NOAA Technical Memorandum NMFS-SEFSC-455

STOCK ASSESSMENTS OF LOGGERHEAD AND LEATHERBACK SEA TURTLES

AND

AN ASSESSMENT OF THE IMPACT OF THE PELAGIC LONGLINE FISHERY ON THE LOGGERHEAD AND LEATHERBACK SEA TURTLES OF THE WESTERN NORTH ATLANTIC

March 2001

U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center
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Miami, FL 33149

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STOCK ASSESSMENTS OF LOGGERHEAD AND LEATHERBACK SEA TURTLES AND AN ASSESSMENT OF THE IMPACT OF THE PELAGIC LONGLINE FISHERY ON THE LOGGERHEAD AND LEATHERBACK SEA TURTLES OF THE WESTERN NORTH ATLANTIC

Preface

On September 7, 2000 the National Marine Fisheries Service announced that it was reinitiating consultation under Section 7 of the Endangered Species Act on pelagic fisheries for swordfish, sharks, tunas, and billfish.[1] Bycatch of a protected sea turtle species is considered a take under the Endangered Species Act (PL93-205). On June 30, 2000 NMFS completed a Biological Opinion on an amendment to the Highly Migratory Pelagic Fisheries Management Plan that concluded that the continued operation of the pelagic longline fishery was likely to jeopardize the continued existence of loggerhead and leatherback sea turtles.[2] Since that Biological Opinion was issued NMFS concluded that further analyses of observer data and additional population modeling of loggerhead sea turtles was needed to determine more precisely the impact of the pelagic longline fishery on turtles. [3,4] Hence, the reinitiation of consultation.

The documents that follow constitute the scientific review and synthesis of information pertaining to the narrowly defined reinitiation of consultation: the impact of the pelagic longline fishery on loggerhead and leatherback sea turtles The document is in 3 parts, plus 5 appendices. Part I is a stock assessment of loggerhead sea turtles of the Western North Atlantic. Part II is a stock assessment of leatherback sea turtles of the Western North Atlantic. Part III is an assessment of the impact of the pelagic longline fishery on loggerhead and leatherback sea turtles of the Western North Atlantic.

These documents were prepared by the NMFS Southeast Fisheries Science Center staff and academic colleagues at Duke University and Dalhousie University. Personnel involved from the SEFSC include Joanne Braun-McNeill, Lisa Csuzdi, Craig Brown, Jean Cramer, Sheryan Epperly, Steve Turner, Wendy Teas, Nancy Thompson, Wayne Witzell, Cynthia Yeung, and also Jeff Schmid under contract from the University or Miami. Our academic colleagues, Ransom

[1] NMFS Reinitiates Consultation Under the Endangered Species Act (ESA) on the Pelagic Fisheries for Swordfish, Sharks, Tunas and Billfish. Press release from Bruce C. Morehead, Acting Director, Office of Sustainable Fisheries, National Marine Fisheries Service, Silver Spring, Md., September 7, 2000, 1 pp.

[2] Endangered Species Act - Section 7 Consultation Biological Opinion. Reinitiation of Consultation on the Atlantic Pelagic Fisheries for Swordfish, Tuna, Shark and Billfish in the U.S. Exclusive Economic Zone (EEZ): Proposed Rule to Implement a Regulatory Amendment to the Highly Migratory Species Fishery Management Plan; Reduction of Bycatch and Incidental Catch in the Atlantic Pelagic Longline Fishery, 118 pp. Consultation conducted by National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Md., June 30, 2000.

[3] Memorandum from Bruce Morehead, Acting Director, Office of Sustainable Fisheries to Donald R. Knowles, Director, Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Md., September 7, 2000.

[4] Memorandum from Donald R. Knowles, Director, Office of Protected Resources to Bruce Morehead, Acting Director, Office of Sustainable Fisheries, National Marine Fisheries Service, Silver Spring, Md., September 7, 2000.

Myers, Keith Bowen, and Leah Gerber from Dalhousie University and Larry Crowder and Melissa Snover from Duke University, also recipients of a Pew Charitable Trust Grant for a Comprehensive Study of the Ecological Impacts of the Worldwide Pelagic Longline Industry, made significant contributions to the quantitative analyses and we are very grateful for their collaboration. We appreciate the reviews of the stock definition sections on loggerheads and leatherbacks by Brian Bowen, University of Florida, and Peter Dutton, National Marine Fisheries Service Southwest Fisheries Science Center, respectively, and the comments of the NMFS Center of Independent Experts reviewers Robert Mohn, Ian Poiner, and YouGan Wang on the entire document. We also wish to acknowledge all the unpublished data used herein which were contributed by many researchers, especially the coordinators and volunteers of the nesting beach surveys and the sea turtle stranding and salvage network and the contributors to the Cooperative Marine Turtle Tagging Program.

Nancy B. Thompson and Sheryan P. Epperly

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Executive Summary

Along the North American coast, the loggerhead sea turtle population structure is described by nesting subpopulations consisting of a northern subpopulation, which extends from northeastern Florida coast northward, a south Florida subpopulation from the central Florida east coast southward, a Dry Tortugas subpopulation, a Florida Panhandle subpopulation, and a Yucatán subpopulation in Mexico. Nesting trends are only available for the northern and south Florida subpopulations.

Trend analyses of the number of nests from sampled beaches from these two subpopulations show that from 1978-1990, the northern subpopulation has been stable at best and possibly declining (less than 5% per year). From 1990 to the present the number of nests has been increasing at 2.8-2.9% annually. Over these same periods, the Florida subpopulation had been increasing at 5.3-5.4% per year, but since 1990 this rate appears to be slowing (3.9-4.2%).

Authorized takes of turtles continue and include several fisheries and other anthropogenic sources. For the longline fishery, it is estimated that between 293 to 2439 loggerhead turtles are taken annually based on observer data from 1992-1999. If 50% of these animals are killed then the mortality from this fishery is estimated to be from 147 to 1220 per year.

The U.S. and 26 other nations participate in longline fishing throughout the western North Atlantic Ocean and the relative proportion of total hooks fished by the U.S. fleet is small as compared with the foreign fleets. However, the relative efficiency of the U.S. fleet as compared with the foreign fleets is high but how this translates into catches of non-target species is not known but clearly turtles are bycatch in the foreign fleets.

To evaluate the magnitude of change in pelagic survivorship (the life history stage longline fishing impacts) required for the northern nesting subpopulation to meet recovery criteria, a female only model was developed based on four different stage length scenarios and applying three different population growth rates with three different sex ratios all derived from empirical studies.

Modeling results indicate that the population growth rate is most sensitive to survivorship in the life history stages with the longest durations. Cumulatively, these are the juvenile stages. Efforts to maximize the survivorship in all of the juvenile life history stages would include evaluating takes from all sources. In particular it is noted that large juvenile turtles are yet to be excluded from current Turtle Excluder Devices.

It is unlikely that any loggerhead nesting subpopulation under the status quo will be extirpated over the next few years. It is recommended that actions to reduce juvenile mortality be identified through research and implemented as soon as feasible.

Genetic analyses indicate that female leatherback turtles nesting in St.Croix/Puerto Rico and those nesting in Trinidad differ from each other and from turtles nesting in Florida, French Guiana/Suriname and along the South African Indian Ocean coast. Turtles nesting in Florida, French Guiana/Suriname and South Africa cannot be distinguished at this time with mtDNA.

The largest known nesting aggregation of the leatherback turtles in the western North Atlantic Ocean occurs in French Guiana. This may be the largest nesting aggregation of leatherback turtles in the world and has been declining at about 15% per year since 1987. From the period 1979-1986, the number of nests was increasing at about 15% annually.

The number of nests in Florida and the U.S. Caribbean has been increasing at about 10.3% and 7.5%, respectively, per year since the early 1980's but the magnitude of nesting is much smaller than that along the French Guiana coast.

Based on observer data from 1992 to 1999 the takes of leatherback turtles from the U.S. longline fishery range from 308 to 1054 annually. If 50% of these turtles die, then the mortality ranges from 154 to 527 per year.

It has been estimated that the U.S. commercial shrimp trawl fishery takes 650 leatherback turtles annually.

It is expected that longline fishing would not be able to discriminate among turtles by nesting beach origin. Assuming that Atlantic Ocean subpopulations exhibit the same life history characteristics, then it is expected that if longline fishing were causing the declines in French Guiana, declines would be measured in other nesting subpopulations.

While the longline fishery, both U.S. and foreign, and the U.S. shrimp trawl fishery may not be the immediate cause in declines in nesting in French Guiana, they could be contributing to these declines.

Four hypotheses are offered to determine the cause of the decline in nesting in French Guiana and all suggest that activities off the coast, such as fishing, likely are causing the decline in nesting. The causes for the observed decline must be identified and actions pursued immediately if the declines are not part of a natural nesting cycle.

It is recommended that research begin immediately to identify and quantify the rate of mortality from the longline fishery, both U.S. and foreign, as well as mortality rates from other fisheries.

A mechanism to initiate discussions with foreign nations relative to fishing activities outside of U.S. waters needs to be immediately identified.

PART I

STOCK ASSESSMENT OF LOGGERHEAD SEA TURTLES OF THE WESTERN NORTH ATLANTIC

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PART I. STOCK ASSESSMENT OF LOGGERHEAD SEA TURTLES OF THE WESTERN NORTH ATLANTIC

The Turtle Expert Working Group, established in 1995 by the Southeast Fisheries Science Center at the behest of the National Marine Fisheries Service, has published two reports (1998, 2000) which, in part, concern the status and condition of the loggerhead sea turtle stocks of the Western North Atlantic. Herein we do not attempt to duplicate material in those reports, but instead provide updated information acquired since the preparation of the last report. Thus, this document is to be used in conjunction with the two TEWG reports.

Stock Definition

Sea turtles have complex migratory behaviors and gender-specific dispersal that must be considered in defining management units. Sexual differences in dispersal or migratory behaviors may lead to different estimates of population structure calculated with mitochondrial (mtDNA) and nuclear (nDNA) DNA (Avise 1995). Bowen (1997) points out that these results are not necessarily conflicting but reflect the expected consequence of sex-specific dispersal. Assays of both biparental (nDNA) and uniparental (mtDNA) lineages are needed to understand the complex stock structure of migratory animals such as sea turtles. Either used in isolation can be misleading, especially conclusions based on nDNA alone, where in the case of sea turtles one might conclude that recruitment of females from other reproductive populations would counter the depletion of a rookery.

Assays of mtDNA illuminate the stock structure of the female lineages that are essential to reproduction and species recovery. mtDNA is used as a genetic tag to show a behavioral aspect of sea turtle life history - natal homing of egg-laying females - not to indicate important genetic differences between nesting colonies of sea turtles. Results of maternally-inherited mtDNA studies of sea turtles support the hypothesis of natal homing region (Encalada *et al.* 1996, Encalada *et al*. 1998, Bass 1999, Dutton *et al*. 1999). Each nesting assemblage represents a distinct reproductive population, regardless of the nDNA findings, because the production of progeny depends on female nesting success. Thus, should a nesting assemblage be depleted, regional dispersal will not be sufficient to replenish the depleted assemblage over ecological time scales germane to immediate management issues (Avise 1995), a consequence with both population and ecological implications. Based on mtDNA results available at the time (Bowen *et al*. 1993, Bowen 1995, Encalada *et al.* 1998), the Turtle Expert Working Group (1998, 2000) recognized at least 4 genetically distinct loggerhead (*Caretta caretta*) nesting subpopulations in the western North Atlantic and suggested that they be considered independent demographically, consistent with the definition of a distinct vertebrate population segment (59 FR 65884-65885, December 21, 1994; 61 FR 4722-4725 February 7, 1996) and of a management unit (MU) (Moritz, 1994*a*, *b*). Recent fine-scale analysis of mtDNA data from Florida rookeries indicate that population separations begin to appear between nesting beaches separated by more than 100 km of coastline that does not host nesting (Francisco *et al*. 2000[1]) and tagging studies are

[1] Francisco, A.M., A.L. Bass, K.A. Bjorndal, A.B. Bolten, R. Reardon, M. Lamont, Y. Anderson, J. Foote, and B.W. Bowen. 2000. Stock structure and nesting site fidelity in Florida loggerhead turtles *(Caretta caretta)* resolved with

consistent with this result (Richardson 1982, Ehrhart 1979[2], LeBuff 1990, CMTTP[3]). Nest site relocations greater than 100 km occur, but generally are rare (CMTTP[4], LeBuff 1974, Ehrhart 1979[5], Bjorndal *et al*. 1983, LeBuff 1990). However, there are a number of reports of recaptured animals nesting on Little Cumberland Island, Georgia that were originally tagged in Melbourne, Florida (J. Richardson personal communication[6]). Based on these results there are at least four management units (MU) in the southeastern U.S: (1) Florida Panhandle, (2) southern Florida, (3) Amelia Island (Volusia County, Florida) and northward, and (4) the Dry Tortugas. The nesting subpopulation on the Yucat<n Peninsula is a fifth MU identified in the Western North Atlantic (Encalada *et al.* 1998) and there may be more. Assemblages throughout the greater Caribbean and those in the Eastern North Atlantic (*e.g*., Cape Verde Islands, Senegal, and Morocco; Sternberg 1981) been not been assayed, but sampling has begun in the Cape Verde Islands where a significant numbers of turtles still nest[7].

The area between Cape Canaveral and Amelia Island has intermediate genotype frequencies that indicate another management unit by some criteria (Francisco *et al*. 1999[8]). Loggerheads nesting from Amelia Island to North Carolina are indistinguishable with mtDNA, but this means only that there is not the resolution to detect any differences, which suggests that the area was colonized by a small number of females after the last (Wisconsin) glacial epoch. Given the recent colonization northward, it is not surprising that there is insufficient genetic diversity for an assessment of stock structure. There may be different units contained in this one management unit as there are significant distances with little or no nesting between rookeries throughout the area and, based on the 100 km yardstick, likely are significantly isolated as to be

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mtDNA sequences. Unpublished Manuscript . Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, 23 pp.

[2] Ehrhart, L.M. 1979. A survey of marine turtle nesting at the Kennedy Space Center, Cape Canaveral Air Force Station, North Brevard County, Florida. Unpublished report by the University of Central Florida, Orlando, to the Florida Department of Natural Resources, Division of Marine Resouces, St. Petersburg, Fla., 122 pp.

[3] Unpublished Data. The Cooperative Marine Turtle Program was established by NMFS in 1980 to centralize the tagging programs among sea turtle researchers, distribute tags, manage tagging data, and facilitate exchange of tag information. Since 1999 the CMTTP has been managed by the Archie Carr Center for Sea Turtle Research at the University of Florida, Gainesville.

[4] *Ibid*.

[5] Ehrhart, L.M. 1979. A survey of marine turtle nesting at the Kennedy Space Center, Cape Canaveral Air Force Station, North Brevard County, Florida. Unpublished report by the University of Central Florida, Orlando to the Florida Department of Natural Resources, Division of Marine Resouces, St. Petersburg, Fla., 122 pp.

[6] Jim Richardson, University of Georgia, Athens. Personal Communication (Phone) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., January 30, 2001.

[7] Luis Felipe López Jurado, University of Las Palmas, Cape Verde Islands, Personal Communication (E-Mail) to CTURTLE Listserver (http://www.lists.ufl.edu/archives/cturtle.html), January 14, 2000.

[8] Francisco, A.M., A.L. Bass, and B.W. Bowen. 1999. Genetic characterization of loggerhead turtles (*Caretta caretta*) nesting in Volusia County. Unpublished report to Florida Department of Environmental Protection.. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, 11 pp.

MUs. We are not identifying subdivisions of the northern subpopulation as separate MUs at this time, however, there is some risk in this decision. Avise (1995) argues that a combination of genetics and demographics needs to be used to define population structure for conservation. Failure to reject the null hypothesis (panmixia) based solely on genetic parameters can lead to incorrect management decisions and managers risk losing local populations (Taylor and Dizon 1996, 1999). The identification of putative management units within the currently defined northern subpopulation as well as the entire issue of loggerhead management units is something that a recovery team needs to address immediately.

Nuclear DNA contains the important genes for adaptation and long-term survival. Since it is biparentally inherited it provides information on the behavior of male sea turtles that is not available from mtDNA. In 1999 NMFS contracted the Department of Fisheries and Aquatic Sciences, University of Florida, to analyze nDNA data from loggerhead rookeries in the western Atlantic. A final report is due soon and the results will be presented at the upcoming meeting of the American Society of Ichthyologists and Herpetologists in July 2001. Very preliminary results indicate that population structuring defined by nDNA (microsatellite) assays is much lower in the southeast U.S. than found in the mtDNA studies[9]. The implication is that males are a conduit for gene flow between the egg-laying populations defined by female site fidelity, but the amount of male-mediated gene flow is not yet determined. Three points need to be made: (1) The population structuring observed with nDNA, while lower than observed with mtDNA, may still be significant across the southeast U.S., supporting the subdivision into multiple stocks, (2) A little male-mediated gene flow between nesting colonies means that concerns about genetic diversity within nesting populations may be less pressing and small nesting populations are less likely to suffer the effects of inbreeding, and (3) These conclusions about nDNA of western North Atlantic loggerhead sea turtles are extremely preliminary and further analysis of the data is ongoing. The results of a study on loggerheads in the eastern Mediterranean demonstrated there was low male-mediated gene flow between nesting sites and that there was genetic substructuring due to the high precision of natal homing by nesting females (Schroth *et al.* 1996). These authors concluded that in order to preserve the genetic diversity of the *Caretta* metapopulation in the eastern Mediterranean one needed to preserve individual nesting sites.

Foraging grounds contain cohorts from nesting colonies from throughout the Western North Atlantic (see Table 10 in TEWG 2000). Since the preparation of the last TEWG report, three more reports have provided additional genetic data on the foraging ground composition of loggerhead sea turtles. The Florida Bay loggerhead foraging population is composed primarily of individuals from the South Florida subpopulation (84%) with some contribution observed from the northern subpopulation (8%), the Florida Panhandle subpopulation (<1%), and the Yucat<n subpopulation (8%) (Bass *et al*. 1998[10]). Additional samples from North Carolina's

[9] Discussions (E-Mail) between Brian Bowen (contractor, University of Florida, Gainesville) and Sheryan Epperly (contract technical monitor, National Marine Fisheries Services, SEFSC, Miami, Fla.) and analyses by Alicia Francisco (graduate student of Dr. Bowen), November 7, 2000, November 14, 2000, December 17, 2000, and December 29, 2000.

[10] Bass, A.L., M. Clinton, and B.W. Bowen. 1998. Loggerhead turtles (*Caretta caretta*) in Florida Bay: an assessment of origin based on genetic markers. Unpublished report to Florida Department of Environmental Protection. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla., 5 pp.

Pamlico-Albemarle Estuarine Complex revealed that the South Florida subpopulation dominated (64%) there (Bass *et al*. 2000[11]). The northern subpopulation contributed 30% and the remaining were divided among Mexico (5%) and possibly Brazil (<1%). The authors also found significant temporal variation in the relative contributions of the subpopulations among the 3 yrs.

In 1998 NMFS contracted the analysis of samples collected from stranded animals throughout the southeastern U.S. and Gulf of Mexico[12]. Those results (Bass *et al*. 1999[13]) (Fig. 1) indicate that the relatively large South Florida subpopulation dominates everywhere, but more so in the Gulf of Mexico where in the western Gulf it accounts for 83% of the animals. In Florida (geographic distribution of sampling unknown), the contribution of the South Florida subpopulation was 73%. In Georgia, its contribution was 73%, also (*Ibid*.). The contribution of this subpopulation decreased to 65-66% off the Carolinas and decreases further north of Cape Hatteras (46%). In the northernmost area sampled, Virginia, the northern subpopulation accounted for 46% of the animals. It contributes 25-28% off the Carolinas, 24% off Georgia, and off Florida east and west coast combined, contributes 20%. The contribution of the northern subpopulation to western Gulf cohorts is but 10%. The Yucat<n subpopulation’s contribution throughout the region ranged from 6-9%, except off Georgia where the contribution was but 3%. The Florida Panhandle subpopulation was not included as a possible contributor in these analyses because it is unlikely that its contribution could be detected against the hundreds of individuals assayed from South Florida; the inclusion of populations that contribute less than 1% in the overall nesting effort generates overestimates of contribution and can compromise the accuracy of estimates made for the other source populations.

