their pelagic existence and the tendency of floating debris to concentrate in convergence zones which adults and juveniles use for feeding areas and migratory routes (Lutcavage *et al*. 1997; Shoop and Kenney 1992). Investigations of the stomach contents of leatherback sea turtles revealed that a substantial percentage (44% of the 16 cases examined) contained plastic (Mrosovsky 1981). Along the coast of Peru, intestinal contents of 19 of 140 (13%) leatherback carcasses were found to contain plastic bags and film (Fritts 1982). The presence of plastic debris in the digestive tract suggest that leatherbacks might not be able to distinguish between prey items and plastic debris (Mrosovsky 1981). Balazs (1985) speculated that the object may resemble a food item by its shape, color, size or even movement as it drifts about and induce a feeding response. Although necropsies conducted between 1980 and 1992 by the Sea Turtle Stranding and Salvage Network (STSSN)[7] participants showed that leatherbacks were more likely to ingest marine debris in the southeastern U.S., it was noted that leatherbacks also consume plastic bags in the northeastern U.S. (Witzell and Teas 1994). When more recent data were included through 1999, the majority of leatherbacks which had ingested marine debris or fishing gear occurred from Virginia through Maine (see Hotspots). Of the 33 leatherbacks that were necropsied in New York, plastic bags were found in 10 animals (Sadove and Morreale 1990).

Entanglement

Sea turtles entangled in fishing gear generally have a reduced ability to feed, dive, surface to breathe or perform any other behavior essential to survival (Balazs 1985). They may be more susceptible to boat strikes if forced to remain at the surface, and entangling lines can constrict blood flow resulting in necrosis (*Ibid.*). Leatherbacks seem more likely to become entangled in fishing gear than other species. Leatherback entanglement in longline fishing gear is discussed in Part III, Chapter 7. The fish trap fishery, operating in Rhode Island from March through December, is known to capture sea turtles. Leatherbacks have been captured alive in large fish traps set off Newport - most are reported to be released alive (Anonymous 1995[13]). Of the

[13] Anonymous. 1995. State and federal fishery interactions with sea turtles in the mid-Atlantic area, p.1-12. In Proceedings of the Workshop of the Management and Science Committee of the Atlantic States Marine Fisheries Commission July 17-18, Richmond, Virginia.

approximately 20 live, entangled sea turtles reported in the National Marine Fisheries Service (NMFS) Northeast Region Stranding Network, the majority are leatherback sea turtles entangled in pot gear in New England waters. The leatherbacks become entangled in the buoy line and/or ground line, possibly mistaking the buoys for cannonball jellyfish (Anonymous 1995[13]). Massachusetts, Rhode Island, Connecticut, and New York all have active lobster pot fisheries which can entangle leatherbacks (Anonymous 1995[13]). Entanglement in lobster pot lines was cited as the leading determinable cause of adult leatherback strandings in Cape Cod Bay, Massachusetts (Prescott 1988; R. Prescott personal communication[11]). During the period 1977-1987, 89% of the 57 stranded adult leatherbacks were the result of entanglement (Prescott 1988). Likewise, during the period 1990-1996, 58% of the 59 stranded adult leatherbacks showed signs of entanglement (R. Prescott personal communication[11]). Many of the stranded leatherbacks for which a direct cause of death could not be documented showed evidence of rope scars or wounds and abraded carapaces, implicating entanglement (*Ibid.*). Entanglement in fishing gear, namely the lobster fishery, was cited as the major cause of leatherback and loggerhead sea turtle strandings in New York (S. Sadove personal communication[12]). In the Southeast U.S. Mid-Atlantic waters, the blue crab fishery is another potential source of leatherback entanglement. In North Carolina, two leatherback sea turtles were reported entangled in a crab pot buoy inside Hatteras Inlet (D. Fletcher personal communication[14]). A third leatherback was reported entangled in a crab pot buoy in Pamlico Sound off of Ocracoke . This turtle was disentangled and released alive, however, lacerations on the front flippers from the lines were evident (D. Fletcher personal communication[15]). Leatherbacks become entangled in Florida's lobster pot and stone crab fisheries also, as documented on stranding forms[7]. Although not documented as the major cause of leatherback strandings in the U.S. Virgin Islands for the time period 1982 to 1997 (1 of 5 leatherbacks stranded due to entanglement out of a total of 122 strandings) (Boulon 2000), leatherbacks have been observed with their flippers wrapped in the line of West Indian fish traps (R. Boulon personal communication[16]). STSSN leatherback strandings[7] for 1980-1999 documented significantly more strandings as a result of entanglement in the northern states (Virginia to Maine)(62%) than southern (Florida's east coast to North Carolina)(18%) or Gulf states (Florida's west coast to Texas) (19%). The majority (67%) of these strandings were the result of being entangled in crab or lobster trap lines; additional sources of entanglement included being entangled in fishing line or nets or having a hook in the mouth or flipper.

Gill Nets

Leatherback sea turtles also are vulnerable to capture in gill nets. Gill net fisheries operating in the nearshore waters of the mid-Atlantic states are likely to take leatherbacks since these fisheries and leatherbacks can co-occur, however, there is very little quantitative data on capture rate and mortality. According to the NMFS Northeast Fisheries Science Center Fisheries

[14] David Fletcher, N.C. Division of Marine Fisheries, Ocracoke, N.C., personal communication to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Beaufort, N.C., September 19, 1990.

[15] David Fletcher, N.C. Division of Marine Fisheries, Ocracoke, N.C., personal communication to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Beaufort, N.C., September 3, 1989.

[16] Rafe Boulon, Virgin Islands National Park, U.S.V.I., personal communication (E-mail) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 7, 2000.

Observer Program, in 1994, 2 live and 2 dead leatherback sea turtles were reported incidentally captured in drift gill nets set in offshore waters from Maine to Florida (with 56% observer coverage); in 1995, 15 live and 12 dead leatherback sea turtles were reported (70% coverage); in 1996 1 live leatherback was reported (54% coverage); in 1998, 3 live and 2 dead leatherbacks were reported (92% coverage)[17].

The NMFS Northeast Fisheries Science Center, Fisheries Observer Program also had observers on the bottom coastal gill net fishery which operates in the mid-Atlantic, but no takes of leatherback sea turtles were observed from 1994-1998. Observer coverage of this fishery, however, ranged from <1% to 5%. In North Carolina, a leatherback was reported captured in a gill net set in Pamlico Sound at the north end of Hatteras Island in the spring of 1990 (D. Fletcher personal communication[14]). It was released alive by the fishermen after much effort. Five other leatherbacks were released alive from nets set in North Carolina during the spring months: one was from a net (unknown gear) set in the nearshore waters near the North Carolina/Virginia border (1985)[7]; two others had been caught in gill nets set off of Beaufort Inlet (1990)[18]; a fourth was caught in a gill net set off of Hatteras Island (1993)[7]; and a fifth was caught in a sink net set in New River Inlet (1993) (*Ibid.*). In September of 1995, however, two dead leatherbacks were removed from a large (11 inch) monofilament shark gill net set in the nearshore waters off of Cape Hatteras, North Carolina (*Ibid.*).

Gill nets set in northwest Atlantic coastal waters are reported to routinely capture leatherback sea turtles (Goff and Lien 1988; Goff *et al.* 1994; Anonymous 1996[19]). Leatherbacks often drown in fish nets set in coastal waters of Sao Tome, West Africa (Castroviejo *et al.* 1994; Graff 1995[1]). Gill nets are one of the suspected causes for the decline in the leatherback sea turtle population in French Guiana (Chevalier *et al.* 1999).

In the waters of coastal Nicaragua, gill nets targeting green and hawksbill turtles also incidentally catch leatherback turtles (Lagueux *et al.* 1998). An estimated 1,000 mature female leatherback sea turtles are caught annually off of Trinidad and Tobago with mortality estimated to be between 50-95% (Eckert and Lien 1999). Many of the turtles do not die as a result of drowning, but rather because the fishermen butcher the turtles in order to get them out of their nets (*Ibid.*).

Trawls

The National Research Council Committee on Sea Turtle Conservation identified incidental capture in shrimp trawls as the major anthropogenic cause of sea turtle mortality (National Research Council 1990). Although federal regulations requiring TEDs in trawls were

---

[17] Unpublished data, National Marine Fisheries Service, NEFSC, Woods Hole, Mass., Personal Communication (Fax) from Richard Merrick to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., November 28, 2000.

[18] Unpublished data, Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., personal communication.

[19] Anonymous. 1996. North Atlantic leatherback turtle workshop. November 22, 1996. Life Sciences Center, Dalhousie University, Halifax, Nova Scotia, 266pp.

fully implemented in May 1991 and U.S. sea turtle strandings have declined since then (Crouse, Crowder and Heppell *unpubl*. as cited by Crowder *et al*. 1995), trawls equipped with TEDs are still taking large immature and adult loggerhead and green sea turtles (Epperly and Teas 1999[20]) and leatherbacks (Henwood and Stuntz 1987).

As leatherbacks make their annual spring migration north, they are likely to encounter shrimp trawls working in the nearshore waters off the Atlantic coast. Although the Leatherback Contingency Plan was developed to protect migrating leatherbacks from being incidentally captured and killed in shrimp trawls (see summary of these regulations in the Strandings Section), the NMFS has also had to implement additional leatherback protections outside of the contingency plan, through emergency rules in response to high strandings of leatherbacks in Florida and Texas. Because of these high leatherback strandings occurring outside the leatherback conservation zone, the lack of aerial surveys conducted in the fall, the inability to conduct required replicate surveys due to weather, equipment or personnel constraints, and the possibility that a 2 week closure was insufficient to ensure that leatherbacks had vacated the area, the NMFS published an Advanced Notice of Proposed Rulemaking in April 2000 (65 FR 17852-17854, April 5, 2000) indicating that NMFS was considering publishing a proposed rule to provide additional protection for leatherback turtles in the shrimp fishery. In the interim, the NMFS has requested all shrimp trawlers to use TEDs modified to release leatherback sea turtles along the east coast of Florida to the Georgia/Florida border through the end of March 2000 (December 11, 2000 NR00-061[21]). This request would likely protect leatherbacks during the winter Florida shrimp season that tend to stay in this area until the start of the spring migration.