Other sources of information indicate structuring of the Western Atlantic nesting assemblages of loggerhead sea turtles. Results of a study on carapace eipbionts on turtles nesting along the Atlantic Coast of the U.S. indicated there were two populations of turtles, divided at northeast Florida (Cape Canaveral to Daytona Beach) (Caine 1986). The epibiont community included a number of long-lived sessile organisms likely unaffected by short term immigration or emigration. The low amount of overlap in the epibiont communities (4.2-7.5%) indicated that turtles were spending time in different foraging environments. Certain epibionts of the southern population of nesting turtles were of Caribbean origin whereas some of the epibionts of the northern nesting turtles were indicative of the Sargasso Sea. Based on recent satellite telemetry studies and on returns of tags, both applied at nesting beaches, non-nesting adult females from the South Florida subpopulation are distributed throughout the Bahamas, Greater Antilles, Cuba, Yucatán, eastern Gulf of Mexico, and southern Florida (Meylan 1982, Meylan *et al*. 1983,

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[11] Bass, A.L., S.P. Epperly, J. Braun-McNeill, and A. Francisco. 2000. Temporal variation in the composition of a loggerhead turtle (*Caretta caretta*) developmental habitat. Unpublished manuscript. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla., 26 pp.

[12] 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.

[13] Bass, A.L., S-M. Chow, and B.W. Bowen. 1999. Final report for project titled: genetic identities of loggerhead turtles stranded in the Southeast United States. Unpublished report to National Marine Fisheries Service, order number 40AANF809090. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla., 11 pp.

http://cccturtle.org/sat1.htm) whereas non-nesting adult females from the northern subpopulation appear to occur almost exclusively along the east coast of the U.S. (http://cccturtle.org/sat1.htm); only one northern subpopulation mature female has been reported to enter the eastern Gulf of Mexico (Bell and Richardson 1978), and none have been reported from international waters (CMTTP[3]). Limited tagging data suggest those adult females nesting in the Gulf of Mexico that are not part of the South Florida subpopulation remain in the Gulf of Mexico, including on feeding grounds off Yucatán (Meylan 1982, http://cccturtle.org/sat1.htm). Annual nesting at rookeries within a subpopulation's nesting range is correlated, but nesting among subpopulations is not (TEWG 2000).

Status and Trends

Nesting beaches

The preparation of the TEWG reports (1998, 2000) pre-dated the identification of the Dry Tortugas as a management unit. The reader is referred to the TEWG reports for discussions on the other subpopulations.

Dry Tortugas

Sea turtle nesting in Dry Tortugas National Park is the highest in all of Monroe County, which encompasses all of the Florida Keys (Reardon 2000[14]) (Fig. 2). The second highest productive nesting area in the Florida Keys is the Marquesas Keys (Florida Fish and Wildlife Conservation Commission 2000[15]), 47 miles east of the Dry Tortugas. The genetic affinity for individuals in the Marquesas Keys as well as the rest of the Florida Keys has yet to be assayed. The Dry Tortugas is a group of seven islands with accompanying marine habitats, 70 miles (113 km) west of Key West, Florida. Since 1995 the beaches of all 7 islands were patrolled daily from early April through late October. The full extent and status of the Dry Tortugas subpopulation is unknown at this time. Two of the seven islands, East Key and Loggerhead Key, are host to 90% of all nesting activity observed in the Park (Reardon 2000[14]). In the early 1980's a tagging study was conducted on the nesting turtles of East Island and the nesting population was estimated at 40 individuals (Dawson 1985[16]). Nesters ranged from 78.5 to 99.0 cm straight carapace length with a mean length of 90.4 cm[3] (Fig. 3). The range in annual number of recorded nests for the period 1995-2000 was 190-269 with a mean of 217 nests/year (Table 1). The average clutch size has ranged from 98-105 eggs annually with an incubation time ranging from 51.0 to 54.6 days

[14] Reardon, R.T. 2000. Annual Report - 2000 Season. Dry Tortugas National Park Sea Turtle Monitoring Program, Monroe County, Florida. Unpublished report. Annual report by Florida International University to Dry Tortugas National Park, Miami, Fla., 49 pp.

[15] Florida Fish and Wildlife Conservation Commission. 2000. Statewide Nesting Beach Survey Program Database. Reported Nesting Activity of the Loggerhead Turtle, *Caretta caretta*, in Florida, 1993-1999. Unpublished Report. Florida Marine Research Institute, St. Petersburg, Fla., 8 May 2000, 26 pp.

[16] Dawson, R.H. 1985. Project completion report: results of the 1985 sea turtle nesting survey at Fort Jefferson National Monument, Dry Tortugas, Florida. Prepared by the National Park Service Southeast Regional Office, Atlanta, Georgia for USFWS Endangered Species Field Station, Jacksonville, Fla., 49 pp.

(average 52.9 days). Eighty percent of loggerhead clutches were inventoried and hatching success ranged from 72.3 to 82% annually with an average of 77.1%.

Due to the relative isolation and lack of fresh water these islands are without mammalian nest predators but about 10% of the nests are lost annually to erosion[14]. Local potential threats to nesting in the Park is mainly limited to visitation; human usage needs to be monitored particularly during the nesting season to limit impacts to nests (Reardon 2000[14], Dawson 1985[16]). Within the Park commercial fishing is prohibited and recreational fishing is limited. Presently the surrounding marine habitats are being considered for a designation as an Ecological Reserve. Although the proposed Tortugas Ecological Reserve concentrates on protecting the coral reef ecosystem and fish stocks, resident turtles and migratory nesters should benefit also due to the intended expansion of "no take" zones (U.S. Department of Commerce[17]).

Nesting Trends

Previous estimates of nesting trends for the northern subpopulation prior to the implementation of TEDs are a decline of 3 percent per year (λ=0.97) (Frazer 1983*b*) for Little Cumberland Island, Georgia and a decline of 5% per year (λ=0.95) (TEWG 1998) for South Carolina. It is possible that these two beaches are not representative of the overall subpopulation trend as Little Cumberland Island is known to be a highly erosional beach and nesting at Cape Island, the largest rookery in South Carolina (and in the northern subpopulation), may have been affected by raccoon predation control in the first half of the 20th century (S. Murphy personal communication[18]). For the south Florida population, Hutchinson Island, Florida was increasing at 2.2 percent per year prior to the implementation of TEDs (TEWG 1998).

Regression analysis of individual beaches in the northern subpopulation revealed both significantly positive and negative trends on some of the beaches. To assess these trends simultaneously, nesting data from selected beaches were used in a meta-analysis to estimate changes in nesting activity over time for the northern subpopulation and the South Florida subpopulation (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. The analysis treats nesting beaches as random samples from the total. It is necessary to have information on relative abundance in each nesting site in order to obtain an unbiased overall trend for the populations as a whole.

The pre-1990 northern subpopulation growth rate calculated in the meta-analysis varied, depending on the statistical assumptions one makes, from not significantly different from $r = 0.0$ or $\lambda = 1.0$ ($r=\ln(\lambda)$ ($r = -0.026$, $SE = 0.105$) to a value ($r = -0.030$, $SE = 0.012$) similar to the rate reported previously for Little Cumberland Island. After 1990, the analysis indicates an

[17] U.S. Department of Commerce. 2000. Strategy for stewardship: Tortugas Ecological Reserve. Final Supplemental Impact Statement/Final Supplemental Management Plan. National Oceanic and Atmospheric Administration, Washington, DC., 310 pp.

[18] Sally Murphy, South Carolina Marine Resources Department, Charleston, S.C. Personal Communication (E-Mail) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., October 4, 2000.

increasing trend of 2.8-2.9% per year. These results should represent the best-case scenario as the effect of Cape Island nesting activity is dampened in the unweighted analysis.

For the south Florida subpopulation, r = 0.054-0.055 (SE = 0.022, 0.014), and it was increasing at 5.3-5.4% per year 1979-1989. Although the subpopulation has been increasing since 1979, the meta-analysis of nesting trends indicates a slowing in the rate of that increase to 3.9-4.2% per year after 1989, but this is not significantly different from the pre-1990 rate. An important caveat for population trends analysis based on nesting beach data is that this may reflect trends in adult nesting females, but it may not reflect overall population growth rates well. Adult nesting females often account for less that 1% of total population numbers.

In-water Surveys

Fishery independent, in-water studies of sea turtles have been carried out at multiple sites in the Gulf and U.S. Atlantic with varying goals and target species. To date, NMFS has not been able to use the results of these studies to determine trends of in-water sea turtle populations (see discussion in TEWG 2000). In March 2000 NMFS sponsored a workshop to determine the feasibility of using sea turtle catch and survey methods to determine relative population abundance and population trends and to train participants in analyzing their data for this purpose (Bjorndal and Bolten 2000). The participants concluded that although the duration to detect trends in relative abundance differed among studies, all techniques reviewed appeared to be feasible. However, many have not been standardized over a long enough period to analyze for trends. Furthermore the statistical power varied among the studies. A fishery-dependent trawl survey examined was an exception – it did not appear to be a feasible method - but those data were not examined with non-parametric statistics. Epperly (in Bjorndal and Bolten 2000) clearly demonstrated the value of using non-parametric statistical models in the analysis of data sets with a large number of zero catches, which is typical of random sampling for sea turtles. As sufficient data are accumulated we encourage researchers to begin publishing the results of their studies to elucidate trends in abundance of non-nesting turtles.

Trends: Southeast Area Monitoring and Assessment Program - (SEAMAP)

In 1986, the South Carolina Marine Resources Department initiated a NMFS-funded fishery-independent trawl survey off the southeastern U.S. states to assess finfish populations (SCMRD 2000). The survey includes ocean waters 15-60 ft (4.6-18.3 m) deep, from Cape Hatteras to Cape Canaveral (Fig. 4). In 1990 the survey was standardized and stations were chosen based on a stratified random design and once established were fixed and trawled repetitively over the years. The survey design is to make 78 tows/season in nearshore strata in spring, summer, and fall and 27 and 16 tows in offshore strata in spring and fall, respectively. Over the 11 yr period of 1990-2000, only 10 stations have been missed. Paired 75 ft (22.9 m) high rise trawls (Mongoose-Falcon nets), originally of 1-7/8 in (4.8 cm) stretch mesh and in later years of 1-5/8 in (4.1 cm) mesh, without turtle excluder devices have been used throughout the study, and with very few exceptions tow duration for each haul has been 20 min. during daylight hours. Sea turtles infrequently are captured. The survey now is more than a decade old and is analyzed for trends in loggerhead sea turtle abundance for the first time.

Methods

The process of calculating the indices of abundance from this data involves the standardization of yearly changes in bycatch rate, accounting for the influence of those factors that have a significant influence. Factors which were considered as possible influences on bycatch rates included year, season, latitude, and precipitation state during the tow (PRECIP, rated as none, light rain, or moderate rain), surface salinity, bottom salinity, air temperature, surface water temperature, bottom water temperature, barometric pressure, time at the start of the tow, water depth at the start of the tow, and vectors of wind velocity from the north (NORTWIND, typically along shore) and from the west (WESTWIND, typically off shore). Effort units were defined as the individual tows, which as stated previously were nearly all 20 minutes in duration.

The areas defined for the survey are shown in Figure 4. Area strata were categorized as either INNER (nearer to shore) or OUTER (further from shore). Few turtles were caught in the OUTER strata; when this did occur, it was usually during the spring season. Preliminary examination of the data suggested that this OUTER turtle bycatch during the spring might result from colder temperatures in the INNER strata during that year-season, with turtles consequently staying in the deeper waters. Furthermore, turtle migration takes place during the spring season, which may result in bycatch levels which are subject to local migration patterns rather than reflective of abundance. For these reasons, the analysis data set was restricted to the INNER area strata and to the summer and fall seasons. The observed loggerhead turtle yearly bycatch rates are shown in Table 2 and Figure 5.

The Lo method (Lo *et al*. 1992) was used to develop standardized indices; with that method separate analyses are conducted of the positive bycatch rates and the proportions of the observed tows on which turtles were caught. This has been used previously for analyses of bluefin tuna catch rates on rod and reel (Ortiz *et al.* 1999, Turner *et al.* 1999, Brown *et al.* 1999), catch rates which are similar to the turtle bycatch rates from the SEAMAP survey data in that they can be extremely low, particularly for the largest size classes of bluefin tuna. For those bluefin tuna analyses, a delta-lognormal model approach was used; this used a delta distribution with an assumed binomial error distribution for the proportion of positive observations (trips), and assumed a lognormal error distribution for the catch rates on successful trips. More recent analyses for bluefin tuna rod and reel catch rates (Brown in prep) and yellowfin tuna longline catch rates (González Ania *et al.* 2001) used a delta-Poisson model approach, differing from the delta-lognormal approach in that a Poisson error distribution is assumed for the catches on successful trips. The delta-Poisson model approach was used for the analyses of the turtle bycatch rates.

Parameterization of the model was accomplished using a Generalized Linear Model (GLM) structure: The proportion of tows with loggerhead bycatch (*i.e.*, positive observations) per stratum was assumed to follow a binomial distribution where the estimated probability was a linearized function of fixed factors. The logit function linked the linear component and the assumed binomial distribution. Similarly, the estimated catch observed on positive trips was a function of similar fixed factors with the log function as a link.

A stepwise approach was used to quantify the relative importance of the main factors explaining the variance in bycatch rates. That is, first the Null model was run, in which no factors were entered in the model. These results reflect the distribution of the nominal data. Each potential factor was then tested one at a time. For each run, the deviance was calculated as the negative of twice the difference between the log-likelihood under the model and the log-likelihood under the maximum achievable (saturated) model:

$$D^*(y;\hat{u}) = -2(l(\hat{u};y) - l(\hat{u}_{\max};y))$$

The results were then ranked from greatest to least reduction in deviance per degree of freedom when compared to the Null model. The factor which resulted in the greatest reduction in deviance per degree of freedom was then incorporated into the model, provided two conditions were met: (1) the effect of the factor was determined to be significant at at least the 5% level based upon a χ^2 (Chi-Square) test, and (2) the deviance per degree of freedom was reduced by at least 1% from the less complex model. This process was repeated, adding factors (including factor interactions) one at a time at each step, until no factor met the criteria for incorporation into the final model. The final model then, included any significant fixed and random (year)*factors interactions.

The product of the standardized proportion positives and the standardized positive catch rates was used to calculate overall standardized catch rates. For comparative purposes, each relative index of abundance was obtained dividing the standardized catch rates by the mean value in each series.

Results and Discussion

The results of the stepwise procedure to develop the models are shown in Table 3 for the proportion positive bycatch model and in Table 4 for the positive bycatch model. The factors examined did not explain much of the catch rate variability in either model. For the proportion positive bycatch model, only the factor of latitude (LAT) met the conditions required for inclusion in the model (significance at the 5% level and reducing deviance per degree of freedom by at least 1%). The factor YEAR was included in the final model since this was the factor of concern and for which the least-square means were to be calculated. Together, LAT and YEAR accounted for only a 4.4% reduction in deviance per degree of freedom from the NULL model. For the positive bycatch model, none of the tested factors met the conditions required for inclusion in the model. This is not surprising, since there is very little contrast in the positive catch data; nearly 95% of the positive catch observations were of 1 turtle, with remainder being 2 turtles caught per tow. Again, YEAR was included in the final model in order to calculate the least square means. Although the positive catch analysis results are unreliable due to the lack of contrast, the end result is that values close to the nominal positive catch rates are combined with the results of the proportion positive analysis to produce annual index values. Therefore, the conclusions are primarily based upon the proportion positive analysis.

The results of the model fits for the updated indices are shown in Table 5 for the proportion positive bycatch model and in Table 6 for the positive bycatch model. The index values are shown in Table 7 and in Figure 6. The relative observed bycatch rates are also shown in Figure 6. It is clear that the standardized trend varies little from the nominal trend. However, the standardization procedure does provide some measure of the uncertainty around the relative indices calculated from this survey. This permits the calculation of the power of this survey to detect changes in abundance.

It does appear that the catches have been increasing; a regression analysis indicated an increasing trend of 11.2%/yr relative to the catch during the first year. However, the error about each year's point estimate is large and the number of captures in 2000 is not significantly different than the number captured in 1990 ($p=0.24$). Thus, no significant trend was detected in this fishery-independent survey to indicate that the in-water population of loggerheads in the Western North Atlantic is increasing.

We assessed the power of the SEAMAP monitoring program to detect a trend in loggerhead sea turtle abundance by utilizing the program TRENDS. At a recent workshop on in-water sea turtle population trends held in March 2000 (Bjorndal and Bolten 2000) the emphasis was on minimizing the Tye II error (maximizing power to detect trends) so the Type I error was set to 0.2 and the Type II error to 0.1. For purpose of comparison to the results of that workshop, we used the same criteria and ran two trials. Trial A was to determine the minimum detectable annual rate of change within the 11 years duration of this program, assuming population growth is exponential and declining, Type I Error (α)=0.2, and Type II Error (β)=0.1, the statistical power = 0.9. Trial B was to determine the minimum duration (yrs) required to detect an annual decline of 25%. These analyses indicated that the SEAMAP monitoring program could detect a trend of –0.24%/year after 11 yrs, the same amount of time required to detect a decline of 25%/year. Therefore, unless the population was changing in size at about 25% per year, it is unlikely (<90% probability) that the SEAMAP monitoring program would be able to detect a trend within the duration that it has been ongoing (11 yrs).

Stock Assessment

Crouse *et al.* (1987) developed the first stage-based matrix population model for the loggerhead turtle. They collapsed Frazer's (1983*a*) 54-stage loggerhead life-table into 7 stages, hatchlings, small juveniles, large juveniles, subadults, novice breeders, 1st year remigrants and adults. In a further refinement of the model, Crowder *et al.* (1994) reduced the 7-stage model to a 5-stage model, combining all breeding adults into one stage. Crowder *et al.* (1994) also presented an age-based matrix model of loggerheads in order to qualitatively assess how population trajectories respond to management practices.

Heppell *et al.* (in press) redefined the stages first changing the model from a post-breeding census to a pre-breeding census, incorporating first year survival into the fertility term and eliminating hatchlings as a separate stage. In addition, Heppell *et al.* (in press) eliminated the subadult stage and defined three juvenile stages, pelagic juveniles, small benthic juveniles and large benthic juveniles. TEWG (1998) defined the cutoff between small and large benthic juveniles at 70 cm straight carapace length (SCL) based on differential habitat utilization. Loggerheads slightly larger that 70 cm may be too large to fit through the smallest current TED openings[19], introducing potentially different mortality rates between the two benthic juvenile stages. Because current regulations require smaller TED openings in the Gulf of Mexico than in the Atlantic, this cutoff can be a bit fuzzy, but large juveniles and adults probably experience limited benefits from TEDs. Heppell *et al*. (in press) used 70 cm SCL as the cutoff between small and large benthic juveniles. Another change from the previous models is that a variable remigration interval is incorporated, making nesting females a separate stage from non-nesting females. As in Crowder *et al.* (1994), Heppell *et al.* (in press) expanded the model to be age-based in order to assess population responses to TED regulations. The model, then, is essentially a Leslie matrix, with annual survival rates on the subdiagonal and fecundity in the top row. The row of the matrix equivalent to age at reproductive maturity represents breeding females. The remaining 4 rows of the matrix cycles the surviving neophytes and remigrants based on the proportion of females returning to nest after 1, 2, 3, 4, or 5 years which are 3%, 56%, 31%, 7% and 3% (Richardson *et al*. 1978).

The models we present here are the same as the 5-stage structured models of Heppell *et al.* (in press) and are similarly expanded to age-based models. However, to update the parameters of the models as much as possible we analyzed new data sets to determine the best available information to use in this current stock assessment. We construct models using both the historical and updated vital rates.

Vital Rates

Duration of Stages

Heppell *et al.* (in press) present two models, both incorporating the structure described above. Model 1 uses stage durations that are consistent with the previous models and derive from a von Bertalanffy growth curve developed by Frazer (1987). Model 2 uses longer stage durations that are based on a von Bertalanffy growth curve developed from a preliminary analysis of a mark-recapture study in North Carolina (Braun-McNeill *et al.* in press). Since Frazer's (1987) growth model was based on loggerheads caught in Florida, we thought that Model 1 might be representative of a faster growing population in the south, and model 2 representative of a slower growing northern population (see previous section on stock definition).

To further assess individual growth rates and the possibility of regional variability, we analyzed published von Bertalanffy growth curves that were based on mark-recapture data from wild loggerheads in the southeast U.S. (Table 9, Fig. 7). The curves prepared by Braun-McNeill *et al.* (in prep)[20] used data for turtles whose time between first capture and recapture was greater than 11 months. Schmid (1995) prepared a curve where he only used recaptures when the time

[19] 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, 31 pp.

[20] Braun-McNeill, J., S.P Epperly, and L. Avens. A preliminary analysis of growth rates of immature loggerhead (*Caretta caretta*) sea turtles from North Carolina, U.S.A. Manuscript in preparation.

between first capture and recapture was greater than or equal to 365 days (designated as ** in Table 8). As with other poikilotherms, metabolic activity in loggerheads is external-temperature dependent and it is likely that little or no growth occurs during the winter months (Castanet 1994), hence inferring growth rates from time periods of less than one year may result in inaccuracies. The Schmid (1995)** curve was prepared from only 19 growth rates and it is unclear what the size distribution was for turtles included in the analysis. The Braun-McNeill *et al.* (in prep)[20] curve was estimated primarily from small benthic juveniles, using growth rates from 57 turtles. In order to apply the Braun-McNeill *et al.* (in prep)[20] curve to the entire benthic life-stage, we extended the size range by adding additional mark-recapture growth rates for animals greater than 70 cm SCL from the CMTTP[21]. We used records from both data sets for animals that were at large for at least 0.9 yr, had a straight carapace length recorded, and did not indicate negative growth. From the CMTTP, in order not to bias the growth curve to the growth rates of a few individuals, we used only one growth rate for each animal included, even if there were multiple recapture records for the animal (Fig. 8 and 9).

Chaloupka and Limpus (1997) and Limpus and Chaloupka (1997) found sex-specific growth rates in hawksbill (*Eretmochelys imbricata*) and green (*Chelonia mydas*) sea turtles in the southern Great Barrier Reef. The turtles in these studies were sexed by internal observation of the gonads. As sex cannot be determined externally for juvenile sea turtles and there are little data on growth of loggerhead turtles of known sex in the Western North Atlantic we could not attempt to look at sex-specific growth rates.

The new growth curve is derived from animals throughout the southeast U.S. and cannot be used to address the question of regional variability in growth rates. But the intrinsic rate of growth (k) for this curve did not deviate much from that calculated by Braun-McNeill *et al*. (in prep) and is comparable to those estimated by Schmid (1995) and Foster (1994) (Table 8, Fig. 7). Hence we feel it is the best overall representation of loggerhead growth rates for the southeast U.S. available to date and we use it in the current model to estimate stage-durations, time-to-maturity and age-at-size.

The Frazer (1987) curve was prepared from juvenile growth rates of wild loggerheads in Florida that had overall higher growth rates than those measured in North Carolina (Mendonca 1981, Frazer and Ehrhart 1985, Frazer 1987, Braun-McNeill *et al*. in prep) and we cannot discount the possibility that this curve is representative of a maximum growth rate for wild loggerheads. Because of this and to be consistent with the previous models, we also consider models based on Frazer's (1987) growth curve.

Bjorndal *et al.* (2000) evaluated the duration of the pelagic stage. Their results estimate a minimum time of 6.5 years and an average time of 8 years for the duration of this stage. As the model we are using incorporates the first year into the fecundity function, we use 6 years and 7 years as minimum and average durations of the pelagic stage.

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[21] Unpublished Data. The Cooperative Marine Turtle Program was established by NMFS in 1980 to centralize the tagging programs among sea turtle researchers, distribute tags, manage tagging data, and facilitate the exchange of tag data.

Size-at-Stage

The earlier models define 58.1 cm SCL as the break between small and large juveniles and 87 cm SCL as the size at maturity (Crouse *et al.* 1987, Crowder *et al.* 1994). TEWG (1998) recommends 92 cm SCL as the average size of neophyte nesters. Heppell *et al.* (in press) uses 45 cm SCL as size at first settlement from pelagic to benthic habitats and 92 cm SCL as size at maturity.

In the models used for this stock assessment, we consider two size-at-stage scenarios. The first looks at a minimum size-to-stage and the second an average size-to-stage. Bjorndal *et al.* (2000) suggests 42 cm SCL as the smallest size at first settlement for loggerheads. Bjorndal *et al.* (2000) also estimate that the average size at settlement is 53 cm CCL or 49cm SCL (using their SCL to CCL conversion equation).

For size at maturity, we analyzed the CMTTP[21] for original tagging events from nesting beach survey projects where SCL was recorded. We calculated an average of 90.38 cm SCL (SD=5.08) with the 5th and 95th percentiles equal to 82.5 and 99.2 cm SCL respectively (Fig 10). Given that some individuals might nest before they get tagged for the first time or the first tag might have been lost and the turtle not recognized as having been tagged, we acknowledge that 90.38 cm SCL is perhaps biased large as an average size-to maturity.

Hence, for the minimum size-to-stage scenario we use 42 cm SCL as the cutoff between pelagic juveniles and small benthic juveniles and 83 cm SCL (from the 5th percentile of the analysis of the CMTTP)[21].as size-to-maturity. For the average size-to-stage scenario we use Bjorndal *et al.*'s (2000) estimate of 49 cm SCL as the cutoff between pelagic juveniles and small benthic juveniles and 90 cm SCL (calculated from the CMTTP[21]) for average size-to-maturity.

Sex Ratios

The sex of loggerhead sea turtle hatchlings is environmentally determined by a restricted range of nest incubation temperatures. Pivotal and transitional ranges of temperatures determine if the nest will produce males, females or both (Mrosovsky and Pieau 1991). Mrosovsky and Provancha (1989) suggest that the majority of a major rookery near Cape Canaveral, Florida incubates at such warm temperatures that virtually no males are produced. Presumably because of a shorter nesting season, characterized by cool beginning and ending temperatures, males are predominately produced in the Northern subpopulation.

We assessed the sex ratios of benthic loggerhead sea turtles by analyzing the STSSN database[22] for dead-stranded loggerheads for which sex had been ascertained by direct examination of the gonads. It is likely that adult loggerheads have sex specific dispersal and consideration of adults in the analyses may bias the results. Therefore, to be conservative we

[22] 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.

only considered loggerheads less than 80 cm SCL in order to eliminate adults from the analysis. Sex ratios were then assessed by statistical zone and by state (Table 9).

From mtDNA analyses, we know that the feeding aggregations of juvenile loggerheads are composed of turtles from the different subpopulations. Bass *et al*. (1999[23]) analyzed genetic samples taken from stranded animals from 5 states, Texas, Florida, South Carolina, North Carolina and Virginia (Fig. 1). We combined information regarding the sex ratios of the juvenile feeding aggregations with the natal origin probabilities to determine the sex ratios specific to the analyzed subpopulations.

We restricted our analysis to states where sample sizes were sufficiently large (N≅100), where samples could be definitely assigned to relatively small (<500 km) geographic areas, and where all samples were analyzed for the same suite of contributing source populations. Data on Florida was not included because it did not meet the small geographic area criteria defined above. The sample size from Virginia was too small (N=35). The sample size from North Carolina also was small (N=60), however in another study, additional North Carolina samples were analyzed, increasing the sample size to 286 (Bass *et al*. 2000[24]).

We used the genetics data from Texas (N=121)[23], South Carolina (N=95)[23] and North Carolina (N=286)[24] in combination with juvenile sex ratios from those states (Table 9) to set up the following linear equations:

$74.21 = 83.36\mathbf{S} + 10.33\mathbf{N} + 6.30\mathbf{M}$ (TX sex ratio and natal origin probabilities[23])
$67.44 = 65.66\mathbf{S} + 24.55\mathbf{N} + 9.77\mathbf{M}$ (SC sex ratio and natal origin probabilities[23])
$65.25 = 64.04\mathbf{S} + 29.78\mathbf{N} + 5.82\mathbf{M}$ (NC sex ratio and natal origin probabilities[24])

S is the percent female hatchlings produced by the South Florida subpopulation, **N** is the percent female produced by northern subpopulation and **M** is the percent female hatchlings from the Yucatán subpopulation. The above three equations in three unknowns solved to give the following percentages:

S = 80% Female
N = 35% Female
M = 69% Female

We can estimate the south Florida subpopulation produces 80% females and the northern subpopulation produces 65% males. Limited data for the Yucatán subpopulation suggest nearly 70% of hatchlings are female. The sex ratios for the northern and south Florida subpopulations are consistent with what is known about the temperature-dependent sex determination of

[23] Bass, A.l. S-M. Chow, and B.W. Bowen. 1999. Final report for project titled: genetic identities of loggerhead turtles stranded in the Southeast United States. Unpublished report to National Marine Fisheries Service, order number 40AANF809090. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla., 11pp.

[24] Bass, A.L. S.P. Epperly, J. Braun-McNeill and A. Francisco. 2000. Temporal variation in the composition of a loggerhead turtle (*Caretta caretta*) developmental habitat. Unpublished manuscript. Department of Fisheries and Aquatic Sciences, University of Florida, Gainesville, Fla., 26 pp.

loggerheads. For lack of specific data to the contrary, previous models have used 0.5 as the default sex ratio for loggerheads (Crouse *et al.* 1987, Crowder *et al.* 1994 and Heppell *et al.* in press). We now have regional sex ratios to use in the model but also construct the same models with a sex ratio of 0.50 for comparison with historical models.

Survival Rates

For the model runs in which stage duration was estimated using Frazer's (1987) growth curve, we use the same survival rates that were estimated by Frazer (1983*a*, 1986) and used in the previous models (Crouse *et al.* 1987, Crowder *et al.* 1994, Heppell *et al.* in press). Heppell *et al.* (in press) found they needed to increase survival rates from the previous models to gain a realistic life history for the longer stage durations. Hence we wanted to readdress benthic juvenile and adult survival rates.

Benthic Juveniles

Frazer (1987) estimated juvenile survival rates for loggerhead sea turtles using a catch curve (Seber 1982). But it seems likely that if a faster growth curve is used to estimate age-at-size, the resulting slope on the catch-curve will be steeper than for age-at-size calculated from slower growth curves. Steeper slopes correlate with higher instantaneous mortalities.

We analyzed the STSSN[22] data using a catch curve analysis. We used only data from 1986-1989 (pre-TED), assuming the population was at a stable age distribution at that time and that dead stranded animals are a representative cross-section of the body sizes of turtles in the population. Catch curves are created by plotting $\ln(N_x)$ versus x where x is age and N_x is the number of individuals in the sampled population at age x. The age at which all individuals have fully recruited to the population (threshold age (Seber 1982)) is estimated as the peak in the curve. Age-at-size was calculated for each dead stranded loggerhead using the new growth curve. N_x was calculated for each one-year age class (x) and $\ln(N_x)$ was plotted versus x (Fig. 11).

Threshold age was determined at 2 years post-settlement. We calculated the instantaneous mortality rate (z) from linear regressions on the declining arm of the catch curve in three different ways (Fig. 12):

- From threshold age to the age corresponding to 70 cm SCL
- From threshold age to the age corresponding to 90 cm SCL
- From threshold age-to-age 20, the point where the trend in the curve start to break-up.

Breaking the catch curve at the 3 different points resulted in similar survival rates, 0.893, 0.929 and 0.908 respectively. To be conservative, we use 0.893 as the pre-TED annual survival rate for small and large benthic juveniles in the current models.

TEWG (2000, pg. 46) reviews estimates of quantitative decreases in strandings after the imposition of TED regulations based on analyses of strandings from South Carolina and Georgia

(Crowder *et al.* 1995, Royle and Crowder 1998[25], Royle 2000[26]). It is unclear how to relate the percent decreases in strandings (reported at between 37 and 58%) to reductions in instantaneous mortality (z). Heppell *et al.* (in press) used a value of 30% reduction in mortality as the amount by which TED use reduces overall mortality of the affected stages of loggerhead sea turtles.

As the smallest TED openings only allow small turtles to pass through[19], we applied a 30% reduction in mortality to small benthic juveniles only to estimate the annual survival rate of this size class after 1990. We calculated the new annual survival rate for small benthic juveniles by multiplying z, the instantaneous rate of mortality by 0.7.

Adults

For adult survival probabilities, we analyzed nesting beach tag return data for two nest monitoring projects using modifications of the Cormack-Jolly-Seber approach (Cormack 1964, Jolly 1965, Seber 1965, Lebreton *et al.* 1992). The two nesting beaches analyzed were Melbourne Beach, Florida[27] and Wassaw Island, Georgia[28] (Williams and Frick 2001). For Wassaw Island, tag-loss was accounted for according to Frazer (1983*b*). The program MARK (White and Burnham 1999) was used to estimate survival rates for each data set based on the models of Lebreton *et al.* (1992). For Wassaw Island, the model incorporating time dependent survival probability (ϕ_t) and time independent capture probability ($p_.$) gave the best goodness-of-fit based on Akaike's Information Criterion. For Melbourne Beach the model giving the best goodness-of-fit incorporates time dependent survival and capture probabilities (ϕ_t, p_t). Average estimated annual survival probabilities were 0.79 for Wassaw Island and 0.83 for Melbourne Beach. The models used do not account for emigration, hence,

$$\phi_t = S_t(1-E_t)$$

where S_t is the annual survival rate and E_t is the emigration rate. We know that nesting loggerheads do not have strict nest-site fidelity (CMTTP[21], LeBuff 1974, Ehrhart 1979[2], Bjorndal et al. 1983, LeBuff 1990) but the actual value of E_t is unknown so we use ϕ_t as an estimate of annual survival acknowledging that this value is lower than the true survival rate and therefore conservative. The annual survival rates calculated from the tag-return data (0.79 and 0.83) are in close agreement with the value of 0.8091 originally estimated from Little Cumberland Island data (Frazer 1983b). In light of the uncertainty associated with these values, we selected the mean of all three values, 0.812 as representative of adult annual survival in the current model.

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[25] Royle, J.A. and L.B. Crowder. 1998. Estimation of a TED effect from loggerhead strandings in South Carolina and Georgia strandings data from 1980-97. Unpublished report, U.S. Fish and Wildlife Service, Laurel, Maryland, 11pp.

[26] Royle, J.A. 2000. Estimation of the TED effect in Georgia shrimp strandings data. Unpublished report, U.S. Fish and Wildlife Service, Laurel, Maryland, 11pp.

[27] Ehrhart, L.M. Unpublished data. Department of Biology, University of Central Florida, Orlando, Fla.

[28] The Caretta Research Project, Savannah Science Museum, P.O. Box 9841 Savannah Ga. and the U.S. Fish and Wildlife Service, Savannah Coastal Refuges, 1000 Business Center Drive, Suite 10, Savannah, Ga.

Pelagic Juveniles

Due to the cryptic nature of this life stage, no data are available to directly measure pelagic juvenile survival rates. Because we have estimates for all other inputs into the model, we can infer pelagic survival rates from those rates and population trends. We assessed the range in potential annual survival rates of pelagic juveniles by allowing for the uncertainties in other parameter estimates and running the model using combinations of the inputs as discussed in the previous sections and three values for λ for the northern subpopulation (λ = 0.95, 0.97 and 1.0) as discussed above in the Status and Trends section. We feel that the overall population trend for the northern subpopulation prior to 1990 is encompassed within the range of λ values we used.

Fecundity

Heppell *et al*. (in press) used reproduction parameters from TEWG (1998) and survival to year 1 from Frazer (1983). We use the same values for the current models, which are nests per breeding female = 4.1, eggs per nest = 115, and survival to year 1 = 0.6747. The fecundity value in the matrix is:

F = 4.1 x 115 x (proportion of female offspring) x 0.6747.

Population Models

We considered four different stage duration scenarios (Models 1-4). These were based on the two individual growth models, Frazer's (1987) (Frazer) and the new one presented here (New). For each growth curve, we estimated stage durations based on the minimum-size-to-stage and the average-size-to-stage values discussed in the size-at-stage section and survival rates were used as discussed previously (Tables 10-13). We used the same fecundity parameters as in Heppell *et al.* (in press) with the exception of the sex ratio.

For each model, we ran 3 scenarios, using λ = 0.95, 0.97 and 1.00. As these reflect the range of estimates for the pre-1990 population growth rates for the northern subpopulation, we used 0.35 as the proportion of female offspring in these models. For each of these 12 (4 models times 3 population growth rates) runs of the model, we determined the appropriate annual survival rate for the pelagic stage (Table 14). In Model 2, the pelagic annual survival probability for the λ = 1.0 scenario would have to have exceeded 1.0, so we discount this possible combination of vital rates and consider only the remaining 11 runs of the model.

The right eigenvector of a projection matrix gives the proportional distribution of ages for a population at a stable age distribution (Caswell 2001). To check how well the age distributions associated with each model correlates with the natural population, we summed the proportional contributions across the benthic stages (small, large, and adult) to get the predicted stable stage structure. We compared this to the observed stage structure based on an analysis of strandings between 1986 and 1989 (the same data used to create the catch curve) (Fig. 13). Models 3 and 4 appear to have the best fit with the strandings data.

Elasticity of Stages

For matrix projection models, an elasticity analysis examines the proportional contribution of the asymptotic population growth rate (λ) to changes in the vital rates that compose the elements of the transition matrix (de Kroon *et al*. 1986, 2000). Elasticities also reveal the proportional contribution of each element of the matrix to λ. For an age-based matrix, elasticities can be summed over stages to find the proportional contribution of each major life-stage to λ. The elasticity of λ to juvenile stage is dependant on the duration of those stages (Caswell 2001, Heppell *et al*. 2000). Longer stage lengths have higher elasticities. Thus, for Model 1, small and large benthic juveniles have the same elasticity (Fig. 14). For Model 2, small benthic juvenile elasticity is lower than that of pelagic juveniles while the elasticity of the large benthic juveniles is much higher than either of the other juvenile stages. Similarly, the elasticities of the juvenile stages for Models 3 and 4 correlate with the stage durations (Tables 12 and 13) and the longest stage duration, the large benthic juvenile stage of Model 4, has the highest elasticity (Fig. 14). These are the elasticities for λ = 0.95, the specific values change only slightly with changes in λ and the overall trends remain the same.

Sex Ratios

There is no reason to expect different pelagic juvenile stage survival rates for loggerheads originating from the south Florida subpopulation as compared to the northern subpopulation. For the benthic stages, there are potential differences in nearshore mortality from anthopogenic sources. As we have no current means of quantifying such differences, we assume the benthic stage survival rates are the same for both subpopulations. There is, however, evidence of a higher proportion of females being produced in the South Florida subpopulation. Hence, we also ran the same 11 models as described previously, with a proportion of female offspring equal to 0.80. For consistency with the historical models, we also ran the 11 models with a proportion of female offspring equal to 0.50.

Population Projection

Following Heppell *et al.* (in press), post-1990 population trajectories were run for each model (now numbering 33 – 11 times the 3 sex ratios) by initializing with a population at stable age distribution for the appropriate combination of model and λ, assuming 2000 nesting females (TEWG 1998). Small benthic juvenile mortality was decreased by 30% and the population projected based on the new survival rates (Fig. 15-17). Obviously, increasing small benthic juvenile survival rates has the effect of increasing population growth rates for each model scenario (see Fig. 18 for new population growth rates). However, when the populations are initialized at a declining rate of 5% per year (λ=0.95), a 30% decrease in mortality of small benthic juveniles is not enough to reverse the declining trends regardless of the sex ratio (Fig. 18). At an initial population decline of 3% per year, declining trends are reversed in Models 1 and 2 except at a sex ratio of 0.35 for Model 2. At stable population growth, λ=1.0, a 30% decrease in small benthic juvenile mortality alone results in increasing population trends in all model scenarios (Fig. 18). Note that the λ values given in Fig. 15-18 are the initial population growth rates. The populations in these projections will eventually stabilize to the respective population growth rates indicated in Fig. 18.