Turtle excluder devices are required in the Mid-Atlantic winter trawl fishery for summer flounder in waters south of Cape Charles, Va., however, these small TEDs can not exclude leatherback sea turtles. Although not documented, it is suspected that this fishery may take turtles to the north of Cape Charles where TEDs are not required. In Rhode Island, leatherbacks are occasionally taken by trawlers targeting scup, fluke and monkfish in state waters (Anonymous 1995[13]). It is likely that leatherbacks may be taken by trawlers operating off of other Mid-Atlantic waters. Observers on board shrimp trawlers operating in the northeastern region of Venezuela documented the capture of 48 sea turtles, of which 6 were leatherbacks, from 13, 600 trawls (Marcano and Alio 2000). They estimated annual capture of all sea turtle species to be 1370 with an associated mortality of 260 turtles, or about 19%.

Other Fisheries

In North Carolina, one leatherback was captured in a channel net set in Core Sound while another was hooked by someone fishing with rod and reel in Core Sound[22]; both of these

[20] Epperly, S.P. and W.G. Teas. 1999. Evaluation of TED opening dimensions relative to size of turtles stranding in the Western North Atlantic. U.S. Department of Commerce, National Marine Fisheries Service SEFSC Contribution PRD-98/99-08, Miami, Fla, 31pp.

[21] News release, NR00-061, National Marine Fisheries Service, Southeast Regional Office, St. Petersburg, Fla., December 11, 2000.

[22] Unpublished data, Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., personal communication.

incidental captures occurred during the late spring when leatherbacks are migrating north. In Virginia, two leatherbacks have been reported involved with pound nets during the summer, one was entangled in the leader and one was inside the net; both were released alive[7]. In Sao Tome, West Africa, hawksbill, green and leatherback sea turtles are captured and eaten (Graff 1995[1]). Fisheries (turtle nets, spear gun, longlines) targeting green and hawksbill turtles in St. Vincent and the Grenadines will catch a few leatherback sea turtles also each year (Scott and Horrocks 1993).

Poaching

In the U.S. Virgin Islands, some poaching is still occurring, both of juveniles and adults in the water and of the eggs on the beach (R. Boulon personal communication[16]). In a summary of strandings data from 1982 - 1997 for St. Croix, St. Thomas and St. John, all leatherback strandings (5 out of a total of 122 strandings) were reported on St. Croix, and most (4 of the 5 strandings) were the result of poaching (Boulon 2000). Leatherback nests are commonly relocated at Sandy Point on St. Croix to reduce the nest loss due to beach erosion, but also to protect nests from poaching (R. Boulon personal communication[16]). There have been a few recorded cases of fishermen killing leatherbacks in Puerto Rico, however, most of the poaching is of the eggs (C. Diez personal communication[23]).

In Ghana, it is estimated that two-thirds of the leatherback sea turtles that come up on the beach are killed by the local fishermen[24]. Nesting leatherback turtles are captured and eaten in Sao Tome, West Africa (Castroviejo *et al.* 1994, Graff 1995[1]), St. Kitts and Nevis (Eckert and Honebrink 1992), and St. Lucia (d'Auvergne and Eckert 1993). The illegal harvest of leatherback eggs is considered to be a serious threat to the nesting population at Tortuguero, Costa Rica (Campbell *et al.* 1996). They estimate that at least 75% of all clutches from the beaches near Tortuguero, Parismina, and Jalova were harvested (*Ibid.*). From aerial surveys conducted in 1982, it was apparent that the fishermen were killing most of the turtles nesting on Almond Beach, in the North-West District of Guyana, and likely that all of the eggs were being harvested (Hart 1984). An estimated 80% of nesting females are killed each year in Guyana (Pritchard 1986[25]).

Boat Strikes

Boat strikes are not a significant source of mortality for leatherbacks in the northeast U.S. (S. Sadove personal communication[12]) or in the Caribbean (R. Boulon personal communication[16]). According to 1980-1999 STSSN strandings data[7], however, the number of leatherback strandings involving boat strikes or collisions (231) was considerably greater than the number of strandings involving entanglement in fishing gear (81), ingestion of marine debris (36) or some kind of intentional interaction - gaff wounds or rope deliberately tied to a flipper (21) combined. It should be noted that it is not known whether the boat strikes were the cause of

[23] Carlos Diez, Programa de Especies Protegidas DRNA-PR, San Juan, Puerto Rico, Personal Communication (Phone) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 7, 2000.

[24] BBC News, Saving the giant sea turtle. Africa Section:Thursday, 20 July, 2000.

[25] Pritchard, P.C.H. 1986. Unpublished manuscript, Sea turtles in Guyana. Florida Audubon Society, 14pp.

death or whether they occurred post-mortem. Interestingly, strandings as a result of boat strikes were equally represented (45%) in northern states (Virginia to Maine) and southern states (Florida's east coast to North Carolina), with Gulf states (Florida's west coast to Texas) contributing 10%. The states where the majority of boat strike related strandings occurred were the Atlantic ocean side of Florida (20%), North Carolina (17%) and New Jersey (15%).

Literature Cited

Binckley, C.A., J.R. Spotila, K.S. Wilson and F.V. Paladino. 1998. Sex determination and sex ratios of Pacific leatherback turtles, *Dermochelys coriacea*. Copeia 1998(2):291-300.

d'Auvergne, C. and K.L. Eckert. 1993. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST). Sea turtle recovery action plan for St. Lucia. Caribbean Environment Program Technical Report 26:70 pp. United Nations Environmental Programme, Kingston, Jamaica.

Bacon, P.R. 1981.The status of sea turtle stocks management in the western Central Atlantic. Western Central Atlantic Fisheries Commission (WECAF) Studies No. 7, 38 pp.

Balazs, G.H. 1985. Impact of ocean debris on marine turtles: entanglement and ingestion. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-54:387-429.

Barbosa, C., A. Broderick, and P. Catry. 1998. Marine turtles in Orango National Park (Bijagós Archipelago, Guinea-Bissau). Marine Turtle Newsletter 81:6-7.

Barnard, D.E., J.A. Keinath, and J.A. Musick. 1989. Distribution of ridley, green and leatherback turtles in Chesapeake Bay and adjacent waters. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-232:201-203.

Bleakney, J.S. 1965. Reports of marine turtles from New England and Eastern Canada. Canadian Field-Naturalist 79:120-128.

Boulon, Jr., R. 2000. Trends in sea turtle strandings, U.S. Virgin Islands: 1982 to 1997. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-436:261-263.

Boulon, R.H., Jr., P.H. Dutton, and D.L. McDonald. 1996. Leatherback turtles (*Dermochelys coriacea*) on St. Croix, U.S. Virgin Islands: fifteen years of conservation. Chelonian Conservation and Biology 2:141-147.

Brongersma, L.D. 1972. European Atlantic turtles. Zoologische Verhandelingen. 121:1-318.

Brongersma, L.D. 1982. Marine turtles of the eastern Atlantic Ocean. In K.A. Bjorndal, ed. Biology and Conservation of Sea Turtles, p. 407-416. Washington DC, Smithsonian Institution Press, Washington, D.C.

Campbell, C.L., C.J. Lageux, J.A. Mortimer. 1996. Leatherback turtle, *Dermochelys coriacea*, nesting at Tortuguero, Costa Rica, in 1995. Chelonian Conservation and Biology 2:169-172.

Carr, T. and N. Carr. 1991. Surveys of the sea turtles of Angola. Biological Conservation 58:19-29.

Castroviejo, J., J.B. Juste, J.P. Del Val, R. Castelo, and R. Gil. 1994. Diversity and status of sea turtle species in the Gulf of Guinea islands. Biodiversity and Conservation 3:828-836.

Chevalier, J., X. Desbois, and M. Girondot. 1999. The reason for the decline of leatherback turtles (*Dermochelys coriacea*) in French Guiana: a hypothesis p.79-88. In Miaud, C. and R. Guyétant (eds.), Current Studies in Herpetology, Proceedings of the ninth ordinary general meeting of the Societas Europea Herpetologica, 25-29 August 1998 Le Bourget du Lac, France.

Chevalier, J. and Girondot, M. 2000. Recent population trend for *Dermochelys coriacea* in French Guiana: U.S. Department Commerce, NOAA Technical Memorandum NMFS-SEFSC-436:56-57.

Collard, S.B. 1990. Leatherback turtles feeding near a water mass boundary in the eastern Gulf of Mexico. Marine Turtle Newsletter 50:12-14.

Crouse, D.T., L.B. Crowder, H. Caswell. 1987. A stage-based population model for loggerhead sea turtles and implications for conservation. Ecology 68:1412-1423.

Crowder, L.B., D.T. Crouse, S.S. Heppell, and T.H. Martin. 1994. Predicting the impact of turtle excluder devices on loggerhead sea turtle populations. Ecological Applications 4:437-445.

Crowder, L. B, S. R. Hopkins-Murphy, and J. A. Royle. 1995. The effects of turtle excluder devices (TEDs) on loggerhead sea turtle strandings with implications for conservation. Copeia 1995:773-779.

Den Hartog, J.C. 1980. Notes on the food of sea turtles: *Eretmochelys imbricata* (Linnaeus) and *Dermochelys coriacea* (Linnaeus). Netherlands Journal of Zoology 30:595-610.

Den Hartog, J.C. and M.M. Van Nierop. 1984. A study on the gut contents of six leathery turtles *Dermochelys coriacea* (Linnaeus) (Reptilia:Testudines: Dermochelyidae) from British waters and from the Netherlands. Zoologische Verhandelingen. 209:3-36.

Dutton, D.L., P.H. Dutton, and R. Boulon. 2000. Recruitment and mortality estimates for female leatherbacks nesting in St. Croix, U.S. Virgin Islands. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-443:268-269.

Dutton, P.H. 1996. Use of molecular markers for stock identification, fingerprinting, and the study of mating behavior in leatherbacks. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-SEFSC-396:79-86.

Dutton, P.H., B.W. Bowen, D.W. Owens, A. Barragan, and S.K. Davis. 1999. Global phylogeography of the leatherback turtle (*Dermochelys coriacea*). Journal of Zoology 248:397-409.

Dutton, P. and D. McDonald. 1995. Hatch rates of leatherback (*Dermochelys coriacea*) clutches reburied with and without yolkless eggs. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-361:177-178.

Eckert, K.L. 1987. Environmental unpredictability and leatherback sea turtle (*Dermochelys coriacea*) nest loss. Herpetologica 43(3):315-323.

Eckert, K.L. 2000. Status and distribution of the leatherback sea turtle, *Dermochelys coriacea*, in the wider Caribbean region, 10 pp. In K.L. Eckert and F.A. Abreu-G. (eds.), Proceedings of the Regional Meeting: "Marine Turtle Conservation in the Wider Caribbean Region – A Dialogue for Effective Regional Management", Santo Domingo, 16-18 November 1999. WIDECAST, IUCN-MTSG, WWF and UNEP-CEP.

Eckert, K.L and T.D. Honebrink. 1992. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST) sea turtle recovery and action plan for St. Kitts and Nevis. Caribbean Environment Program Technical Report 17;116p. United Nations Environmental Programme, Caribbean Environment program, Kingston, Jamaica.

Eckert, S.A. 1998. Perspectives on the use of satellite telemetry and other electronic technologies for the study of marine turtles, with reference to the first year long tracking of leatherback sea turtles. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-SEFSC-415:44-46.

Eckert, S.A. 1999*a*. Global distribution of juvenile leatherback sea turtles. Hubbs Sea World Research Institute Technical Report 99-294, 13p.

Eckert, S.A. 1999*b*. Habitats and migratory pathways of the Pacific leatherback sea turtle. Hubbs Sea World Research Institute Technical Report 99-290, 15p.

Eckert, S.A. and J. Lien. 1999. Recommendations for eliminating incidental capture and mortality of leatherback turtles, *Dermochelys coriacea*, by commercial fisheries in Trinidad and Tobago. A report to the Wider Caribbean Sea Turtle Conservation network (WIDECAST). Hubbs-Sea World research Institute Technical Report No. 2000-310, 7pp.

Fretey, J. and N. Girardin. 1989. La nidification de la tortue luth, *Dermochelys coriacea* (Vandelli, 1761) (Chelonii, Dermochelyidae) sur les côtes du Gabon. Revue de Zoologie Africaine - Journal of African Zoology 102:125-132.

Fretey, J. and J.P. Malaussena. 1991. Sea turtle nesting in Sierra Leone, West Africa. Marine Turtle Newsletter 54:10-12.

Fritts, T.H. 1982. Plastic bags in the intestinal tracts of leatherback marine turtles. Herpetological Review 13(3):72-73.

Fritts, T.H., W. Hoffman, and M.A. McGehee. 1983. The distribution and abundance of marine turtles in the Gulf of Mexico and nearby Atlantic waters. Journal of Herpetology 17:327-344.

Girondot, M and J. Fretey. 1996. Leatherback turtles, *Dermochelys coriacea*, nesting in French Guiana, 1978-1995. Chelonian Conservation and Biology 2(2):204-208.

Goff, G.P. and J. Lien. 1988. Atlantic leatherback turtles, *Dermochelys coriacea*, in cold water off Newfoundland and Labrador. Canadian Field-Naturalist 102:1-5.

Goff, G.P., J. Lien, G.B. Stenson, and J. Fretey. 1994. The migration of a tagged leatherback turtle, *Dermochelys coriacea*, from French Guiana, South America to Newfoundland, Canada in 128 days. Canadian Field-Naturalist 108:72-73.

Grant, G.S., H. Malpass, and J. Beasley. 1996. Correlation of leatherback turtle and jellyfish occurrence. Herpetological Review 27:123-125.

Hart, S. 1984. The National Report for the Country of Guyana to the Western Atlantic Turtle Symposium, p.209-215. In P. Bacon et al. (eds.), Proceedings of the Western Atlantic Turtle Symposium, 17-22 July 1983, San Jose, Costa Rica. Vol. 3, Appendix 7. University of Miami Press, Miami, Florida.

Henwood,T. and W.E. Stuntz. 1987. Analysis of sea turtle captures and mortalities during commercial shrimp trawling. Fishery Bulletin 85:813-817.

Hildebrand, H.H. 1982. A historical review of the status of sea turtle populations in the western Gulf of Mexico p.447-454. In K.A. Bjorndal, ed. Biology and Conservation of sea turtles. Smithsonian Institute Press. Washington, DC.

Hoffman, W. and T.H. Fritts, 1982. Sea turtle distribution along the boundary of the Gulf Stream current off eastern Florida. Herpetologia, 38 1982:405-409.

Hughes, G.R. 1996. Nesting of the leatherback turtle (Dermochelys coriacea) in Tongaland, KwaZulu-Natal, South Africa, 1963-1995. Chelonian Conservation and Biology 2(2):153-158.

Hughes, G.R., B. Huntley, and D. Wearne. 1973. Sea turtles in Angola. Biological Conservation 5:58-59.

Hughes, G.R., P. Luschi, R. Mencacci, and F. Papi. 1998. The 7000-km oceanic journey of a leatherback turtle tracked by satellite. Journal of Experimental Marine Biology and Ecology 229:209-217.

James, M.C. 2000. Distribution of the leatherback turtle (*Dermochelys coriacea*) in Atlantic Canada: evidence from an observer program, aerial surveys and a volunteer network of fish harvesters. Masters of Science Thesis. Acadia University, Wolfville, Nova Scotia, Canada. 71 p.

Knowlton, A.R. and Weigle, B. 1989. A note on the distribution of leatherback turtles (*Dermochelys coriacea*) along the Florida coast in February 1988. NOAA Technical Memorandum, NMFS-SEFC-232:83-85.

Lagueux, C.J., C. Campbell, and L.H. Herbst, Knowlton and Weigle. 1998. Demography of marine turtles harvested by Miskitu Indians of Atlantic Nicaragua. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-412:90.

Leary, T.R. 1957. A schooling of leatherback turtles, *Dermochelys coriacea coriacea*, on the Texas coast. Copeia 1957:232.

Leslie, A.J., D.N. Penick, J.R. Spotila, and F.V. Paladino. 1996. Leatherback turtle, *Dermochelys coriacea*, nesting and nest success at Tortuguero, Costa Rica, in 1990-1991. Chelonian Conservation and Biology 2:159-168.

Lutcavage, M.E. and J.A. Musick 1985. Aspects of the biology of sea turtles in Virginia. Copeia 1985:449-456.

Lutcavage, M.E. and P. Plotkin, B. Witherington, and P.L. Lutz. 1997. Human impacts on sea turtle survival, p.387-409. In P.L. Lutz and J.A. Musick, (eds.), The Biology of Sea Turtles, CRC Press, Boca Raton, Florida. 432pp.

Marcano, L.A. and J.J. Alio-M. 2000. Incidental capture of sea turtles by the industrial shrimping fleet off northwestern Venezuela. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-436:107.

McDonald, D.L. and P.H. Dutton. 1996. Use of PIT tags and photoidentification to revise remigration estimates of leatherback turtles (Dermochelys coriacea) nesting in the U.S. Virgin Islands, 1979-1995. Chelonian Conservation and Biology 2(2):148-152.

Meylan, A., Schroeder, B. A., and Mosier, A. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. Florida Marine Research Publications No. 52, 51 pp.

Mrosovsky, N. 1981. Plastic jellyfish. Marine Turtle Newsletter 17:5-6.

Mrosovsky, N., P.H. Dutton, and C.P. Whitmore. 1984. Sex ratios of two species of sea turtle nesting in Suriname. Canadian Journal of Zoology 62: 2227-2239.

National Research Council. 1990. Decline of the Sea Turtles: Causes and Prevention, National Academy Press, Washington, D.C., 259 pp.

Paladino, F.V., M.P. O'Connor, and J.R. Spotila. 1990. Metabolism of leatherback turtles, gigantothermy, and thermoregulation of dinosaurs. Nature (London) 344:858-860.

Prescott, R.L. 1988. Leatherbacks in Cape Cod Bay, Massachusetts, 1977-1988. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-214:83-84.

Pritchard, P.C.H. 1971. The leatherback or leathery turtle, *Dermochelys coriacea*. International Union for the Conservation of Nature, Monograph Number 1: 39 pp.

Pritchard, P.C.H. 1976. Post-nesting movements of marine turtles (Cheloniidae and Dermochelyidae) tagged in the Guianas. Copeia 1976:749-754.

Pritchard, P.C.H. 1982. Nesting of the leatherback turtle, *Dermochelys coriacea*, in Pacific Mexico, with a new estimate of the world population status. Copeia 1982:741-747.

Pritchard, P.C.H. 1996. Are leatherbacks really threatened with extinction? Chelonian Conservation and Biology 2:303-305.

Pritchard, P.C.H. and P. Trebbau. 1984. Family Dermochelyidae, *Dermochelys coriacea*. In The Turtles of Venezuela, Society for the Study of Amphibians and Reptiles, Contribution to Herpetology No. 2:249-267.

Reichart, H.A. and J. Fretey. 1993. WIDECAST Sea turtle recovery action plan for Suriname (K.L. Eckert, Editor). Caribbean Environment Program Technical Report No. 24. United Nations Environmental Programme, Kingston, Jamaica. 65 p.

Rhodin, A.G.J. 1985. Comparitive chondro-osseous development and growth of marine turtles. Copeia 1985:752-771.

Ross, J.P. 1982. Historical decline of loggerhead, ridley, and leatherback sea turtles. In Bjorndal, K. A. (ed.), Biology and Conservation of Sea Turtles, p. 189-195, Smithsonian Institution Press, Washington D.C.

Ruckdeschel, C. and C.R. Shoop. 1982. *Dermochelys coriacea* (leatherback sea turtle). nesting. Herpetological Review 13:126.

Sadove, S.S. and S.J. Morreale. 1990. Marine mammal and sea turtle encounters with marine debris in the New York Bight and the northeast Atlantic. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-154:562-570.

Schroeder, B.A. and N.B. Thompson. 1987. Distribution of the loggerhead turtle *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida area: results of aerial surveys. Pp. 45-54 *In*: W.N. Witzell (editor), Ecology of east Florida sea turtles, Proceedings of the Cape Canaveral, Florida, sea turtle workshop, Miami, Florida, USA, February 26-27, 1985. U.S. Department of Commerce, NOAA Technical Report NMFS-53: 80 pp.

Schultz, J.P. 1975. Sea turtles nesting in Surinam. Zoologische Verhandelingen (Leiden), Number 143: 172 pp.

Scott, N. and J.A. Horrocks. 1993. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST) sea turtle recovery action plan for St. Vincent and the Grenadines. Caribbean Environment Program Technical Report 27:80pp. United Nations Environmental Programme, Kingston, Jamaica.

Shoop, C.R. and R.D. Kenney. 1992. Seasonal distributions and abundances of loggerhead and leatherback sea turtles in waters of the Northeastern United States. Herpetological Monographs 6:43-67.