TEWG (1998) presented a population model for the Kemp's ridley sea turtle for which the model projections were fit to observed nesting trends. This was possible for Kemp's as there is only a single stock with one primary nesting aggregation and 30 years of nesting trend and hatchling production data. Loggerheads of the southeast U.S. have a much more complicated stock structure with numerous nesting aggregations, only some of which are currently monitored and very few were regularly monitored prior to 1989.

We are using the four model scenarios, each with three starting λ values to address the uncertainties in the model parameters. The actual stage duration and population growth rates are likely bracketed. Due to the uncertainty inherent in these models, we do not assert that the population projections presented here and elsewhere in this document are quantitative predictions of future sea turtle numbers. They should be viewed only as qualitative outcomes of the implementation of management strategies (or lack thereof), indicating the time lags that can be expected before the effects of management are seen in terms of numbers of nesting females (Crowder *et al.* 1994). This is also why we do not put specific years on the x-axis of the projection plots (Fig. 15-17).

We start the population projections at stable age distribution. At time one we increase survival of the small benthic juveniles which perturbs the population out of stable age distribution, giving a pulse of small benthic juveniles. The lag time before the initial pulse of small benthic juveniles are seen as an increase in the number of nesting females is equal to the length of the duration of the large benthic juvenile stage. After a length of time equivalent to the duration of the small benthic juvenile stage, this pulse in the numbers of nesting females levels out and the populations temporarily stabilize. However, there are now increased numbers of nesting females producing increased numbers of offspring. Following a period equal to age at reproductive maturity, when these increased numbers of offspring begin to mature, another pulse is observed in the number of nesting females. Due to the duration of the stages, the latter pulse is seen only in Model 1. For this model the duration of the large benthic juvenile stage is 7 years. The first pulse for Model 1 occurs at 7 years (Fig. 15-17, Model 1). The duration of the small benthic juvenile stage is 7 years, hence, after 14 years the initial pulse levels out (Fig. 15-17, Model 1). Age to reproductive maturity for Model 1 is 21 years, therefore, 21 years after the first pulse began, or at 28 years, the number of nesting females pulses again. The pulses will continue until the populations again reach stable age distribution, which often takes two generations or more. Similar dynamics are occurring in the population projections for the other models, however, the time series were not run long enough to see the effects of increased numbers of offspring (Fig. 15-17; Models 2-4).

In model 2, the populations are still declining for 35% female offspring and starting λ = 0.95 and 0.97, and for 50 % female offspring and starting λ = 0.95 following the increase in small benthic juvenile survival (Fig. 18). The populations are slightly increasing following the increase in small benthic juvenile survival for starting λ = 0.97 (Fig. 18). As described above, there is a surge in number of nesting females as the increased numbers of small benthic juveniles pulse through, after which the population continues to decline (Fig. 15-17; Model 2). For Models 3 and 4, λ = 0.95 and 0.97, similar dynamics are occurring, however, the length of the large benthic juvenile stage is very long and the populations are still declining by as much as 4%

per year (Fig 15-17, Models 3 and 4; Fig. 18), hence the pulse of small benthic juveniles is not as obvious.

The meta-analysis of nesting trends for the northern subpopulation indicates that numbers of nesting females in this region may have increased since 1990. In our models, we only allow for increases in small benthic juvenile survival and thus it takes a period equal to the duration of the large benthic juvenile stage to begin to see increases in numbers of nesting females (Fig. 15-17, Tables 10-13). The effects of TED use on decreasing mortality in sea turtles have been documented quantitatively (TEWG 1998, Crowder *et al.* 1995, Royle and Crowder 1998[25], Royle 2000[26]). Using the cut-off of 70 cm SCL and below for the benefits of TED use is also justified as that is about the maximum size turtle that can fit through the smallest size TED openings allowed under current regulations (Epperly and Teas 1999[19]).

There are other anthropogenic sources of sea turtle mortality that have been mitigated over the years. For example, when the loggerhead sea turtle was listed as a threatened species in 1978 under the Endangered Species Act of 1973 (PL93-205), taking eggs and nesting females, and keeping in-water catches became illegal. South Carolina sturgeon fishers using large mesh gill nets and operating in the coastal waters of South Carolina and North Carolina, were implicated in mass-dead-stranding events of loggerheads up to 89 cm SCL from mid-April to early May of 1977 and 1981 (Crouse 1985, Ulrich 1978[29]). This fishery was closed in 1986 in South Carolina (NMFS and USFWS 1991) due to declines in sturgeon populations. North Carolina initially imposed restrictions on the use of large mesh gill nets between February and September (N.C. Marine Fisheries Regulations, NCAC 15 3B.0402(5)) and as of 1991, the sturgeon fishery has been closed. The state of Florida now prohibits the use of entangling nets (Florida Fish and Wildlife Conservation Commission, Division of Marine Fisheries Regulations, Chapter 68B-4.0081, issued 3-1-92, amended, 7-18-94 and 4-27-98). Takes of pelagic juvenile loggerheads in US and international longline fisheries in the North Atlantic are only now being quantified, but estimates from the Eastern North Atlantic are large (Bolten *et al*. 1994) and could alter population trends (Crowder *et al.* 1994).

Combining these factors and possibly others that are not documented may contribute to the potentially increasing trends in nesting females seen in the meta-analysis results for the northern subpopulation, but that analysis is presented with caution as it is unweighted and does not consider the relative abundance of each beach. As factors may have combined to contribute to possibly increasing nesting population trends for the northern subpopulation, they would be accounted for in the scenarios that set $\lambda = 1.0$. Conversely, there are likely other sources of mortality offsetting the mitigated ones that are resulting in the slow-down of increasing nesting trends in the south Florida subpopulation. None of these other mortality sources are well studied or documented and cannot be considered quantitatively in the population models.

There is some concern about the nest trend data used in the meta-analysis. It is possible that what appears to be increasing trends is an artifact of increasing survey efforts. Attempts were made to circumvent this possibility by only using data that appeared to represent consistent

[29] Ulrich, G.F. 1978. Incidental catch of loggerhead turtles by South Carolina commercial fisheries. Unpublished report to National Marine Fisheries Service, contract numbers 03-7-042-35151 and 03-7-042-35121. South Carolina Wildlife and Marine Resources Department, Charleston, S.C. 36pp.

effort, however, we also do not want to overestimate population growth rates for loggerheads. Therefore, we continue to consider all three possible scenarios in the impact assessment. We also need to consider that nesting trends reflect trends in only a very small portion of the overall population and that uncertainties not included in the model do not provide assurance that populations will recover.

For λ=0.97 (the median λ evaluated) the models based on the new individual growth curve, Models 3 and 4, using sex ratios of 0.35 or 0.50, all suggest declining populations after a 30% reducation in mortality for small benthic juveniles. At a sex ratio of 0.8, the population growth rates were postive for all models except for Model 4. For the sex ratio representative of the northern subpopulation, 0.35, a 30% decrease in mortality for small benthic juveniles was not enough to stabilize the population growth rate unless the initial λ=1.0.

Impacts on the Populations

Recent Stranding Events and Trends

From 1998-2000, strandings decreased in the traditionally high zones 28-32 along the Atlantic coast (Table 15)[12]. Strandings in the mid-Atlantic zones 35-37 continued to show an increasing trend, with loggerhead strandings in zone 35 reaching an unprecedented total of 396 in 2000. More than half of these turtles washed ashore during April and the first week of May and were likely due to large-mesh gillnet fisheries operating in the area (65 FR 31500-31503, May 18, 2000).

Strandings along the southern Florida Gulf coast and in the Florida Keys were approximately double historic levels in 2000. A persistent red tide during the first five months of the year[30] may have played a role in the increased strandings, especially in zone 3. Loggerhead strandings in southwest Florida were elevated throughout the shrimping season, possibly as a result of the turtles being too large to fit through the current TED openings (Epperly and Teas 1999[31]). Beginning in October, many large loggerheads have been found floating with an illness of undetermined cause in southern Florida and the Keys. These turtles all are extremely weak; they cannot lift their heads out of water to breathe and most have developed secondary pneumonia due to aspiration of water into the lungs[32]. The mortality rate for turtles found alive with these symptoms has been greater than 50% and the turtles that are still alive in rehabilitation facilities are showing few signs of improvement. Researchers believe the turtles may be suffering from a toxin (*Ibid.*).

[30] Mote Marine Laboratory, Sarasota, Fla. 2000. Red Tide Chronology. www.mote.org/~mhenry/rtchrono.phtml

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

[32] Richie Moretti, Sea Turtle Hospital, Marathon, FL. Personal Communication (phone) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., January 17, 2001.

Fate of Dead Turtles

In FY96 NMFS Office of Protected Resources contracted with Duke University Marine Laboratory to study the fate of turtles dying at sea to better understand what numbers of stranded turtles represent. The results will be presented at the upcoming 21st Annual Symposium on Sea Turtle Biology and Conservation in Philadelphia, Pennsylvania in February (P. Mooreside personal communication[33]). Fifteen years of hourly wind speed data, recorded off the North Carolina coast, were transformed into vectors, converted into wind stress magnitude and direction values, and averaged by month. Near-shore surface currents were then modeled for the South Atlantic Bight via a three-dimensional physical oceanographic model (Werner *et al*. 1999). Estimated water currents and particle tracks were compared to the spatial locations of sea turtle carcasses stranded along ocean-facing beaches of North Carolina. On average, the number of carcasses stranded on ocean-facing beaches may represent, at best, approximately 20% of the total number of available carcasses at-sea. This evidence, in accordance with the spatial behavior of modeled lagrangian drogues, indicates that only those turtles killed very close to the shore may be most likely to strand.

Anthropogenic Impacts

A number of anthropogenic impacts have been identified for loggerhead sea turtles (National Research Council 1990, NMFS & USFWS 1991) but few outside drowning in bottom trawls have been quantified with any degree of confidence. While they still cannot be quantified, new information in recent years has come to light concerning longline fisheries and coastal gillnet fisheries, and about marine debris and pollution, mortality sources that primarily affect the pelagic immature stage. A more thorough assessment of anthropogenic mortality sources is provided in the TEWG reports (1998, 2000). Known sources of impact are listed in Appendix 2.

Pelagic longline fisheries

See Part III.

Trawls

A detailed summary of the U. S. shrimp trawl fishery and the Mid-Atlantic winter trawl fishery impacts can be found in the TEWG reports (1998, 2000). Other bottom trawl fisheries that are suspect for the incidental capture of sea turtles are the horseshoe crab fishery in Delaware (Spotila *et al.* 1998[46]) and the whelk trawl fishery in South Carolina (Sally Murphy personal communication[34]) and Georgia (Mark Dodd personal communication[35]). In South Carolina, the whelk trawling season opens in late winter and early spring when offshore bottom waters are > 55ºF. One criterion for closure of this fishery is water temperature: whelk trawling closes for the season and does not reopen throughout the State 6 days after water temperatures first reach 64ºF in the Fort Johnson boat slip. Based on the South Carolina Department of Natural Resources Office of Fisheries Management data, approximately 6 days will usually lapse before water temperatures reach 68ºF, the temperature at which sea turtles move into State waters (David Cupka personal communication[36]). From 1996-1997, observers onboard whelk

[33] Pete Mooreside, Duke University Marine Laboratory. Personal Communication (E-Mail of draft extended abstract) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., January 23, 2001.

trawlers in Georgia reported a total of 3 Kemp's ridley, 2 green and 2 loggerhead sea turtles captured in 28 tows for a CPUE of 0.3097 turtles/100ft net hour[35]. As of December 2000, TEDS are required in Georgia state waters when trawling for whelk (*Ibid*.).

A loggerhead was reported captured in a Florida try net (W. Teas personal communication[37]). Shrimp trawlers operating in the waters off Venezuela were reported to have captured a total of 48 sea turtles, of which 15 were loggerheads, from 13, 6000 trawls (Marcano and Alio 2000). They estimated annual capture of all sea turtle species to be 1370 with an associated mortality of 260 turtles.

Gill nets

A detailed summary of the gill net fisheries currently operating along the mid- and southeast U.S. Atlantic coastline that are known to incidentally capture loggerhead can be found in the TEWG reports (1998, 2000). Although all or most nearshore gill netting in state waters of South Carolina, Georgia, Florida, Louisiana, and Texas is prohibited by state regulations, gill netting in other states' waters and in federal waters does occur. Of particular concern are the nearshore and inshore gill net fisheries of the mid-Atlantic operating in Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina state waters and/or federal waters offshore thereof. Incidental captures in these gill net fisheries (both lethal and non-lethal) of loggerhead, leatherback, green and Kemp's ridley sea turtles have been reported (W. Teas, personal communication[37,] J. Braun-McNeill personal communication[38]). In addition, illegal gill net incidental captures have been reported in South Carolina, Florida, Louisiana and Texas (W. Teas personal communication[37]). See Appendix 2 for additional information.

On October 27, 2000, the North Carolina Division of Marine Fisheries (NCDMF) closed waters in the southeastern portion of the Pamlico Sound to commercial large-mesh flounder gill netting as a result of elevated turtle takes by the fishery. From September 15–October 25, observers documented 17 gill net interactions, eight of which were loggerheads (six released

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[34] Sally Murphy, South Carolina Department of Natural Resources, Charleston, S.C. Personal Communication. (Phone) to J.Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., November 27, 2000.

[35] Mark Dodd, Georgia Department of Natural Resources, Brunswick, Ga. Personal Communication (Fax) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 8, 2000.

[36] David Cupka, South Carolina Department of Natural Resources, Marine Resources Division, Charleston, S.C. Personal Communication (E-Mail of the Management Plan for South Carolina's Offshore Whelk Trawling Fishery - updated January 1999) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 18, 2000.

[37] Wendy Teas, National Marine Fisheries Service, SEFSC, Miami, Fla. Unpublished STSSN strandings data. Personal Communication (E-Mail of strandings data) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 12, 2000.

[38] Unpublished Data. Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C. Personal Communcation, December 21, 2000.

alive and two dead or injured[39]). There also were 15 strandings documented from nearby areas during the same time period.[40] The NCDMF and NMFS had just agreed on details of a Section 10 Permit to the Endangered Species Act for the flounder fishery just prior to the closure [41]. The permit established allowable levels of live and lethal gill net interactions for each turtle species, with a goal of reducing strandings by at least 50 percent from 1999 levels. The fishery was closed when the incidental take level was met for green sea turtles[42]. The NCDMF estimated that there were 50 loggerheads captured at the time of closure and that 44 of those had been drowned[39].

From 1981-1990, 397 loggerhead sea turtles were incidentally captured in gill nets set by Italian fishermen in the central Mediterranean Sea; gill net mortality was reported to be 73.6% (Argano *et al.* 1992). An additional study in this same area estimated 16,000 loggerheads/year are captured by net with 30% mortality (De Metrio and Megalfonou 1988). Observers of the Spanish driftnet fishery in the western Mediterranean documented the incidental capture of 30 loggerheads from 1993-1994, of which one was dead; an estimated 236 loggerheads were caught in 1994 (Silvani *et al.* 1999). In Nicaragua, although green and hawksbill turtles are targeted, loggerhead and leatherback turtles are incidentally caught by gill net (Lagueux 1998, Lagueux *et al.* 1998, Lima *et al.* 1999); an estimated 600 loggerheads are caught each year (Lagueux 1998). Gill nets set for finfish and sharks in Belize are also suspected of catching sea turtles (Smith *et al.* 1992). Of the 500-800 turtles sold annually in Belize, 30% are reported to be loggerheads (*Ibid*.).

Hook and line

Loggerheads are known to bite a baited hook, frequently ingesting the hook. Hooked turtles have been reported by the public fishing from boats, piers, beach, banks, and jetties (Cannon *et al.* 1994, J. Braun-McNeill personal communication[38], A. Cannon personal communication[43], Spotila *et al.* 1998[44], STSSN unpublished data[12]) and from commercial fishermen fishing for reef fish and for sharks with both single rigs and bottom longlines (S.

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[39] Excel spreadsheet as attachment to E-Mail from Jeff Gearhart, N.C. Division of Marine Fisheries, Morehead City, N.C. to David Bernhard, National Marine Fisheries Service, SERO, St. Petersburg, Fla., October 25, 2000.

[40] North Carolina Division of Marine Fisheries news release, NR-61-2000, “Commercial Flounder Season Closes to Protect Sea Turtles”, Morehead City, N.C., October 25, 2000.

[41] National Marine Fisheries Service. Endangered Species Act Section 10 Permit #1259 issued to State of North Carolina, Department of Environmental and Natural Resources, Division of Marine Fisheries, Morehead City, N.C., October 5, 2000.

[42] North Carolina Division of Marine Fisheries news release, NR-61-2000, “Commercial Flounder Season Closes to Protect Sea Turtles”, Morehead City, N.C., October 25, 2000.

[43] Andrea Cannon, National Marine Fisheries Service, SEFSC, Galveston, Texas. Personal Communication to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla.

[44] Spotila, J.R., P.T. Plotkin, and J.A. Keinath. 1998. In water population survey of sea turtles of Delaware Bay. Unpublished Report. Final Report to NMFS, Office of Protected Resources for Work Conducted Under Contract #43AANF600211 and NMFS Permit No. 1007 by Drexel University, Philadelphia, Penn., 21 pp.

Epperly personal communication[45]). A detailed summary of the impact of hook and line incidental captures to loggerhead sea turtles can be found in the TEWG reports (1998, 2000).

Power plants

Power plants are known to entrain loggerhead sea turtles at the intake canals to their cooling systems. A detailed summary of the incidental capture of loggerhead sea turtles in power plant intake screens can be found in the TEWG reports (1998, 2000).

Pound Nets

Pound nets are a passive, stationary gear that are known to incidentally capture loggerhead sea turtles in Massachusetts (R. Prescott personal communication[46]), Rhode Island, New Jersey, Maryland (W. Teas personal communication[37]), New York (Morreale and Standora 1998), Virginia (Bellmund *et al.*, 1987) and North Carolina (Epperly *et al.* 2000). Although pound nets are not a significant source of mortality for loggerheads in New York (Morreale and Standora 1998) and North Carolina (Epperly *et al.* 2000), they have been implicated in the deaths of loggerheads in the Chesapeake Bay from mid-May through early June (Bellmund *et al.* 1987). The turtles were reported entangled in the large mesh (>8 inches) pound net leads.

Other Fisheries

Incidental captures of loggerheads in fish traps set in Massachusetts, Rhode Island, New York, and Florida have been reported (W. Teas personal communication[37]). Although no incidental captures have been documented from fish traps set in North Carolina[47] and Delaware (Anonymous 1995[48]), they are another potential anthropogenic impact to loggerheads and other sea turtles. Lobster pot fisheries are prosecuted in Massachusetts (Prescott 1988), Rhode Island (Anonymous 1995[48]), Connecticut (*Ibid*.) and New York (S. Sadove personal communication[49]). Although they are more likely to entangle leatherback sea turtles, lobster pots set in New York are also known to entangle loggerhead sea turtles (*Ibid*.). No incidental capture data exist for the other states. Long haul seines and channel nets in North Carolina are known to incidentally capture loggerhead and other sea turtles in the sounds and other inshore waters (J. Braun-McNeill personal communication[38]). No lethal takes have been reported. Whelk pots set in

[45] Sheryan Epperly, National Marine Fisheries Serivce, SEFSC, Beaufort, N.C. Personal Communication (discussions with commercial reef-fish and shark fishermen in North Carolina), 1984-1998.

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

[47] Epperly, S.P. and V.G. Thayer. 1995. Marine mammal and sea turtle/fisheries interactions in North Carolina. Unpublished manuscript. National Marine Fisheries Service, SEFSC, Beaufort, N.C.