Soto, J.M.R., R.C.P. Beheregaray, and R.A.R. De P.Rebello. 1997. Range extension: nesting by *Dermochelys* and *Caretta* in southern Brazil. Marine Turtle Newsletter 77:6-7.

Spotila, J.R., A.E. Dunham, A.J. Leslie, A.C. Steyermark, P.T. Plotkin, and F.V. Paladino. 1996. Worldwide population decline of *Dermochelys coriacea*: are leatherback turtles going extinct? Chelonian Conservation and Biology 2:209-222.

Starbird, C.H., A. Baldridge, and J.T. Harvey. 1993. Seasonal occurrence of leatherback sea turtles (*Dermochelys coriacea*) in the Monterey Bay region, with notes on other sea turtles, 1986-1991. California Fish and Game 79:54-62.

Steyermark, A.C., K.Williams, J.R. Spotila, F.V. Paladino, D.C. Rostal, S.J. Morreale, M.T. Koberg, and R Arauz. 1996. Nesting leatherback turtles at Las Baulas National Park, Costa Rica. Chelonian Conservation and Biology 2(2):173-183.

Thompson, N.B. and Huang, H. 1993. Leatherback turtle in Southeast U.S. waters. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC 318:11pp.

Tomás, J., J. Castroviejo, and J.A. Raga. 1999. Sea turtles in the south of Bioko Island (Equatorial Guinea). Marine Turtle Newsletter 84:4-6.

Turtle Expert Working Group. 1998. An assessment of the Kemp's Ridley (*Lepidochelys kempii*) and Loggerhead (*Caretta caretta*) sea turtle populations in the Western North Atlantic. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-409, 96 pp.

Turtle Expert Working Group. 2000. Assessment Update for the Kemp's Ridley and Loggerhead sea turtle populations in the Western North Atlantic. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-444,115 pp.

Willgohs, J.F. 1957. Occurrence of the leathery turtle in the northern North Sea and off western Norway. Nature 179:163-164.

Witzell, W.N, and W.G. Teas. 1994. The impacts of anthropogenic debris on marine turtles in the western North Atlantic Ocean. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFSC-355: 21 pp.

Zug, G.R. and J.F. Parham. 1996. Age and growth in leatherback turtles, *Dermochelys coriacea* (Testudines: Dermochelyidae): a skeletochronological analysis. Chelonian Conservation and Biology 2:244-249.

Table 1. Summary of vital rates for leatherback sea turtles.

Source	Remigration Rates	Nests/yr	Yolked Eggs/Nest	Hatch success	Sex Ratio	Size of Nesters	Adult Mortality	Location
Boulon *et al.* 1996	34.1%	5.26	79.7	67.1%				St. Croix, USVI
McDonald and Dutton 1996	Revised above to 48.5%							"
Dutton and McDonald 1995				59.9-67.9%				"
Eckert 1987		4.9						"
Dutton *et al.* 1999							19-49%	"
Hughes 1996	30.5-33.7%					159.6-162.2 cm		South Africa
Eckert 2000		5-7	79-90					Caribbean
Campbell *et al.* 1996			80.2			159.9 cm		Costa Rica, Caribbean
Leslie *et al.* 1996			80-86	42%		156.2 cm		"
Steyermark *et al.* 1996		4.9-5.1		44%		144.4-147.6 cm CCL		"
Chevalier *et al.* 1999	2.5yrs avg interval	7.5						French Guiana
Girondot and Fretey 1996		7.52				154.6 cm SCL		"
Hoekert *et al.* 1998				22-35% 20%				French Guiana Surinam
Mrosovsky *et al.* 1984					49%F			Surinam
Binckley *et al.* 1998					100%F 93.5%F 74.3%F			Costa Rica, Pacific
Godfrey *et al.* 1996					35-70%F avg=53.4%F			

Table 2. Leatherback strandings by region, 1986-1999[7].

Year	Northeast U.S.	Southeast U.S.	Eastern Gulf	Western Gulf	Total
1986	34	14	2	10	60
1987	80	64	1	2	147
1988	39	30	2	9	80
1989	25	54	19	6	104
1990	31	57	4	10	102
1991	60	78	3	5	146
1992	40	69	9	3	121
1993	80	45	6	10	141
1994	30	35	4	3	72
1995	117	53	6	20	196
1996	33	41	4	12	90
1997	51	38	3	10	102
1998	23	19	10	8	60
1999	54	60	5	19	138

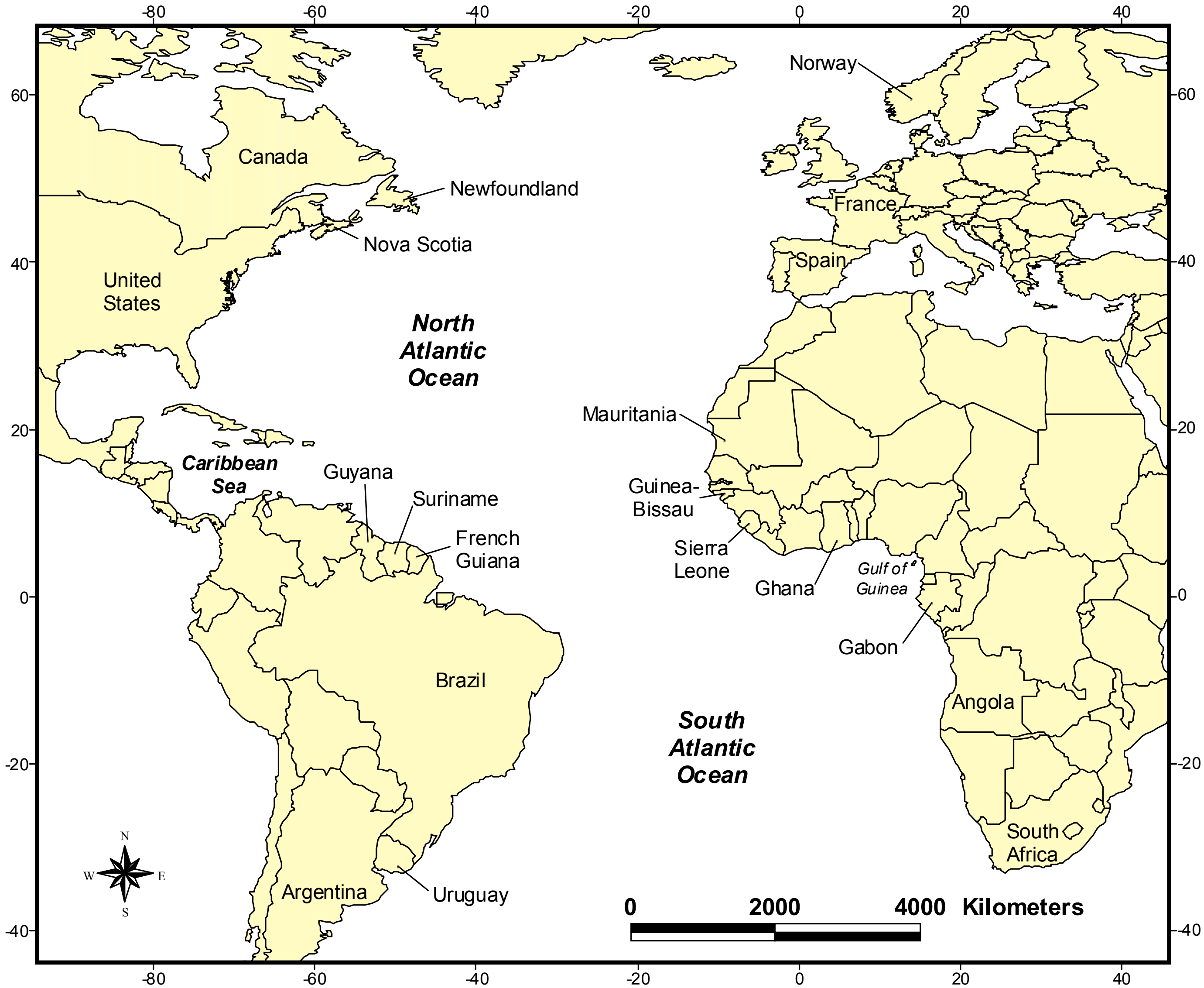


Figure 1. Map of Atlantic Ocean basin and localities for leatherback distribution.

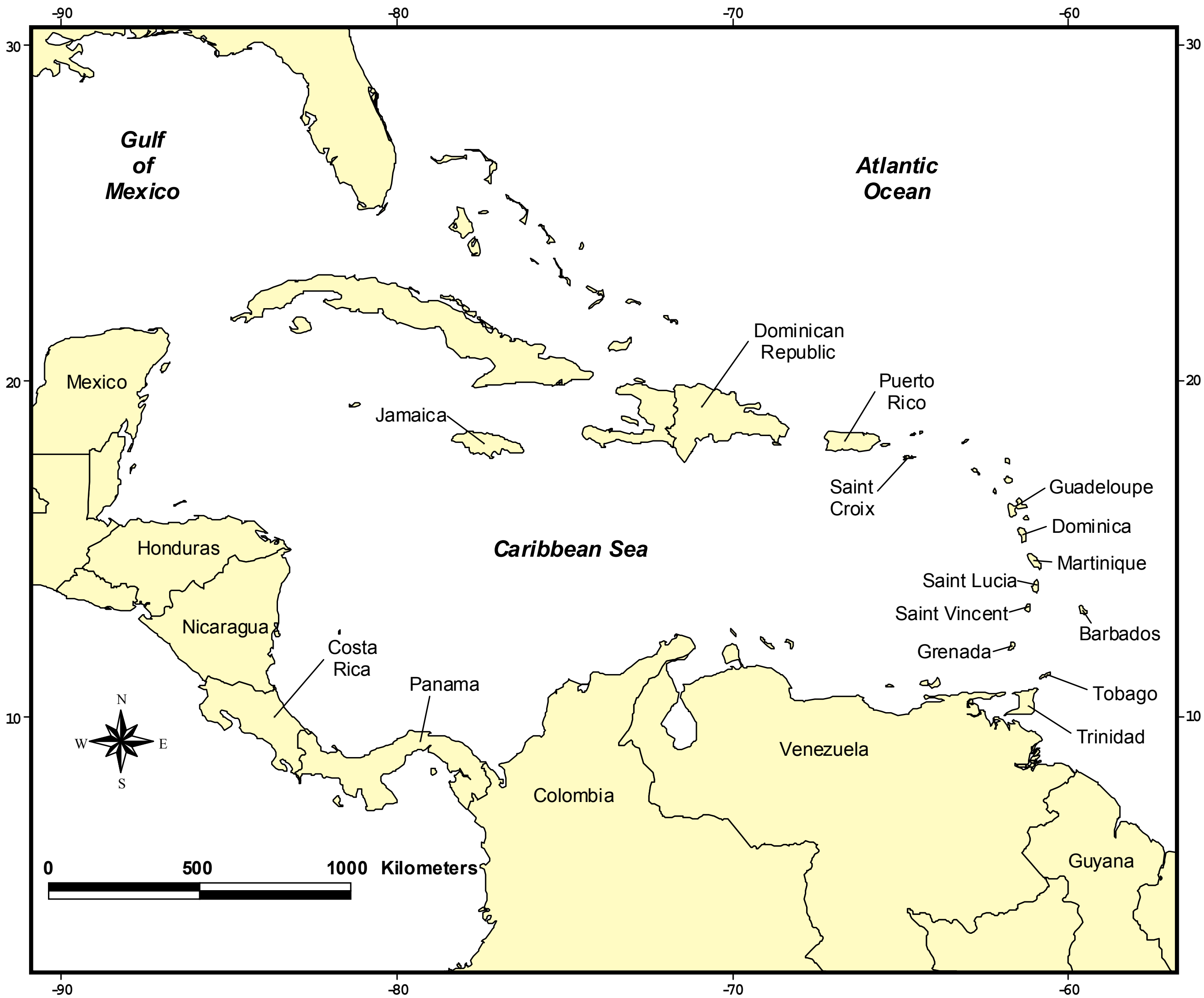
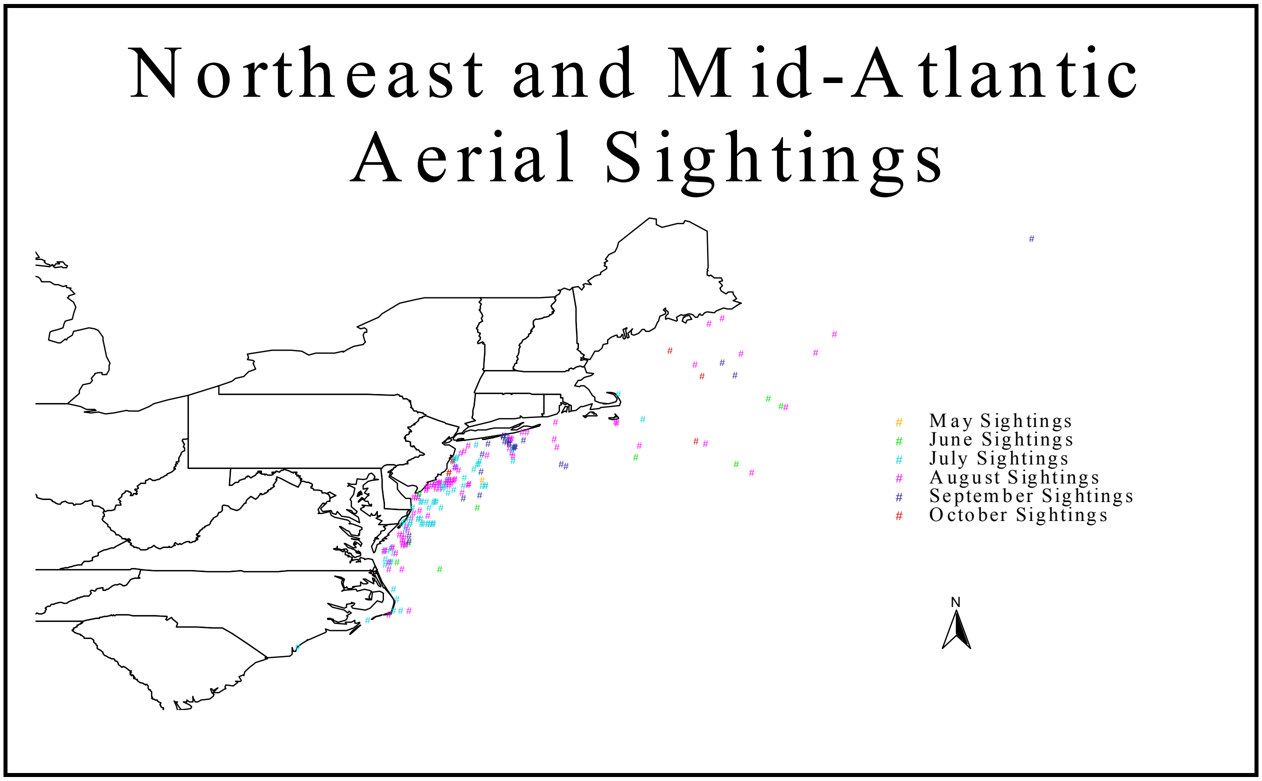


Figure 2. Map of Caribbean Sea basin and localities for leatherback distribution.



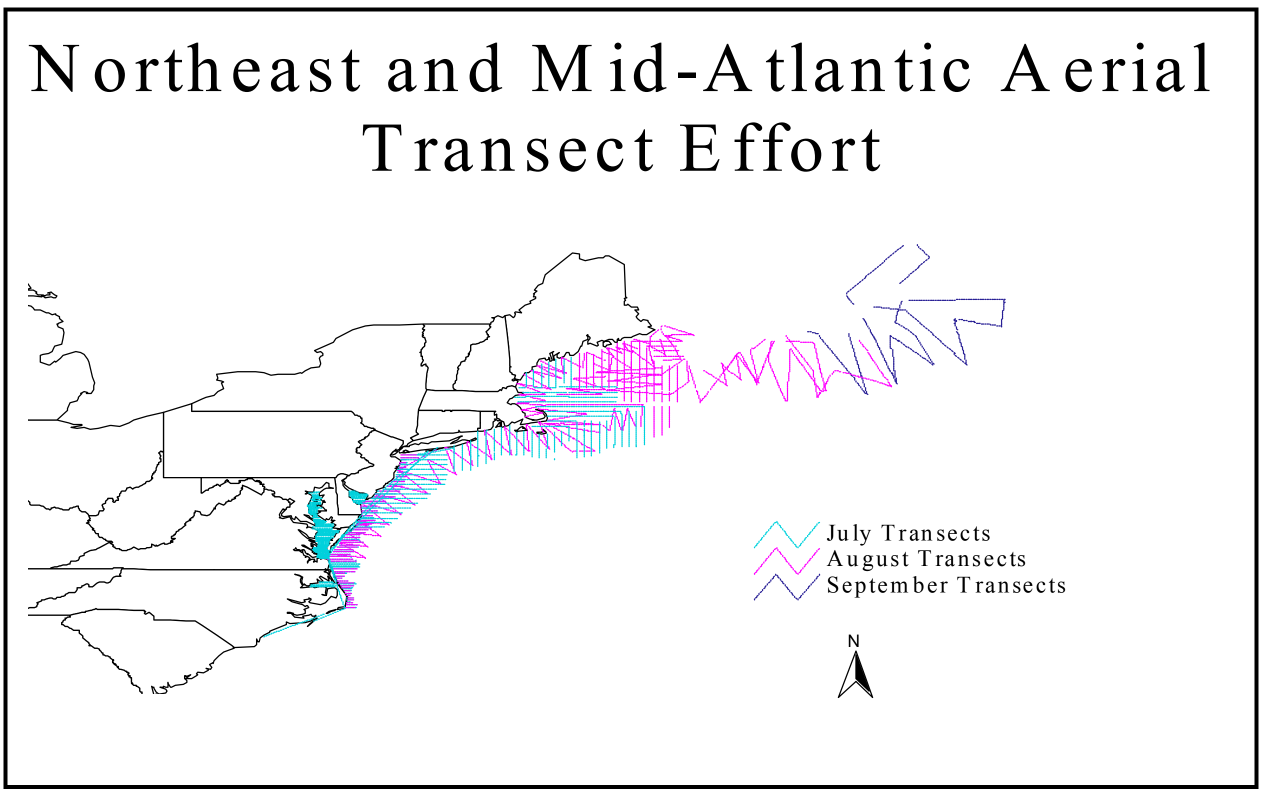


Figure 3. Leatherback sightings and transect effort in aerial surveys of the Northeast U.S. and Mid-Atlantic, 1994-1998. Some sightings may be obscured by others. Transect effort of Shoop and Kenney (1992) is not included, while sightings are.