[48] 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. Unpublished report of the ASMFC, Washington, D.C.

[49] Sam Sadove, Long Island University, Southampton College, Southampton, N.Y. Personal Communication (Phone) to Joanne Braun-McNeill, National Marine Fisheries Service, SEFSC, Beaufort, N.C., December 6, 2000.

Virginia and North Carolina could potentially entrap loggerheads as they attempt to get to the bait or the whelks within the trap (Mansfield and Musick 2000[50]).

Bottom set lines in the coastal waters of Madeira, Portugal are reported to take an estimated 500 pelagic immature loggerheads each year (Dellinger and Encarnacao 2000). Adult female loggerheads are taken by hand by the indigenous people inhabiting Boavista Island, Cape Verde, Western Africa (Cabrera *et al.* 2000). In Cuba, loggerhead, along with green and hawksbill sea turtles, are commercially harvested (Gavilan 2000, Alvarez 2000).

Marine Debris

An additional source of mortality that has not been adequately assessed is the ingestion of anthropogenic debris by pelagic turtles. A summary of marine debris impacts can be found in the TEWG reports (1998, 2000).

Discussion

The recovery plan for this species (NMFS and USFWS 1991) states that southeastern U.S. loggerheads can be considered for delisting if, over a period of 25 years, adult female populations in Florida are increasing and there is a return to pre-listing annual nest numbers totaling 12,800 for North Carolina, South Carolina and Georgia combined (equates to approximately 3,100 nesting females per year at 4.1 nests per female per season). Nesting trends indicate the numbers of nesting females associated with the south Florida subpopulation are increasing. Likewise, nesting trend analyses indicate potentially increasing nest numbers in the northern subpopulation TEWG 2000, Appendix 1). Given the uncertainties in survival rates discussed previously and the stochastic nature of populations, the population trajectories should not be used now to quantitatively assess when the northern population may achieve 3,100 nesting females.

Similar to results found in previous models, in all model scenarios presented herein, the juvenile stages have the highest elasticity and maintaining or decreasing current sources of mortality in those stages will have the greatest impact on maintaining or increasing current population growth rates. Again, these values are in direct proportion to the stage lengths determined from the individual growth models used, particularly for the model pairs that use the same survival rates (Models 1 and 2 and Models 3 and 4) (Heppell *et al.* 2000). We feel we have bracketed age-to-maturity with these model pairs, and, for the models using average age-to-maturity (Models 2 and 4), the elasticity of the large benthic juveniles are much higher than small benthic juveniles while the difference is not as pronounced in the minimum age-to-maturity models (Models 1 and 3). If the new individual growth model presented here accurately describes loggerhead growth rates and average size-to-maturity is around 90 cm SCL, large benthic juveniles greater than 70 cm SCL are a critical stage. This stage may not be fully

[50] Mansfield, K.L. and J. A. Musick. 2000. Characterization of the Chesapeake Bay pound net and whelk pot fisheries and their potential interactions with marine sea turtle species. Unpublished Report. Virginia Institute of Marine Sciences Interim Report to the National Marine Fisheries Service, Northeast Regional Office, Gloucester, Mass., 12 pp.

protected under current TED regulations. More information regarding growth rates, habitat utilization and related mortality sources specific to this stage is important.

As with the previous loggerhead models, the models presented herein assess females only and make the assumption that there are plenty of males in the population for maximum fecundity. The actual operational sex ratio necessary on the breeding grounds for maximum fecundity is unknown. In a genetic analysis of loggerhead clutch paternity, Moore (2000) found that eggs contained in 31% of the sampled nests reflected contributions from multiple fathers and 10% of the nests had 3 or more fathers. This degree of multiple paternity was detected by only sampling 10 eggs (<10%) per nest. She expressed concern that males may be a limiting factor at her study site as a previous study indicated >90% female hatchling production based on incubation temperatures (Mrosovsky and Provancha 1989).

New results from nuclear DNA analyses indicate that males do not show the same degree of site fidelity, as do females.[9] It is possible, then, that the high proportion of males produced in the northern subpopulation are an important source of males throughout the southeast U.S, lending even more significance to the critical nature of this small subpopulation. Our current understanding of the loggerhead mating system is rudimentary, but further declines or loss of the northern nesting population (which produces a disproportionate share of males for the whole population) could contribute to a serious population decline over the entire region.

We have very little sex specific information on the vital rates of sea turtles. If males mature significantly faster than females and/or if males reproduce every year while females an average of every 2.5 years (Richardson and Richardson 1982), then the functional sex ratio will be very different from the actual sex ratio based on hatchling output. This would serve to alleviate the extreme female bias in hatchling production in Florida. Much more information is needed about the mating system of loggerheads and sex-specific vital rates in order to truly assess the impacts of the low production of males in the south Florida subpopulation.

Literature Cited

Alvarez, B.L.A. 2000. Hawksbill turtle feeding habits in Cuban waters. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-436:65.

Argano, R., R. Basso, M. Cocco, and G. Gerosa. 1992. Nouvi data sugli spostamenti di tartaruga marina comune (*Caretta careta*) in Mediterraneo. Bollettino Musel Istitiuti Universita Genova 56-57:137-163.

Avise, J.C. 1995. Mitochondrial DNA polymorphism and a connection between genetics and demography of relevance to conservation. Conservation Biology 9:686-690.

Bass, A.L. 1999. Genetic analysis to elucidate the natural history and behavior of hawksbill turtles (*Eretmochelys imbricata*) in the Wider Caribbean: a review and re-analysis. Chelonian Conservation and Biology 3:195-199.

Bell, R. and J.I. Richardson. 1978. An analysis of tag recoveries from loggerhead (*Caretta caretta*) nesting on Little Cumberland Island, Georgia. Florida Marine Research Publication 33:20-24.

Bellmund, S.A., J.A. Musick, R.C. Klinger, R.A. Byles, J.A. Keinath, and D.E. Barnard. 1987. Ecology of sea turtles in Virginia. Virginia Institute of Marine Science Special Scientific Report No. 119, 48 pp.

Bjorndal, K.A. and A.B. Bolten. 2000. Proceedings of a workshop on assessing abundance and trends for in-water sea turtle populations. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-445, 83 pp.

Bjorndal, K.A., A.B. Bolten, and H.R. Martins. 2000. Somatic growth model of juvenile loggerhead sea turtles *Caretta caretta*: duration of pelagic stage. Marine Ecology Progress Series 202:265-272.

Bjorndal, K.A., A.B. Meylan, and B.J. Turner. 1983. Sea turtles nesting at Melbourne Beach, Florida. I. Size, growth and reproductive biology. Biological Conservation 26:65-77.

Bolten, A.B., K.A. Bjorndal, H.R. Martins. 1994. Life history model for the loggerhead sea turtle (*Caretta caretta*) population in the Atlantic: potential impacts of a longline fishery. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SWFSC-201:48-55.

Bowen, B.W. 1995. Tracking marine turtles with genetic markers. BioScience 45:528-534.

Bowen, B.W. 1997. Complex population structure and the conservation genetics of migratory marine mammals: lessons from sea turtles. In A.E. Dizon, S.J. Chivers, and W.F. Perrin, eds. Molecular Genetics of Marine Mammals. Society for Marine Mammalogy Special Publication 3:77-84.

Bowen, B.W., J.C. Avise, J.I. Richardson, A.B. Meylan, D. Margaritoulis, and S.R. Hopkins-Murphy. 1993. Population structure of loggerhead turtles (*Caretta caretta*) in the northwestern Atlantic Ocean and Mediterranean Sea. Conservation Biology 7:834-844.

Braun-McNeill, J., S.P Epperly, L. Avens, and S. Sadove. (in prep.) A preliminary analysis of growth rates of benthic immature loggerhead (*Caretta caretta*) sea turtles from North Carolina, U.S.A. In Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC.

Brown, C.A. in prep. Updated standardized catch rates of bluefin tuna, *Thunnus thynnus*, from the rod and reel/handline fishery off the northeast United States during 1980-1999. International Commission for the Conservation of Atlantic Tunas, Collected Volume of Scientific Papers Working Document SCRS/2000/96.

Brown, C.A., S.C. Turner, and M. Ortiz. 1999. Standardized catch rates of large (> 195 cm) and large medium (178-195 cm) bluefin tuna, *Thunnus thynnus*, from the rod and reel/handline fishery off the northeast United States during 1983-1997. International Commission for the Conservation of Atlantic Tunas, Collected Volume of Scientific Papers 49(2):347-359.

Cabrera, I, D. Cejudo, and L.F.Lopez-Jurado. 2000. Human predation on marine turtles in the Archipelago of Cape Verdes, Western Africa. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-443:217.

Caine, E.A. 1986. Carapace epibionts of nesting loggerhead sea turtles: Atlantic coast of U.S.A. Journal of Experimental Marine Biology and Ecology 96:15-26.

Cannon, A.C., C.T. Fontaine, T.D. Williams, D.B. Revera, and C.W. Caillouet, Jr. 1994. Incidental catch of Kemp's ridley sea turtles (*Lepidochelys kempi*), by hook and line, along the Texas Coast, 1980-1992. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-341:40-42.

Castanet, J. 1994. Age estimation and longevity in reptiles. Gerontology 40:174-192.

Caswell, H. 2001. Matrix population models. 2nd Edition. Sinauer Associates, Inc. Sunderland, Ma. 722 pp.

Chaloupka, M.Y. and C.J. Limpus. 1997. Robust statistical modeling of hawksbill sea turtle growth rates (southern Great Barrier Reef). Marine Ecology Progress Series 146:1-8.

Cormack, R.M. 1964. Estimates of survival from the sightings of marked animals. Biometrika 51:429-439.

Crouse, D.T. 1985. The biology and conservation of sea turtles in North Carolina. Ph.D. Dissertation. University of Wisconsin, Madison.

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.

de Kroon, H., A. Plaisier, J. van Groenendael, and H. Caswell. 1986. Elasticity: the relative contribution of demographic parameters to population growth rate. Ecology 67:1427-1431.

de Kroon, H., J. van Groenendael, and J. Ehrlen. 2000. Elasticities: a review of methods and model limitations. Ecology 81:607-618.

Dellinger, T. and H. Encarnacao. 2000. Accidental capture of sea turtles by the fishing fleet based at Madeira Island, Portugal. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-443:218.

De Metrio, G. and P. Megalofonou. 1988. Mortality of marine turtles (*Caretta caretta* L. and *Dermochelys coriacea* L.) consequent to accidental capture in the Gulf of Taranto. Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration de la Mer Mediterranee 31(2):285.

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

Encalada, S.E., K.A. Bjorndal, A.B. Bolten, J.C. Zurita, B. Schroeder, E. Possardt, C.J. Sears, and B.W. Bowen. 1998. Population structure of loggerhead turtle (*Caretta caretta*) nesting colonies in the Atlantic and Mediterranean as inferred from mitochondrial DNA control region sequences. Marine Biology 130:567-575.

Encalada, S.E. P.N. Lahanas, K.A. Bjorndal, A.B. Bolten, M.M. Miyamoto, and B.W. Bowen. 1996. Phylogeography and population structure of the green turtle (*Chelonia mydas*) in the Atlantic Ocean and Mediterranean Sea: a mitochondrial DNA control region assessment. Molecular Ecology 5:473-484.

Epperly, S.P., J. Braun-McNeill, and A. Bass. 2000. In-water population index surveys: North Carolina, U.S.A. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-436:62.

Foster, K. 1994. A growth curve for wild Florida *Caretta caretta*. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-351:221-224.

Frazer, N.B. 1983*a*. Demography and life history of the Atlantic loggerhead sea turtle (*Caretta caretta*). Ph.D. Dissertation. University of Georgia.

Frazer, N.B. 1983*b*. Survivorship of adult female loggerhead sea turtles, *Caretta caretta*, nesting on little Cumberland Island, Georgia, U.S.A. Herpetologica 39:436-447.

Frazer, N.B. 1986. Survival from egg to adulthood in a declining population of loggerhead turtles, *Caretta caretta*. Herpetologica 42:47-55.

Frazer, N.B. 1987. Preliminary estimates of survivorship for wild loggerhead sea turtles (*Caretta caretta*). Journal of Herpetology 21:232-235.

Frazer, N.B. and L.M. Ehrhart. 1985. Preliminary growth models for green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles in the wild. Copeia 1985: 3-79.

Gavilan, F.M. 2000. Impact of regulatory measures on Cuban marine turtle fisheries. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-436:108-109.

González Ania, L.V., C.A. Brown, and E. Cortes. 2001. Standardized catch rates for yellowfin tuna (*Thunnus albacares*) in the 1992-1999 Gulf of Mexico longline fishery based upon observer programs from Mexico and the United States. International Commission for the Conservation of Atlantic Tunas, Collected Volume Scientific Papers Working SCRS/2000/67, in press.

Henwood, T.A. 1987. Sea turtles of the southeastern United States, with emphasis on the life history and population dynamics of the loggerhead. Ph.D Dissertation. Auburn University.

Heppell, S.S., H. Caswell, and L.B. Crowder. 2000. Life history and elasticity patterns: perturbation analysis for species with minimal demographic data. Ecology 81:654-665.

Heppell, S.S., L.B. Crowder, D.T. Crouse, S.P. Epperly, and N.B. Frazer. *in press*. Population models for Atlantic loggerheads: past, present and future. In A. Bolton and B. Witherington, Editors, Synopsis of the Biology and Conservation of Loggerhead Sea Turtles, Smithsonian Institution Press.

Jolly, G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225-247.

Lagueux, C.J. 1998. Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends. Ph.D. Dissertation, University of Florida, Gainesville, Florida, 215 pp.

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

Lebreton, J-D, K.P. Burnham, J. Clobert, and D.R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62:67-118.

LeBuff, C.R., Jr. 1974. Unusual nesting relocation in the loggerhead turtle, *Caretta caretta*. Herpetologica 30:29-31.

LeBuff, C.R., Jr. 1990. The loggerhead turtle in the eastern Gulf of Mexico. Caretta Research, Inc., Sanibel, FL, 216 pp.

Lima, E., C. Lagueux, D. Castro, and M. Marcovaldi. 1999. From one feeding ground to another: Green turtle migration between Brazil and Nicaragua. Marine Turtle Newsletter 85:10.

Limpus, C. and M. Chaloupka. 1997. Nonparametric regression modeling of green sea turtle growth rtes (southern Great Barrier Reef). Marine Ecology Progress Series 149:23-34.

Lo, N.C. L.D. Jackson, and J.L. Squire. 1992. Indices of relative abundance form fish spotter data based on delta-lognormal models. Canadian Journal of Fisheries and Aquatic Science 49:2515-2526.

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.

Mendonça, M.T. 1981. Comparative growth rates of wild immature *Chelonia mydas* and *Caretta caretta* in Florida. Journal of Herpetology 15:444-447.

Meylan, A.B. 1982. Sea turtle migration – evidence from tag returns, p. 91-100. In K.A. Bjorndal, ed., Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.

Meylan, A.B., K.A. Bjorndal, and B.J. Turner. 1983. Sea turtle nesting at Melbourne Beach, Florida. II. Postnesting movements of *Caretta caretta*. Biological Conservation 26:79-90.

Moore, K.M. 2000. Determining paternity in loggerhead turtle (*Caretta caretta*) nests on Melbourne Beach, Florida using microsatellite markers. M.Sc. Thesis. University of Charleston, South Carolina. 64 pp.

Morreale, S.J. and E.A. Standora. 1998. Early life stage ecology of sea turtles in northeastern U.S. Waters. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-413, 49 pp.

Moritz, C. 1994*a*. Application of mitochondrial DNA analysis in conservation: a critical review. Molecular Ecology 3:401-411.

Moritz, C. 1994*b*. Defining 'evolutionary significant units' for conservation. Trends in Ecology and Evolution 9:373-375.

Mrosovosky, N. and J. Provancha. 1989. Sex ratio of loggerhead sea turtles hatching on a Florida Beach. Canadian Journal of Zoology 67:2533-2539.

Mrosovsky, N. and C. Pieau. 1991. Transitional range of temperature, pivotal temperatures and thermosensitive stages for sex determination in reptiles. Amphibia-Reptilia 12:169-179.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991. Recovery plan for U.S. population of loggerhead turtle *Caretta caretta*. National Marine Fisheries Service, Washington, D.C., 64 pp.

National Research Council. 1990. Decline of the sea turtles: causes and prevention. National Academy Press, Washington, D.C., 259 pp.

Ortiz, M., S.C. Turner and C.A. Brown. 1999. Standardized catch rates of small bluefin tuna, *Thunnus thynnus,* from the rod and reel/handline fishery off the northeast United States during 1983-1997. International Commission for the Conservation of Atlantic Tunas, Collected Volume Scientific Papers 49(2):254-286.

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.

Richardson, J.I. 1982. A population model for adult female loggerhead sea turtles (*Caretta caretta*) nesting in Georgia. Ph.D. Dissertation, University of Georgia, Athens, Georgia, 204 pp.

Richardson, J.I. and T.H. Richardson. 1982. An experimental population model for theloggerhead sea turtle (*Caretta caretta*), pp. 165-174. In K.A. Bjorndal, ed. Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.

Richardson, T.H., J.I. Richardson, C.A. Ruckdeschel, and M.W. Dix. 1978. Remigration patterns of loggerhead sea turtles (*Caretta caretta*) nesting on Little Cumberland and Cumberland Islands, Georgia. Florida Marine Research Publications 33:39-44.

Schmid, J.R. 1995. Marine turtle populations on the east-central coast of Florida: results of tagging studies at Cape Canaveral, Florida, 1986-1991. Fishery Bulletin 93:139-151.

Schroth, W., B. Streit, and B. Schierwater. 1996. Evolutionary handicap for turtles. Nature 384:521-522.

Seber, G.A.F. 1965. A note on the multiple recapture census. Biometrika 52:249-259.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Second Edition. Macmillan Publishing Co., Inc., New York, N.Y., 600 pp.

Silvani, L., M. Gazo, A. Aguilar. 1999. Spanish driftnet fishing and incidental catches in the western Mediterranean. Biological Conservation 90:79-85.

Smith, G.W., K.L. Eckert, and J.P. Gibson. 1992. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST) sea turtle recovery action plan for Belize. Caribbean Environmental Programme, United Nations Environmental Programme, Technical Report 18, 86 pp. Kingston, Jamaica.

South Carolina Marine Resources Division. 2000. SEAMAP-South Atlantic 10-Year Trawl Report. Results of trawling efforts in the coastal habitat of the South Atlantic Bight, FY1990-1999. Atlantic States Marine Fisheries Commission Special Report No. 71, 143 pp.

Sternberg, J., compiler. 1981. The worldwide distribution of sea turtle nesting beaches. Sea Turtle Rescue Fund, Center for Environmental Education, Washington, D.C., 19 pp.

Taylor, B.L. and A.E. Dizon. 1996. The need to estimate power to link genetics and demography for conservation. Conservation Biology 10:661-664.

Taylor, B.L. and A.E. Dizon. 1999. First policy and then science: why a management unit based solely on genetic criteria cannot work. Molecular Ecology 8:511-516.

Turner, S.C., C.A. Brown and M. Ortiz. 1999. Review of the available information on medium bluefin tuna, *Thunnus thynnus*, from the rod and reel/handline fishery off the northeast United States. International Commission for the Conservation of Atlantic Tunas, Collected Volume Scientific Papers 49(2):334-343.

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.

Werner, F., B. Blanton, J. Quinlan, and R. Luettich, Jr. 1999. Physical oceanography of the North Carolina continental shelf during the fall and winter seasons: implications for the trnasport of larval menhaden. Fisheries Oceanography 8(Supplement 2):7-21.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement:120-138.

Williams, K.L. and M.G. Frick. 2001. Results from the long-term monitoring of nesting loggerhead sea turtles (*Caretta caretta*) on Wassaw Island, Georgia: 1973-2000. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-446, 32 pp.

Table 1. Annual loggerhead turtle (*Caretta caretta*) nesting and hatching statistics, Dry Tortugas National Park, 1995-2000. Reproduced from Reardon (2000[14]).

Data Category	1995	1996	1997	1998	1999	2000
Total Nests	269	190	210	190	242	202
Nests Inventoried (n)	169	167	187	142	207	177
Average Clutch Size	98 eggs (50-188)	100 eggs (32-169)	105 eggs (48-169)	102 eggs (60-149)	103 eggs (30-162)	99 eggs (42-148)
Average Hatching Success *	82.00% (Not available)	78.80% (15.3-100.0%)	72.30% (0.0-100%)	76.30% (0.0-98.3%)	78.50% (0.0-99%)	74.90% (0.0-100.0%)
Average Incubation	54.0 days (45-58; n=94)	52.6 days (46-66; n=148)	52.8 days (45-68; n=158)	51.0 days (44-62; n=133)	54.6 days (48-68; n=184)	52.4 days (45-68; n=152)

* Hatching Success = (hatched eggs/total number of eggs) x 100

Table 2. Observed loggerhead turtle bycatch rates in the SEAMAP analysis data set.

YEAR	LOGGERHEADS	LOGGERHEADS PER TOW	LOGGERHEADS PER STANDARD UNIT OF EFFORT*
1990	8	0.0261	0.0894
1991	8	0.0258	0.0894
1992	9	0.0288	0.1006
1993	6	0.0192	0.0671
1994	12	0.0387	0.1342
1995	5	0.0160	0.0559
1996	9	0.0288	0.1006
1997	14	0.0449	0.1565
1998	19	0.0609	0.2124
1999	11	0.0353	0.1230
2000	19	0.0609	0.2124

***** The standard unit of effort is a one hour tow with a 100 foot headrope.

Table 3. Results of the stepwise procedure to develop the proportion positive bycatch rate model for the SEAMAP analysis data set.

FACTOR	df	deviance	Deviance/df	% diff.	delta%	L	ChiSquare	Pr>Chi
NULL	3421	999.7656	0.2922			-499.88.	.	
LAT	3420	969.0417	0.2833	3.046	3.046	-484.52	30.7239	0
YEAR	3411	982.8878	0.2882	1.369		-491.44	16.8778	0.07711
PRECIP	3420	990.6407	0.2897	0.856		-495.32	9.1249	0.00252
SURFACE_SALINITY	3416	991.6322	0.2903	0.650		-495.82	1.1198	0.28997
SURFACE_TEMP	3416	992.4236	0.2905	0.582		-496.21	0.3283	0.56665
NORTWIND	3366	978.7567	0.2908	0.479		-489.38	3.8778	0.04893
BOTTOM_SALINITY	3406	991.6663	0.2912	0.342		-495.83	0.4123	0.52082
BOTTOM_TEMP	3406	991.9716	0.2912	0.342		-495.99	0.1069	0.74366
WESTWIND	3366	982.3208	0.2918	0.137		-491.16	0.3136	0.57546
SEASON	3420	999.4015	0.2922	0.000		-499.7	0.3641	0.54624
START_TIME	3420	999.4426	0.2922	0.000		-499.72	0.323	0.56982
START_DEPTH	3420	999.4965	0.2923	-0.034		-499.75	0.2691	0.60393
BAROMETRIC	3420	999.7322	0.2923	-0.034		-499.87	0.0334	0.85489
AIR_TEMP	3418	999.4576	0.2924	-0.068		-499.73	0.1724	0.67795
LAT+								
YEAR	3410	951.9734	0.2792	4.449	1.403	-475.99	17.0683	0.07287
PRECIP	3419	960.4634	0.2809	3.867		-480.23	8.5783	0.0034
SURFACE_TEMP	3415	961.4029	0.2815	3.662		-480.7	1.4663	0.22594
SURFACE_SALINITY	3415	962.3245	0.2818	3.559		-481.16	0.5447	0.46049
BOTTOM_TEMP	3405	961.5905	0.2824	3.354		-480.8	0.878	0.34875
BOTTOM_SALINITY	3405	962.1786	0.2826	3.285		-481.09	0.2899	0.59031
NORTWIND	3365	951.4821	0.2828	3.217		-475.74	1.868	0.17171
AIR_TEMP	3417	967.0103	0.283	3.149		-483.51	1.8022	0.17945
START_DEPTH	3419	967.7791	0.2831	3.114		-483.89	1.2627	0.26115
WESTWIND	3365	953.2602	0.2833	3.046		-476.63	0.0899	0.76437
SEASON	3419	968.6614	0.2833	3.046		-484.33	0.3803	0.53742
START_TIME	3419	968.94	0.2834	3.012		-484.47	0.1017	0.7498
BAROMETRIC	3419	969.0391	0.2834	3.012		-484.52	0.0026	0.95909
LAT+YEAR+								
PRECIP	3409	942.3413	0.2764	5.407	0.958	-471.17	9.6321	0.00191
SURFACE_TEMP	3405	944.5417	0.2774	5.065		-472.27	2.1093	0.1464
SURFACE_SALINITY	3405	946.3728	0.2779	4.894		-473.19	0.2782	0.5979
BOTTOM_TEMP	3395	944.9606	0.2783	4.757		-472.48	1.3408	0.24689
NORTWIND	3355	934.1122	0.2784	4.723		-467.06	2.1519	0.14239
START_DEPTH	3409	949.6511	0.2786	4.654		-474.83	2.3223	0.12753
BOTTOM_SALINITY	3395	946.081	0.2787	4.620		-473.04	0.2204	0.63877
AIR_TEMP	3407	949.7093	0.2788	4.586		-474.85	2.0874	0.14852
WESTWIND	3355	935.9986	0.279	4.517		-468	0.2655	0.60635
BAROMETRIC	3409	951.2455	0.279	4.517		-475.62	0.7279	0.39358
SEASON	3409	951.5995	0.2791	4.483		-475.8	0.3739	0.54088
START_TIME	3409	951.7685	0.2792	4.449		-475.88	0.2049	0.65082
LAT+YEAR+								
LAT*YEAR	3400	934.7971	0.2749	5.921	0.513	-467.4	17.1763	0.07055

% diff: percent difference in deviance/df between each factor and the null model**;** delta%: percent difference in deviance/df between the newly included factor and the previous factor entered into the model; L: log likelihood; ChiSquare: Pearson Chi-square statistic; Pr>Chi: significance level of the Chi-square statistic.
FINAL MODEL: LAT + YEAR

Table 4. Results of the stepwise procedure to develop the positive bycatch rate model for the SEAMAP analysis dataset.

FACTOR	df	deviance	Deviance/df	% diff.	delta%	L	ChiSquare	Pr>Chi
NULL	113	4.3251	0.0383			-113.8448.	.	
START_TIME	112	4.2286	0.0378	1.305	1.305	-113.7965	0.0966	0.75599
LAT	112	4.2334	0.0378	1.305		-113.7989	0.0918	0.76195
AIR_TEMP	112	4.2985	0.0384	-0.261		-113.8315	0.0266	0.87034
START_DEPTH	112	4.3002	0.0384	-0.261		-113.8323	0.0249	0.87455
SEASON	112	4.3014	0.0384	-0.261		-113.8329	0.0237	0.87761
BAROMETRIC	112	4.3197	0.0386	-0.783		-113.8421	0.0054	0.9413
NORTWIND	110	4.2522	0.0387	-1.044		-111.8084	0.0675	0.79508
SURFACE_TEMP	111	4.2948	0.0387	-1.044		-112.8296	0.0277	0.8679
BOTTOM_TEMP	111	4.3037	0.0388	-1.305		-112.8341	0.0187	0.89117
BOTTOM_SALINITY	111	4.321	0.0389	-1.567		-112.8428	0.0014	0.97014
SURFACE_SALINITY	111	4.3224	0.0389	-1.567		-112.8434	0.0001	0.99237
WESTWIND	110	4.3144	0.0392	-2.350		-111.8394	0.0053	0.94192
YEAR	103	4.071	0.0395	-3.133		-113.7177	0.2541	1

% diff: percent difference in deviance/df between each factor and the null model**;** delta%: percent difference in deviance/df between the newly included factor and the previous factor entered into the model; L: log likelihood; ChiSquare: Pearson Chi-square statistic; Pr>Chi: significance level of the Chi-square statistic.
FINAL MODEL: YEAR

NOTE: No factors were found to be significant. Year was included in the final model as this is the factor of interest for which least-square means are calculated.

Table 5. Results of the loggerhead turtle bycatch analysis (1990-2000) in SEAMAP analysis dataset.

Lo method with binomial error assumption for proportion positives.

Class Level Information

Class	Levels	Values
year	11	1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000

Model Fitting Information for _Z
Weighted by _W

Description	Value
Res Log Likelihood	-11114.2
Akaike's Information Criterion	-11115.2
Schwarz's Bayesian Criterion	-11118.3
-2 Res Log Likelihood	22228.5

Solution for Fixed Effects

Effect	YEAR	Estimate	Std Error	DF	t	Pr > |t|	Alpha		
Intercept		7.1539	1.7880	3410	4.00	<.0001	0.05	3.6482	10.6596
lat		-0.3099	0.05585	3410	-5.55	<.0001	0.05	-0.4194	-0.2004
year	1990	-0.8199	0.4408	3410	-1.86	0.0630	0.05	-1.6842	0.04450
year	1991	-0.8537	0.4409	3410	-1.94	0.0529	0.05	-1.7181	0.01070
year	1992	-0.8571	0.4408	3410	-1.94	0.0520	0.05	-1.7214	0.007256
year	1993	-1.1535	0.4869	3410	-2.37	0.0179	0.05	-2.1082	-0.1988
year	1994	-0.5189	0.3993	3410	-1.30	0.1938	0.05	-1.3017	0.2639
year	1995	-1.3396	0.5209	3410	-2.57	0.0102	0.05	-2.3609	-0.3184
year	1996	-0.7338	0.4244	3410	-1.73	0.0839	0.05	-1.5658	0.09829
year	1997	-0.3485	0.3808	3410	-0.92	0.3602	0.05	-1.0952	0.3982
year	1998	-0.06168	0.3556	3410	-0.17	0.8623	0.05	-0.7590	0.6356
year	1999	-0.5236	0.3992	3410	-1.31	0.1898	0.05	-1.3063	0.2592
year	2000	0	.	.	.	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	Chi-Square	F Value	Pr > ChiSq	Pr > F
lat	1	3410	30.79	30.79	<.0001	<.0001
year	10	3410	16.22	1.62	0.0936	0.0942

Least Squares Means

Effect	year	Margins	Estimate	Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
year	1990	WORK._DS	-3.7294	0.3669	3410	-10.17	<.0001	0.05	-4.4487	-3.0101
year	1991	WORK._DS	-3.7633	0.3675	3410	-10.24	<.0001	0.05	-4.4838	-3.0428
year	1992	WORK._DS	-3.7667	0.3674	3410	-10.25	<.0001	0.05	-4.4870	-3.0463
year	1993	WORK._DS	-4.0631	0.4217	3410	-9.64	<.0001	0.05	-4.8898	-3.2363
year	1994	WORK._DS	-3.4285	0.3161	3410	-10.84	<.0001	0.05	-4.0483	-2.8086
year	1995	WORK._DS	-4.2492	0.4605	3410	-9.23	<.0001	0.05	-5.1520	-3.3463
year	1996	WORK._DS	-3.6433	0.3474	3410	-10.49	<.0001	0.05	-4.3245	-2.9622
year	1997	WORK._DS	-3.2581	0.2924	3410	-11.14	<.0001	0.05	-3.8313	-2.6848
year	1998	WORK._DS	-2.9713	0.2584	3410	-11.50	<.0001	0.05	-3.4779	-2.4647
year	1999	WORK._DS	-3.4331	0.3161	3410	-10.86	<.0001	0.05	-4.0529	-2.8134
year	2000	WORK._DS	-2.9096	0.2518	3410	-11.55	<.0001	0.05	-3.4033	-2.4158

Table 6. Results of the loggerhead turtle bycatch analysis (1990-2000) in SEAMAP analysis data set.

Lo method with binomial error assumption for positive bycatch tows.

Class Level Information

Class	Levels	Values
year	11	1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000

Model Fitting Information for _Z
Weighted by _W

Description	Value
Res Log Likelihood	0.4
Akaike's Information Criterion	-0.6
Schwarz's Bayesian Criterion	-1.9
-2 Res Log Likelihood	-0.9

Effect	year	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
Intercept		0.05407	0.05025	103	1.08	0.2845	0.05	-0.04560	0.1537
year	1990	-0.05407	0.09232	103	-0.59	0.5594	0.05	-0.2372	0.1290
year	1991	-0.05407	0.09232	103	-0.59	0.5594	0.05	-0.2372	0.1290
year	1992	0.06372	0.08864	103	0.72	0.4739	0.05	-0.1121	0.2395
year	1993	-0.05407	0.1026	103	-0.53	0.5993	0.05	-0.2575	0.1494
year	1994	0.03294	0.08077	103	0.41	0.6842	0.05	-0.1272	0.1931
year	1995	-0.05407	0.1101	103	-0.49	0.6244	0.05	-0.2724	0.1643
year	1996	-0.05407	0.08864	103	-0.61	0.5432	0.05	-0.2299	0.1217
year	1997	0.02004	0.07715	103	0.26	0.7956	0.05	-0.1330	0.1731
year	1998	0.05716	0.07107	103	0.80	0.4231	0.05	-0.08379	0.1981
year	1999	-0.05407	0.08299	103	-0.65	0.5162	0.05	-0.2187	0.1105
year	2000	0	.	.	.	.	.	.	.

Type 3 Tests of Fixed Effects

Effect	Num DF	Den DF	Chi-Square	F Value	Pr > ChiSq	Pr > F
year	10	103	5.30	0.53	0.8703	0.8654

Least Squares Means

Effect	year	Margins	Estimate	Standard Error	DF	t Value	Pr > |t|	Alpha	Lower	Upper
year	1990	WORK._DS	1.39E-17	0.07744	103	0.00	1.0000	0.05	-0.1536	0.1536
year	1991	WORK._DS	1.39E-17	0.07744	103	0.00	1.0000	0.05	-0.1536	0.1536
year	1992	WORK._DS	0.1178	0.07301	103	1.61	0.1098	0.05	-0.02702	0.2626
year	1993	WORK._DS	3.47E-17	0.08942	103	0.00	1.0000	0.05	-0.1774	0.1774
year	1994	WORK._DS	0.08701	0.06323	103	1.38	0.1718	0.05	-0.03840	0.2124
year	1995	WORK._DS	1.39E-17	0.09796	103	0.00	1.0000	0.05	-0.1943	0.1943
year	1996	WORK._DS	1.39E-17	0.07301	103	0.00	1.0000	0.05	-0.1448	0.1448
year	1997	WORK._DS	0.07411	0.05854	103	1.27	0.2084	0.05	-0.04200	0.1902
year	1998	WORK._DS	0.1112	0.05025	103	2.21	0.0291	0.05	0.01156	0.2109
year	1999	WORK._DS	2.78E-17	0.06604	103	0.00	1.0000	0.05	-0.1310	0.1310
year	2000	WORK._DS	0.05407	0.05025	103	1.08	0.2845	0.05	-0.04560	0.1537

Table 7. Loggerhead turtle relative abundance indices in SEAMAP analysis data set.

YEAR	value	c.v
1990	0.753	0.734
1991	0.728	0.744
1992	0.817	0.697
1993	0.543	0.963
1994	1.101	0.539
1995	0.452	1.137
1996	0.819	0.671
1997	1.281	0.473
1998	1.75	0.375
1999	1.004	0.565

Table 8. Published von Bertalanffy growth curves based on mark-recapture studies of loggerhead sea turtles from the Southeast U.S.

Source	*Parameters*	*N*	*Study Region*	*Size Range of Turtles in Study (Initial Capture)*	*Time Interval Between Captures*
Braun-McNeill (in prep[51])	a=106.9 k=0.0521	57	NC	45.1-75.8 cm SCL	0.936-3.523 yrs.
Foster (1994)	a=96.74 k=0.0637	54	Southeast US	62.2-104.2 cm SCL	1-2186 days
Frazer (1987)	a=94.7 k=0.115	41	FL	N=8: 53.3-77.3 cm SCL N=20: Adults, lengths not specified. N=13: Not specified.	N=8: 0.25-1.64 yrs. N=20: 1.0-4.1 yrs N=13: Not specified.
Henwood (1987)	a=110.0 k=0.0313	118	FL, GA, SC	45-110 cm SCL, t-t total for study (N=3679). Not specified for N=118.	> 90 days
Schmid (1995)*	a=96.08 k=0.0586	51	FL	38.2-110 cm SCL	Less than 90 days to greater than 365 days.
Schmid (1995)**	a=96.10 k=0.0573	19	FL	38.2-110 cm SCL total for study (N=49), but not specified for N=19.	>365 days

*Compiled from all data in study
**Compiled from occasions where the interval between capture and recapture was greater than 1 year.

[51]Braun-McNeill, J., S.P Epperly, L. Avens, and S. Sadove. A preliminary analysis of growth rates of juvenile loggerhead (*Caretta caretta*) sea turtles from North Carolina, U.S.A. Manuscript in preparation.

Table 9. Juvenile loggerheads (<86 cm CCL) that dead stranded between 1995 and 1999 and for which sex was determined via direct examination of the gonads. **A.** Total counts of each sex by zone with sex ratios by region. **B.** Sex ratios by state.

A.

Zone	Female	Males	% Female
1	1	0	
2	0	0	
3	1	0	
4	0	0	
5	2	0	
6	0	0	
7	0	0	
8	2	2	
9	1	0	
10	0	0	
11	0	0	
12	1	0	
13	0	0	
14	0	0	
15	0	0	
16	0	0	
17	0	0	
18	21	10	
19	8	2	
20	97	30	
21	15	7	
22	0	0	
23	0	0	
Gulf:	149	51	0.745
24	1	1	
25	7	4	
26	2	3	
27	11	1	
28	10	4	
SE FL:	31	13	0.705
29	12	6	
30	102	59	
31	39	24	
32	20	10	
33	9	4	
34	28	18	
35	28	13	
36	12	6	
37	12	6	
38	5	2	
39	2	3	
40	16	8	
41	62	8	
42	0	0	
43	0	0	
44	0	0	
NEFL-ME:	347	167	0.675
Total:	527	231	0.695

State (zones)	**% Female**
TX (18-21)	0.742105
FL (1-10, 24-30)	0.655172
GA (30, 31)	0.629464
SC (32, 33)	0.674419
NC (33-36)	0.652542
VA (36-38)	0.674419

B.

Table 10. Model 1, Frazer – Minimum Size-To-Stage		
Stage	Duration	Annual Survival Rate
Pelagic Juvenile	6	Varies
Small Benthic Juvenile	7	0.6758
Large Benthic Juvenile	7	0.7425
Breeding Adult	Indefinite	0.809
Non-breeding Adult	Indefinite	0.809

Table 11. Model 2, Frazer – Average Size-To-Stage		
Stage	Duration	Annual Survival Rate
Pelagic Juvenile	7	Varies
Small Benthic Juvenile	6	0.6758
Large Benthic Juvenile	14	0.7425
Breeding Adult	Indefinite	0.809
Non-breeding Adult	Indefinite	0.809

Table 12. Model 3, New – Minimum Size-To-Stage		
Stage	Duration	Annual Survival Rate
Pelagic Juvenile	6	Varies
Small Benthic Juvenile	13	0.893
Large Benthic Juvenile	11	0.893
Breeding Adult	Indefinite	0.812
Non-breeding Adult	Indefinite	0.812

Table 13. Model 4, New – Average Size-To-Stage		
Stage	Duration	Annual Survival Rate
Pelagic Juvenile	7	Varies
Small Benthic Juvenile	11	0.893
Large Benthic Juvenile	21	0.893
Breeding Adult	Indefinite	0.812
Non-breeding Adult	Indefinite	0.812

Table 14. Annual pelagic stage survival rates estimated from the 4 model scenarios at 3 values of λ.