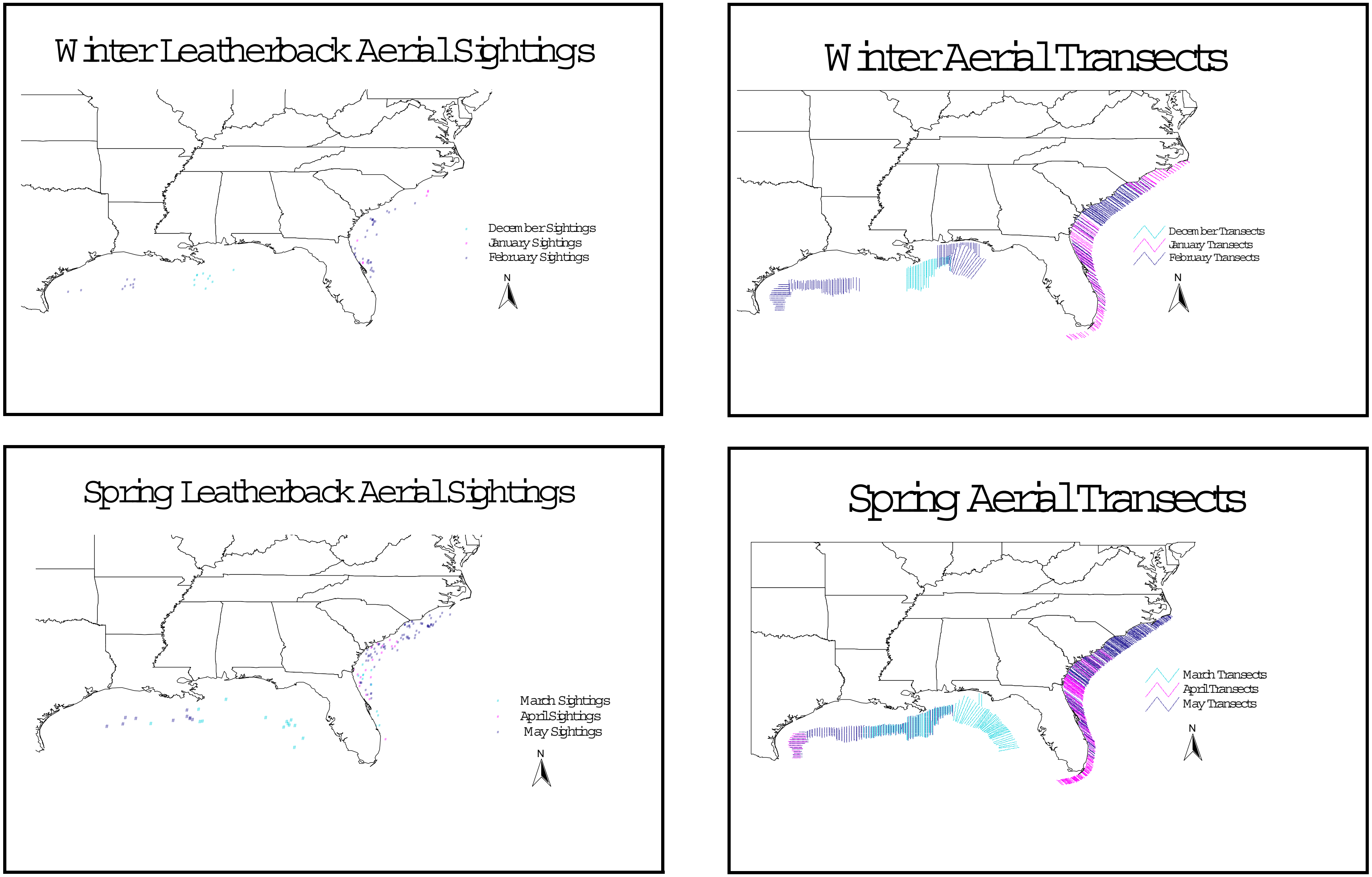
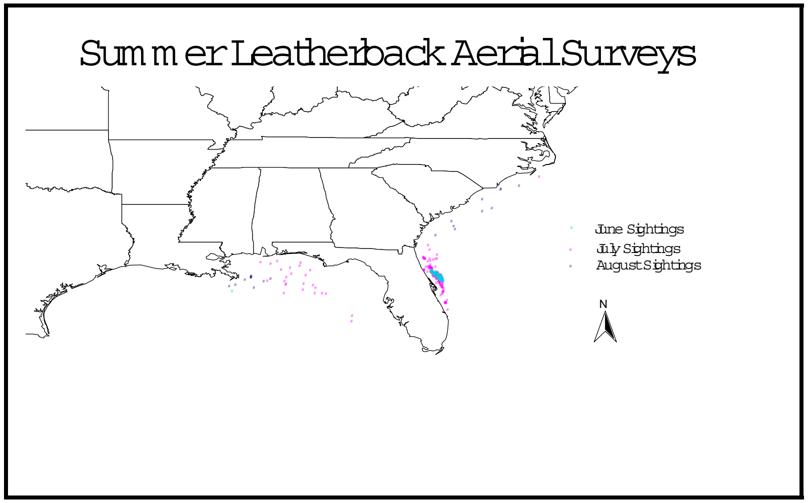
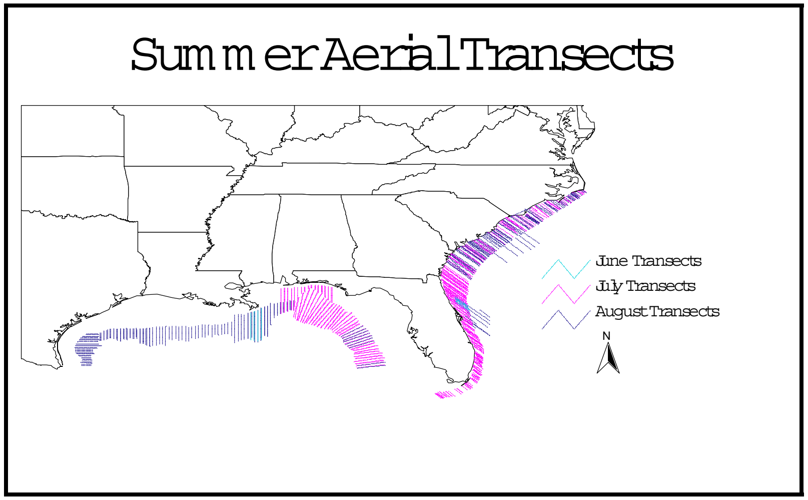
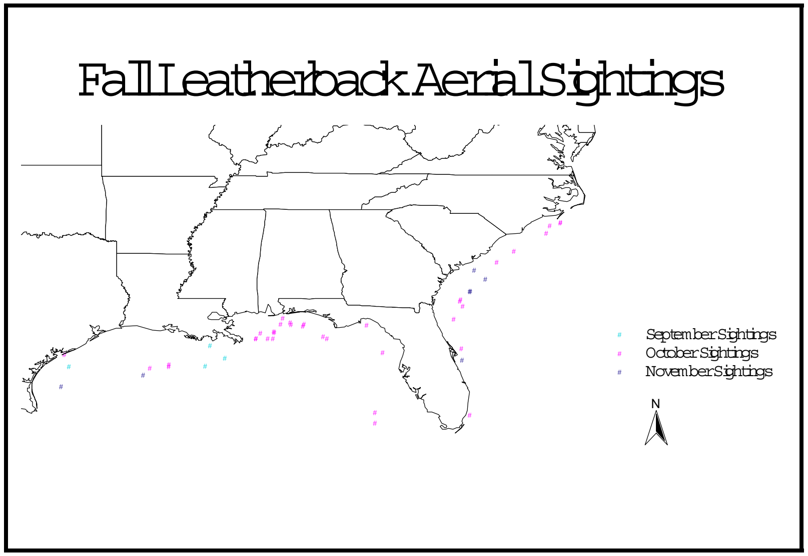


Figure 4. Leatherback sightings and transect effort in aerial surveys of the Southeast U.S. and Gulf of Mexico, 1982 – 1997.







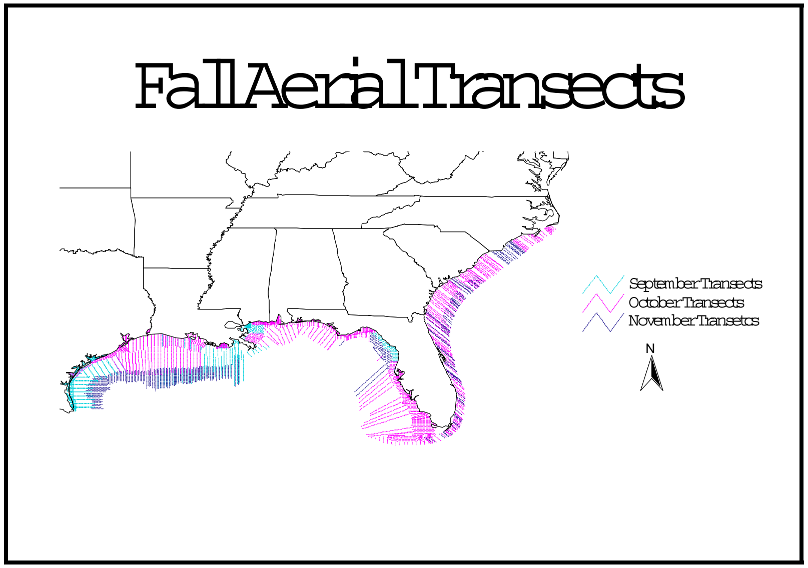


Figure 4. (continued)

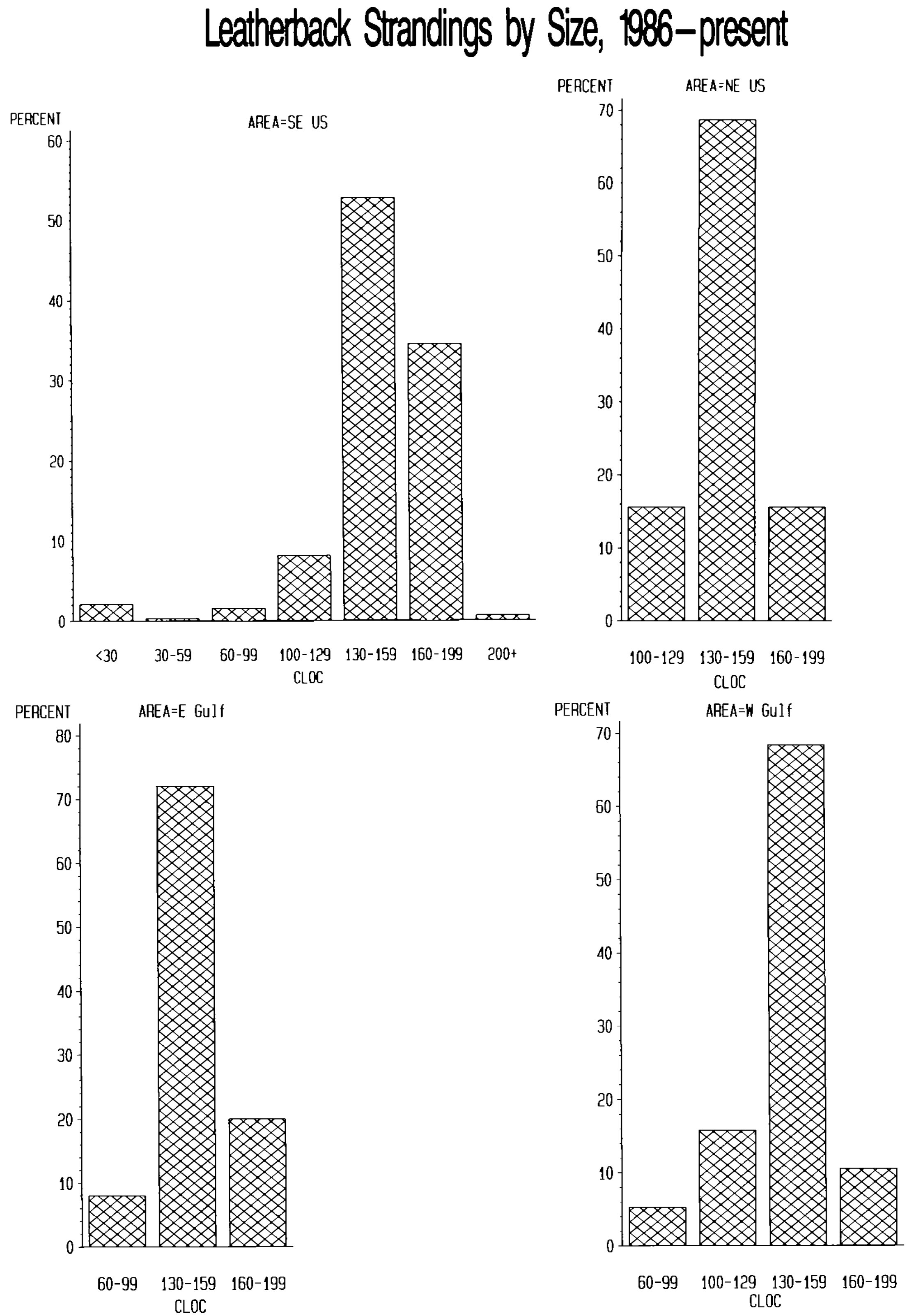


Figure 5. Size distribution of leatherback strandings by region, 1986-1999[7].