	Annual Survival Rate for Pelagic Juveniles			
l	**Model 1**	**Model 2**	**Model 3**	**Model 4**
0.95	0.744	0.910	0.510	0.585
0.97	0.803	0.990	0.565	0.657
1.0	0.894	>1.000	0.660	0.780

Table 15. Loggerhead turtle strandings by zone, 1998 – 2000.[12] Data for 2000 are preliminary. Cold-stunned turtles, captive-reared turtles and post-hatchlings are not included.

Zone	1998	1999	2000
1	17	19	44
2	5	0	3
3	6	6	19
4	37	48	110
5	39	34	73
6	2	2	3
7	9	6	9
8	22	26	33
9	8	6	16
10	10	9	11
11	19	15	4
12	5	6	1
13	0	0	1
14	5	0	4
15	0	0	0
16	0	0	0
17	8	16	0
18	32	52	37
19	24	40	21
20	65	90	77
21	48	28	27
24	11	14	27
25	34	30	25
26	41	29	54
27	58	50	60
28	102	66	73
29	74	91	58
30	151	128	82
31	127	133	70
32	145	79	81
33	61	58	79
34	87	75	89
35	77	187	396
36	181	164	178
37	100	77	119
38	49	54	38
39	27	48	43
40	24	13	12
41	3	7	12
42	0	1	0

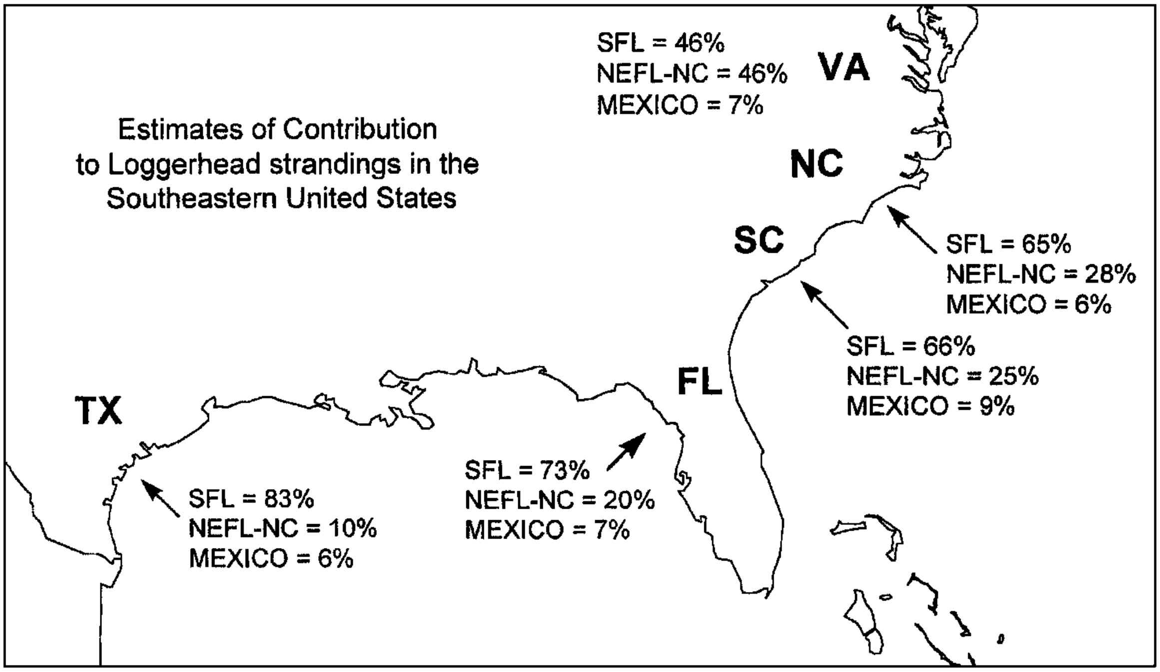

Figure 1. Geographic representation of maximum likelihood estimates of percent contribution to loggerhead strandings in the Southeastern United States. Abbreviations: SFL=South Florida, NEFL-NC=Northeast Florida to North Carolina. Figure is reproduced from Bass *et al*. (1999[13]).

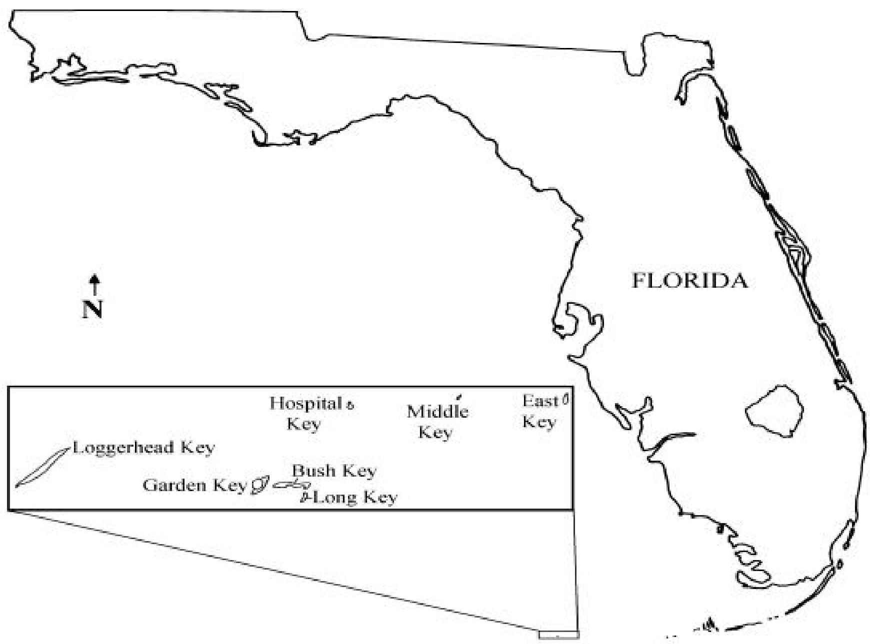

Figure 2. Location of the Dry Tortugas, where loggerhead turtles nest.

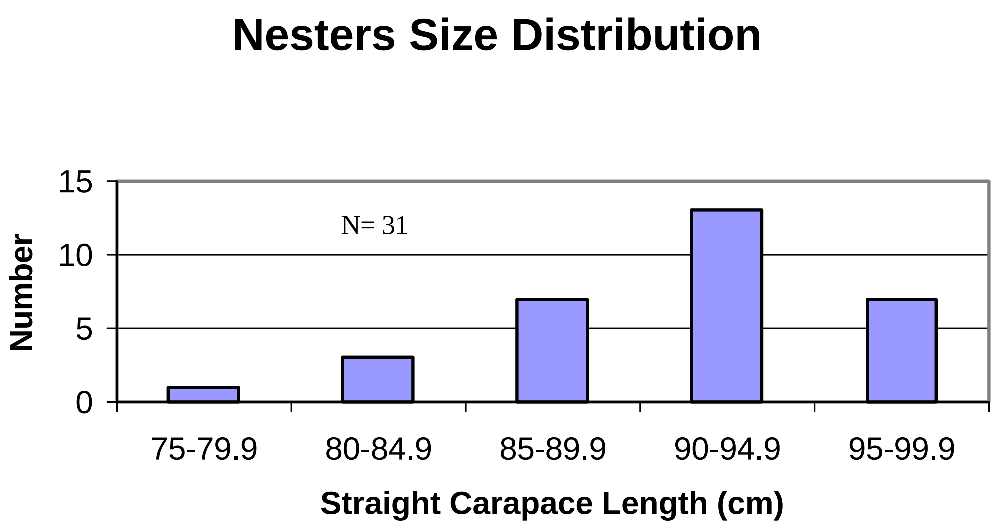

Figure 3 Size distribution of loggerhead turtles nesting in the Dry Tortugas National Park, 1981-1984. The mean straight carapace length was 90.4 cm (CMTTP[3]).

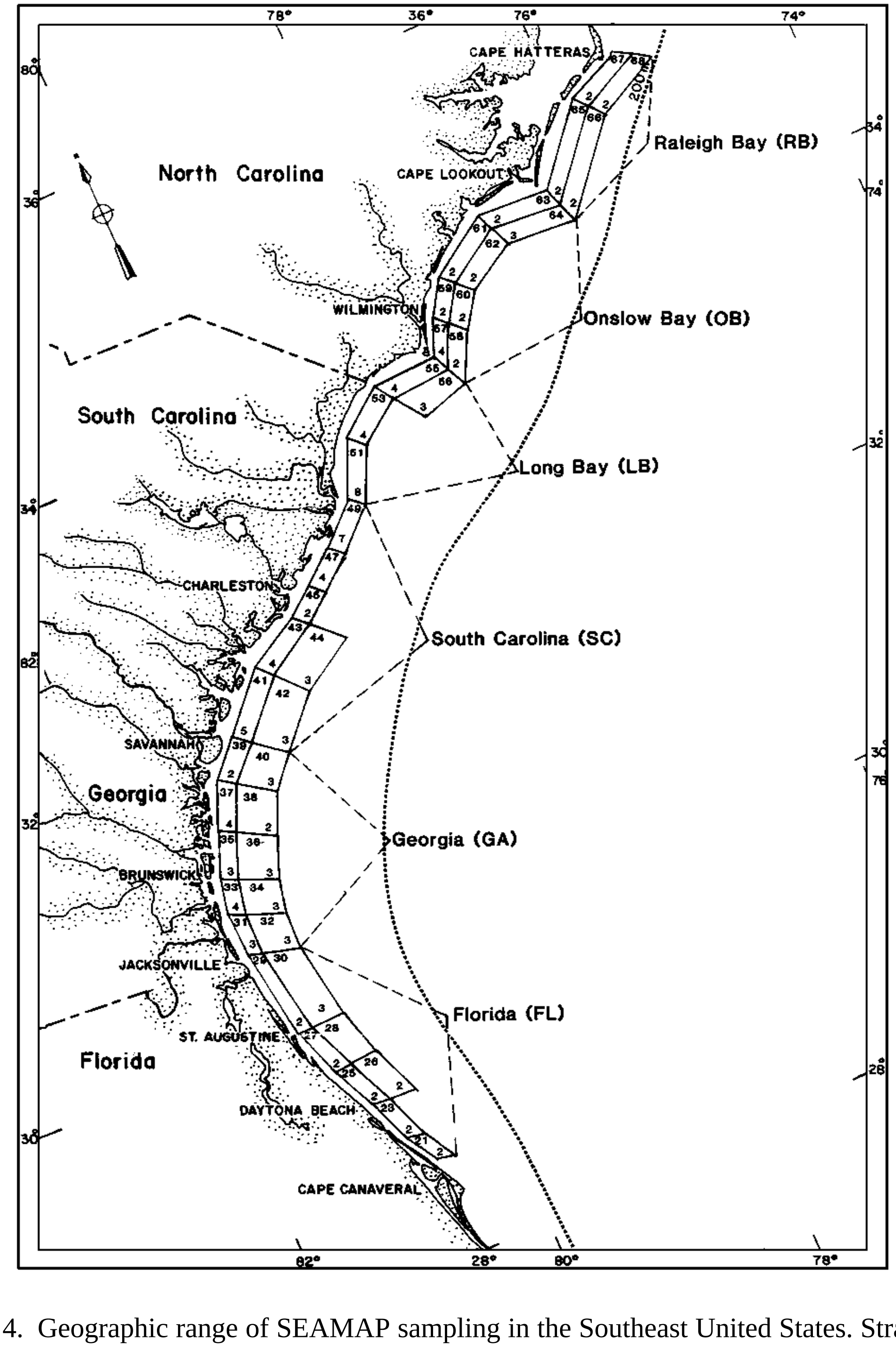

Figure 4. Geographic range of SEAMAP sampling in the Southeast United States. Stratum number is located in the upper left and number of trawl samples collected in the lower right of each stratum. Strata are not drawn to scale. Reprinted from SCMRD (2000).

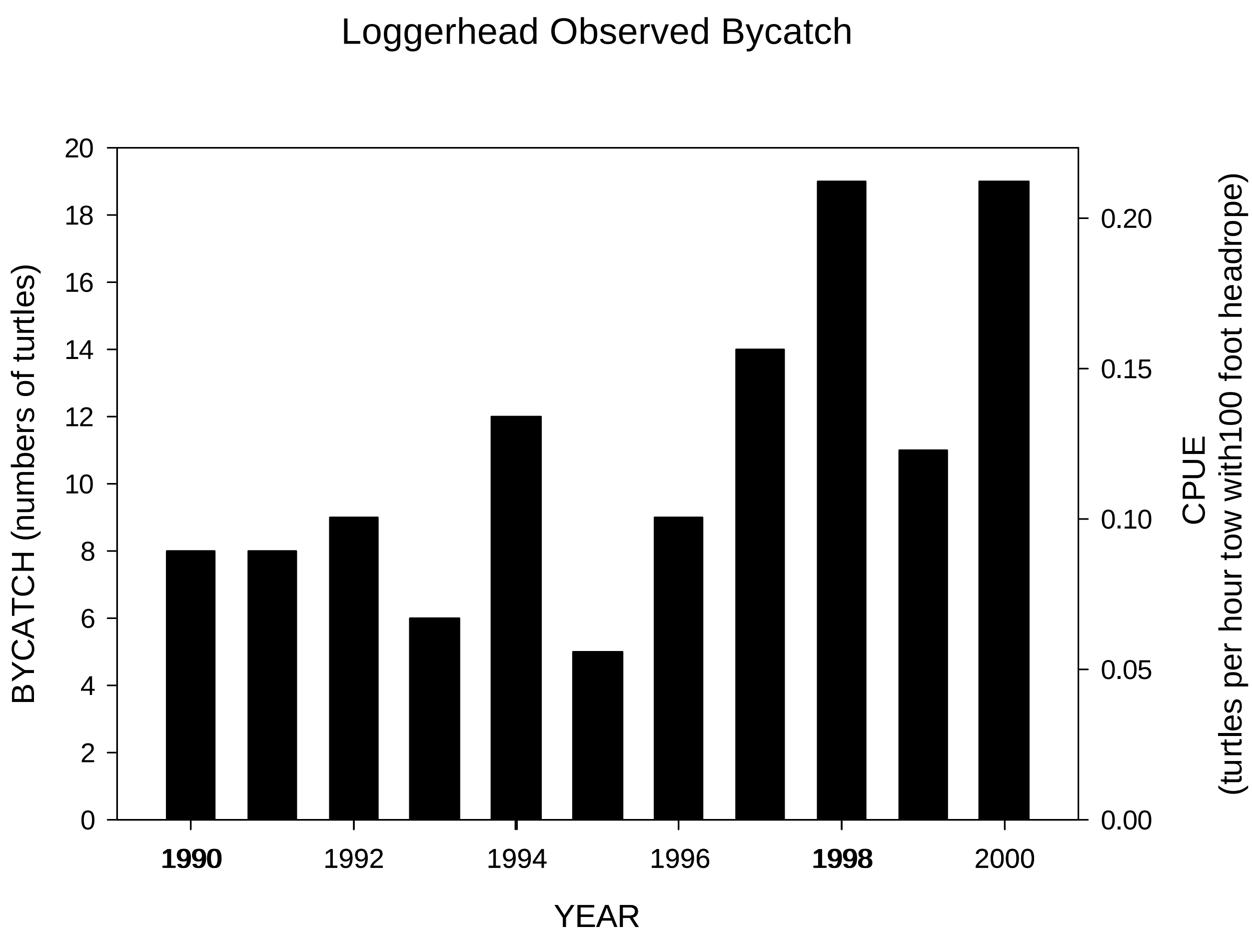

Figure 5. Observed loggerhead turtle bycatch rates in the SEAMAP analysis data set.

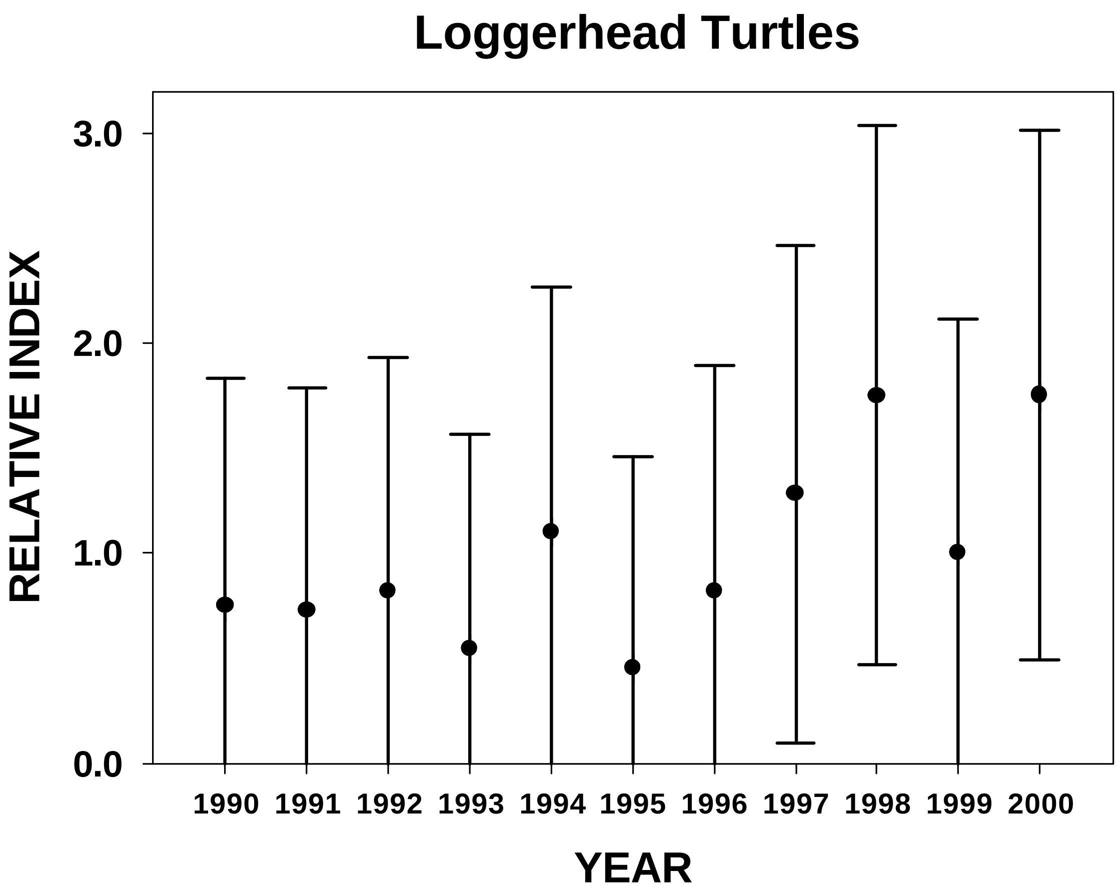

Figure 6. Relative standardized abundance indices for loggerhead turtles in SEAMAP analysis data set with approximate 95% confidence intervals (solid circles) and observed relative bycatch rates (open diamonds).

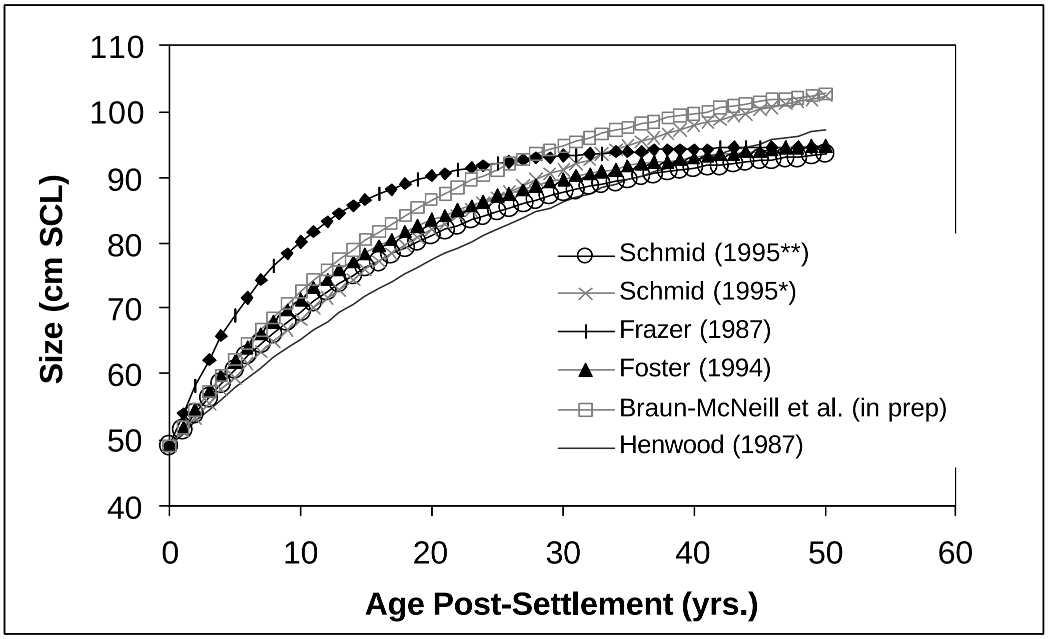

Figure 7. Published von Bertalanffy growth curves (see Table 1 for parameters). Curves were plotted using the equation $y=a-(a\text{-initial size})e^{-kx}$. As only post-settlement growth rates are being considered, 49 cm SCL was used as initial size.