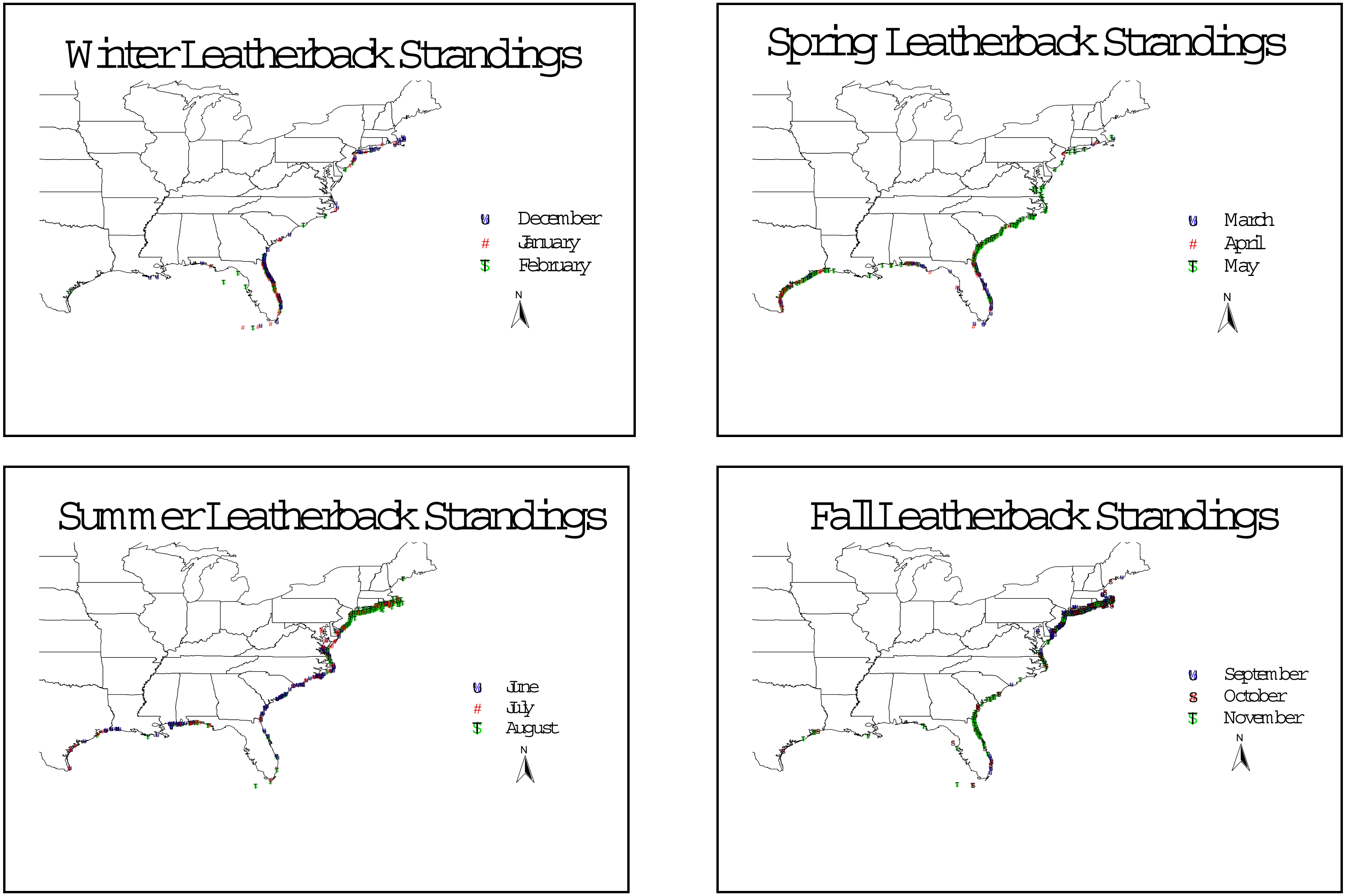


Figure 6. Seasonal leatherback strandings along the U.S. Atlantic and Gulf of Mexico coasts, 1980-1999[7].

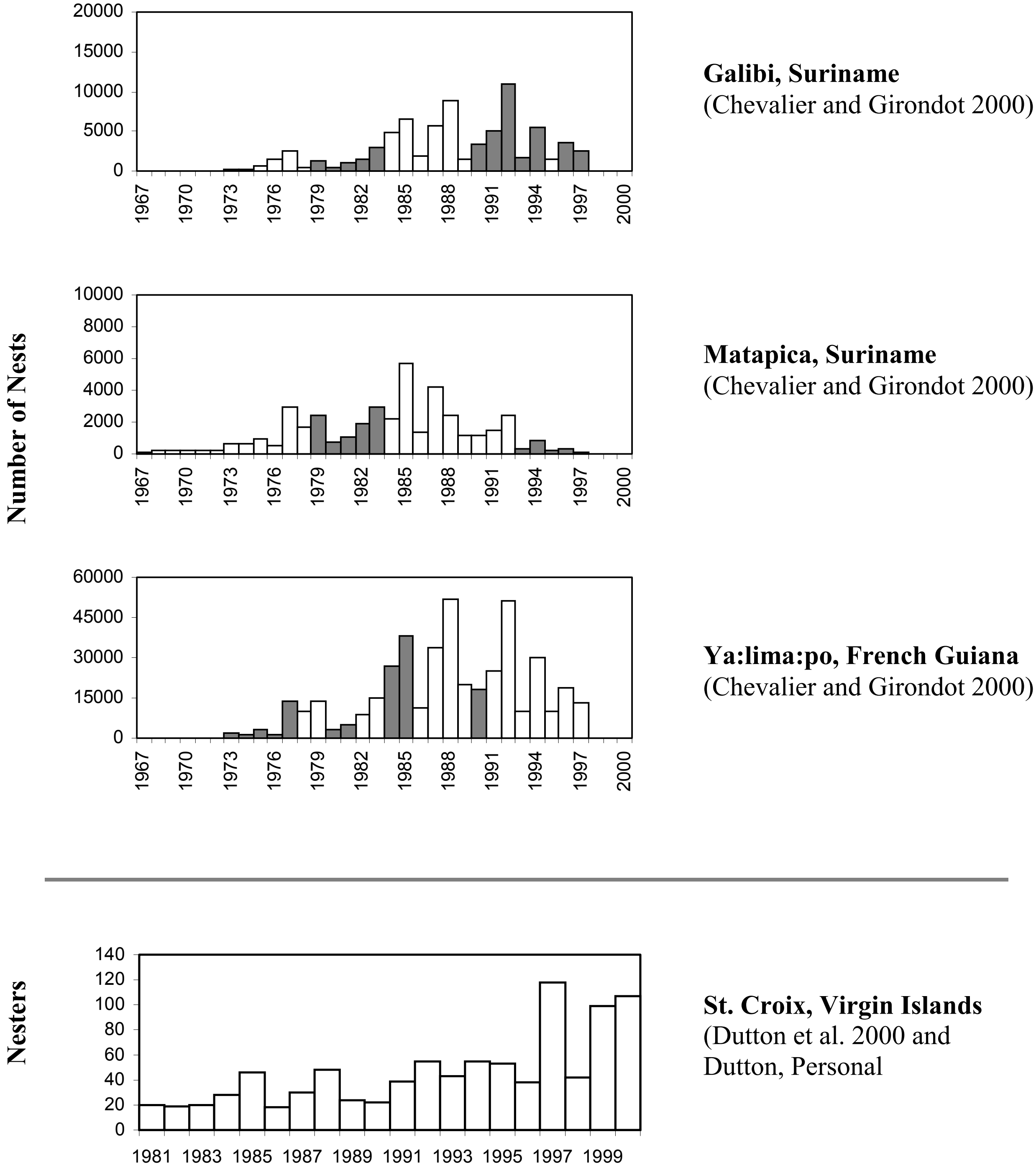


Figure 7. Nesting activity in the Guianas and St. Croix, U.S. Virgin Islands. Shaded bars are extrapolated values.

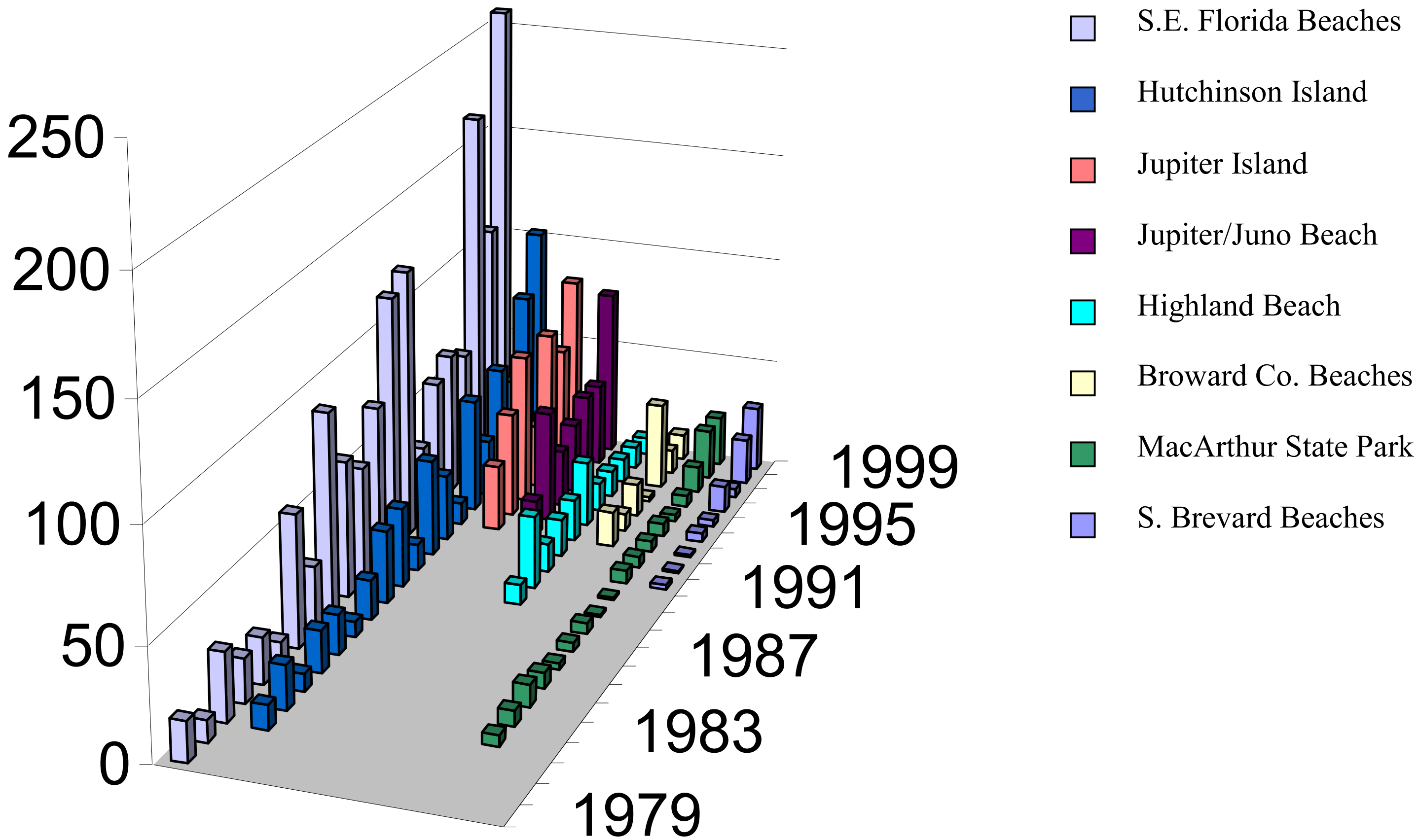


Figure 8. Leatherback nesting activity (number of nests) on selected Southeast Florida beaches that have consistent survey effort (Meylan *et al.* 1995, FWC 2000[26]).

---

[26] Unpublished data, Florida Fish and Wildlife Conservation Commission, statewide nesting beach survey program database.

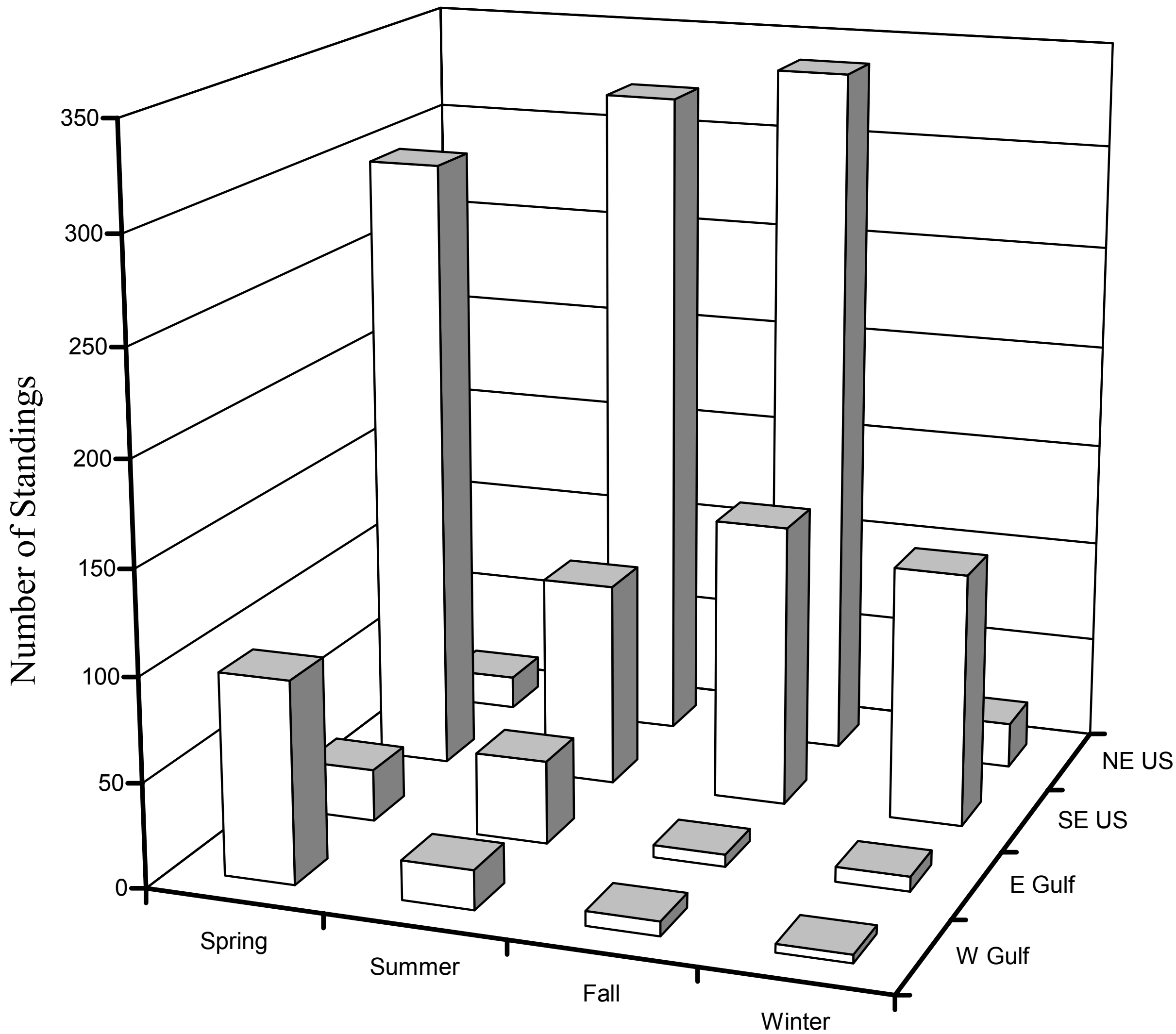


Figure 9. Seasonal leatherback stranding totals by region, 1986-1999[7].

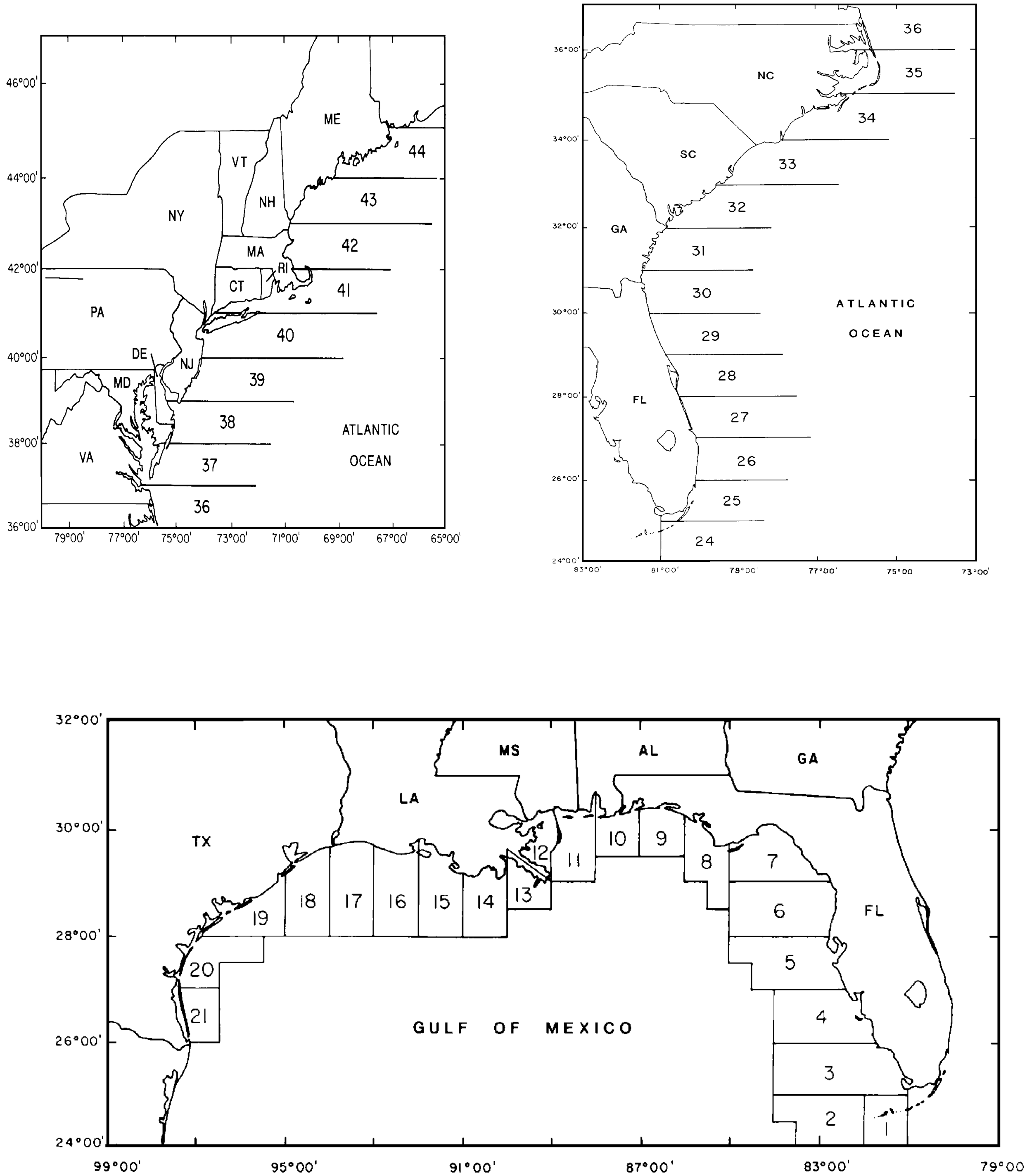


Figure 10. Statistical zones along the U.S. Atlantic and Gulf of Mexico coasts.