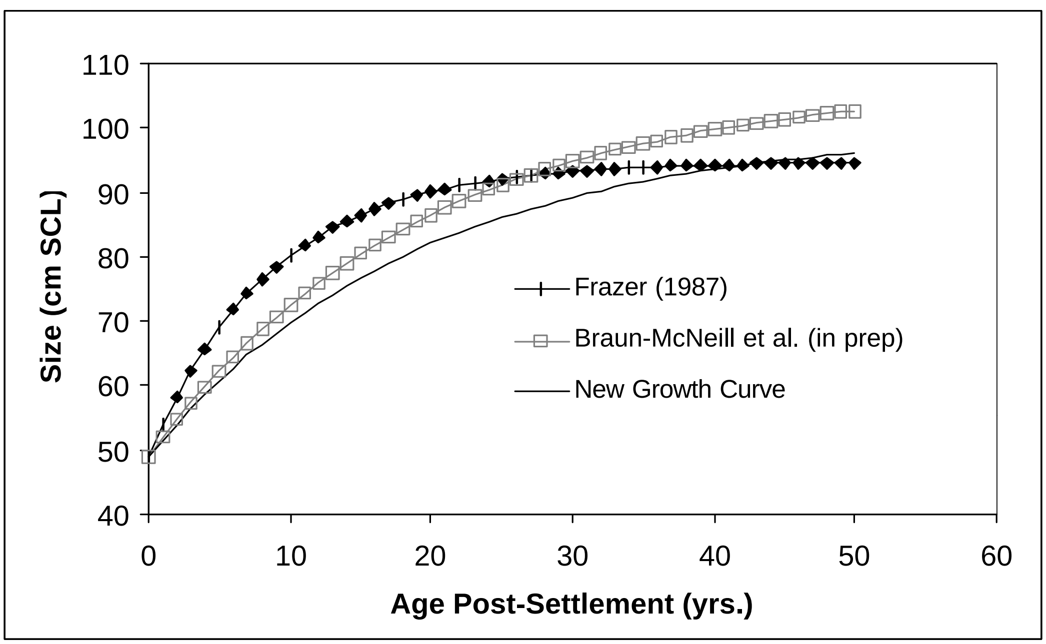

Figure 8. New growth curve generated by adding additional recaptures of turtles > 70 cm SCL to the data from Braun-McNeill et al (2001). The parameters are a=99.7 and k=0.053. The curve is shown with curves from Frazer (1987) and Braun-McNeill et al (in prep[52]) for comparison.

[52] Braun-McNeill, J., S.P Epperly, L. Avens, and S. Sadove. A Preliminary analysis of growth rates of juvenile loggerhead (*Caretta caretta*) sea turtles from North Carolina, U.S.A. Manuscript in preparation.

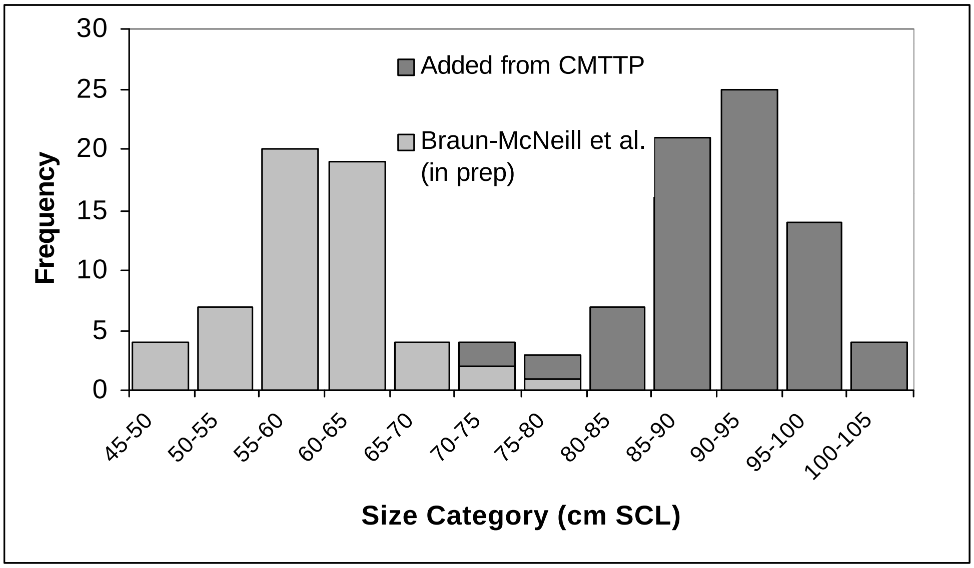

Figure 9. Size distibution of turtles from mark-recapture studies used to estimate a new von Bertalanffy growth curve for loggerhead sea turtles from the Southeast U.S.

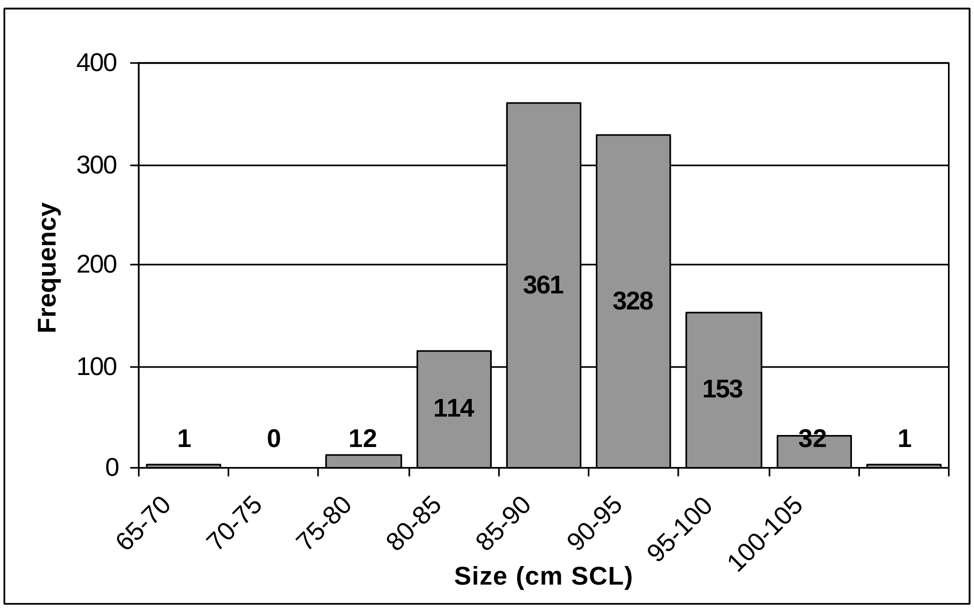

Figure 10. Size frequency of nesting loggerheads from the CMTTP database, using only reported SCL's (no conversions from CCL) and initial captures (no recaptures). Average size is 90.38 cm SCL (SD=5.08). The smallest nester is 68.5 cm SCL and the largest is 105.1 cm SCL.

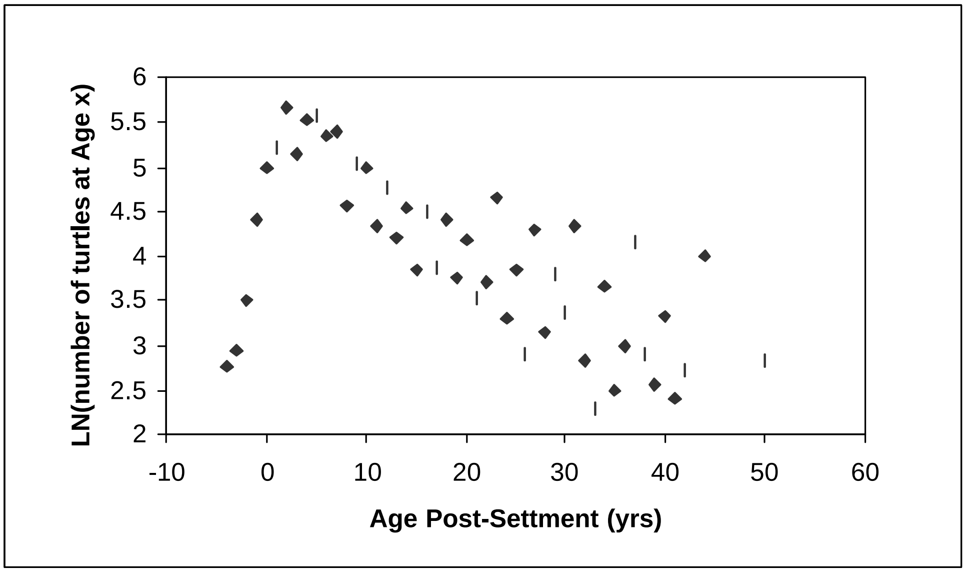

Figure 11. Catch curve for 1986-1989 loggerheads sea turtle strandings, zones 1-35. Size-at-age estimated using the 'New' von Bertalanffy growth curve (see text).

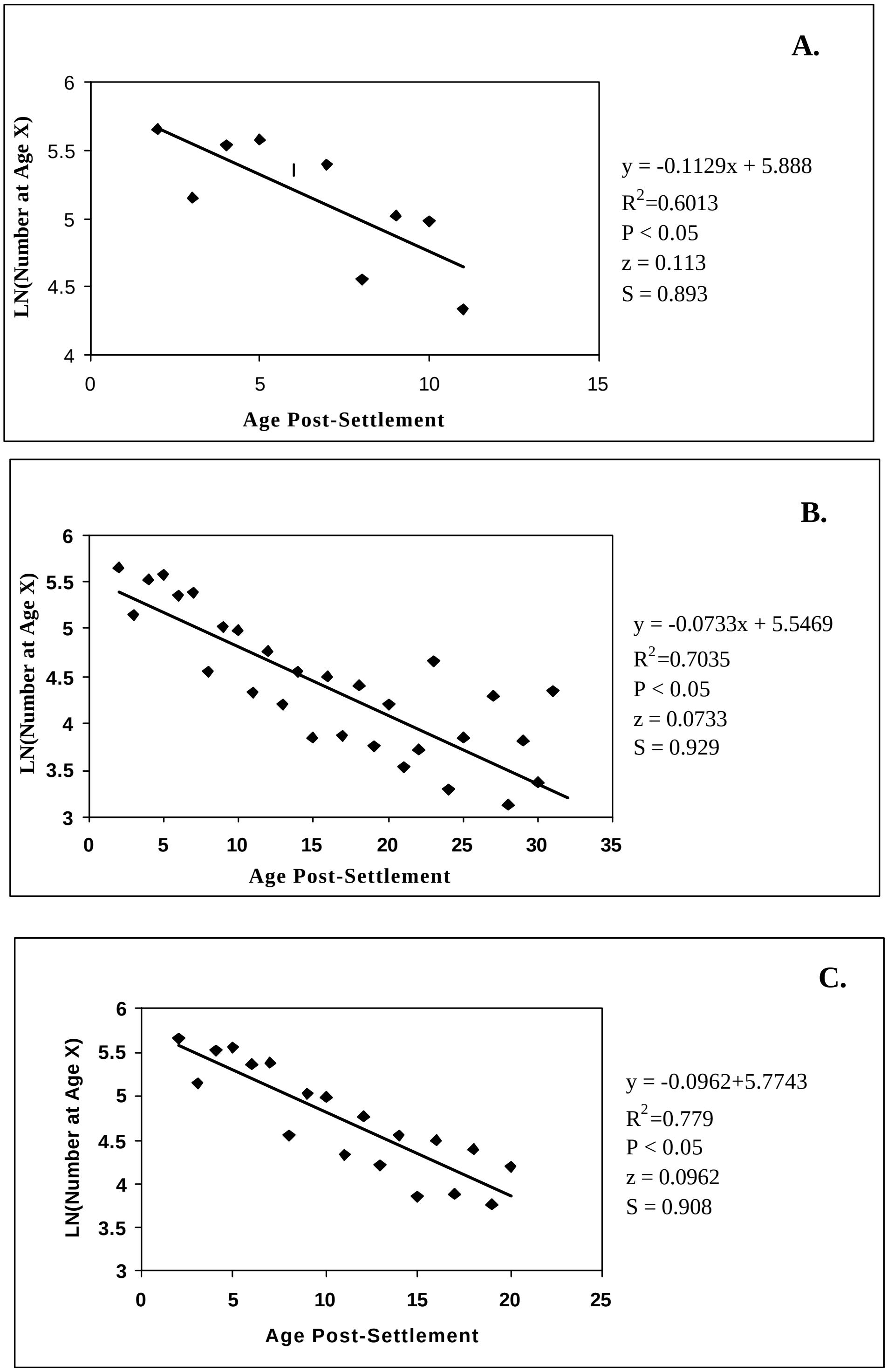

Figure 12. Catch curve from Fig 11 with instantaneous mortality rates (z) and annual survival rate (S) estimated by examining the slope of the declining arm of the catch curve at 3 different points. A) At the age corresponding to 70 cm SCL. B) At the age corresponding to 90 cm SCL. C) At the point where the data begin to scatter (Fig. 5).

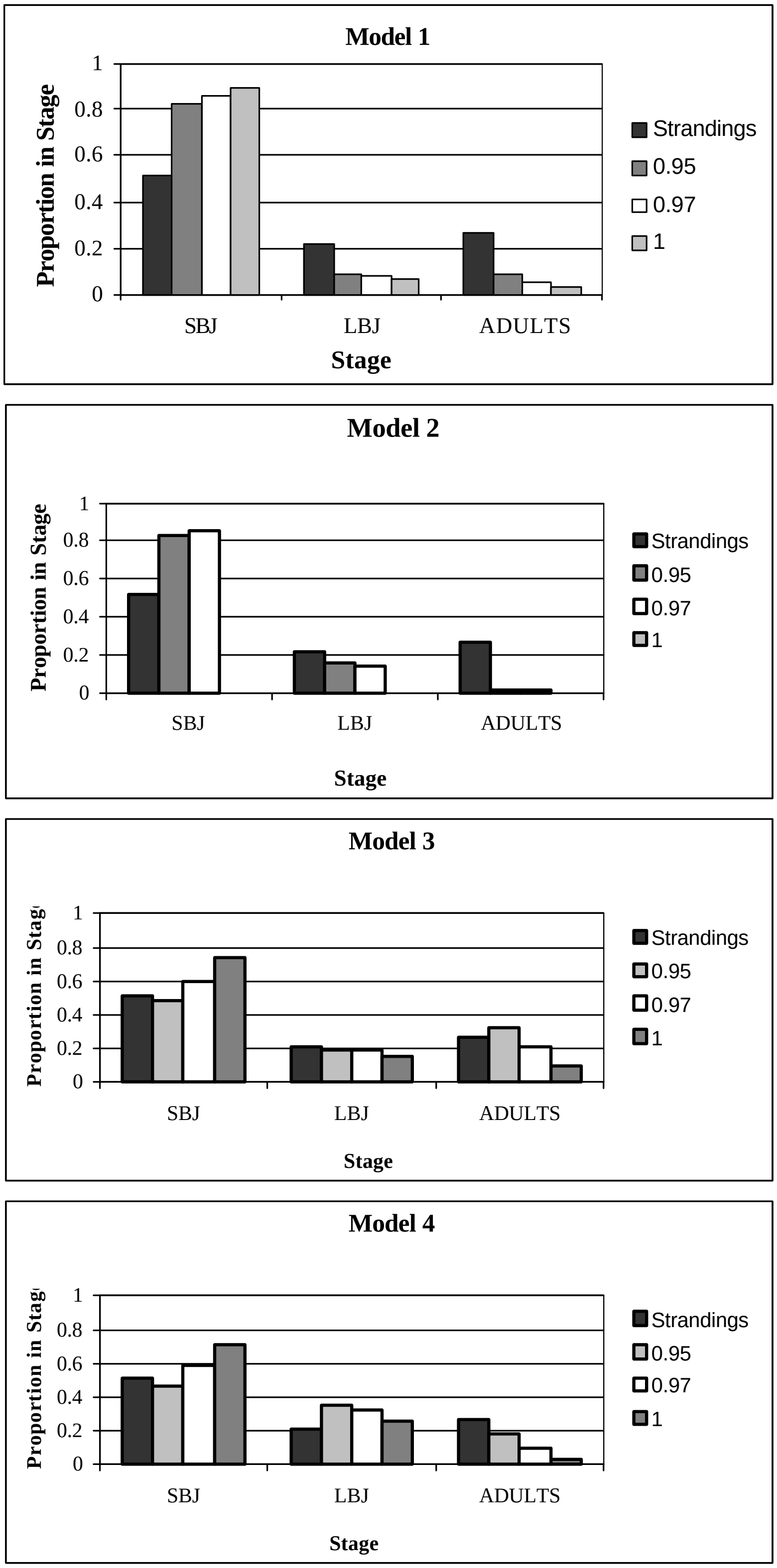

Figure 13. The proportion of animals in the three benthic stages, small benthic juvenile (SBL), large benthic juvenile (LBJ) and adults, predicted by the stable-age distribution of the 4 models. These resilts are compared to the proportion of animals within each stage based on size from dead strandings in the southeast U.S. from 1986 to 1989.

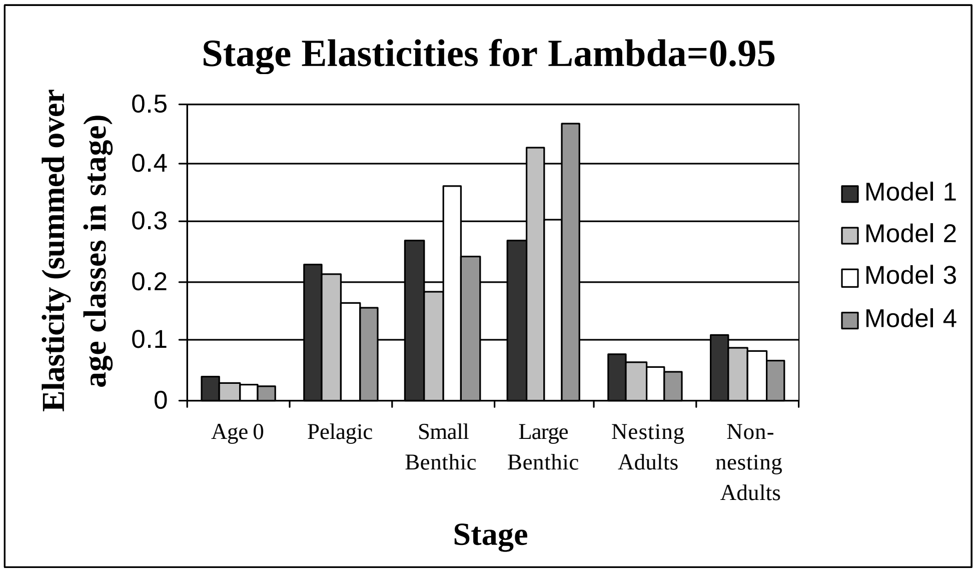

Figure 14. Elasticities summed over all ages in stage. Values given are for proportion female offspring = 0.35 and λ = 0.95.

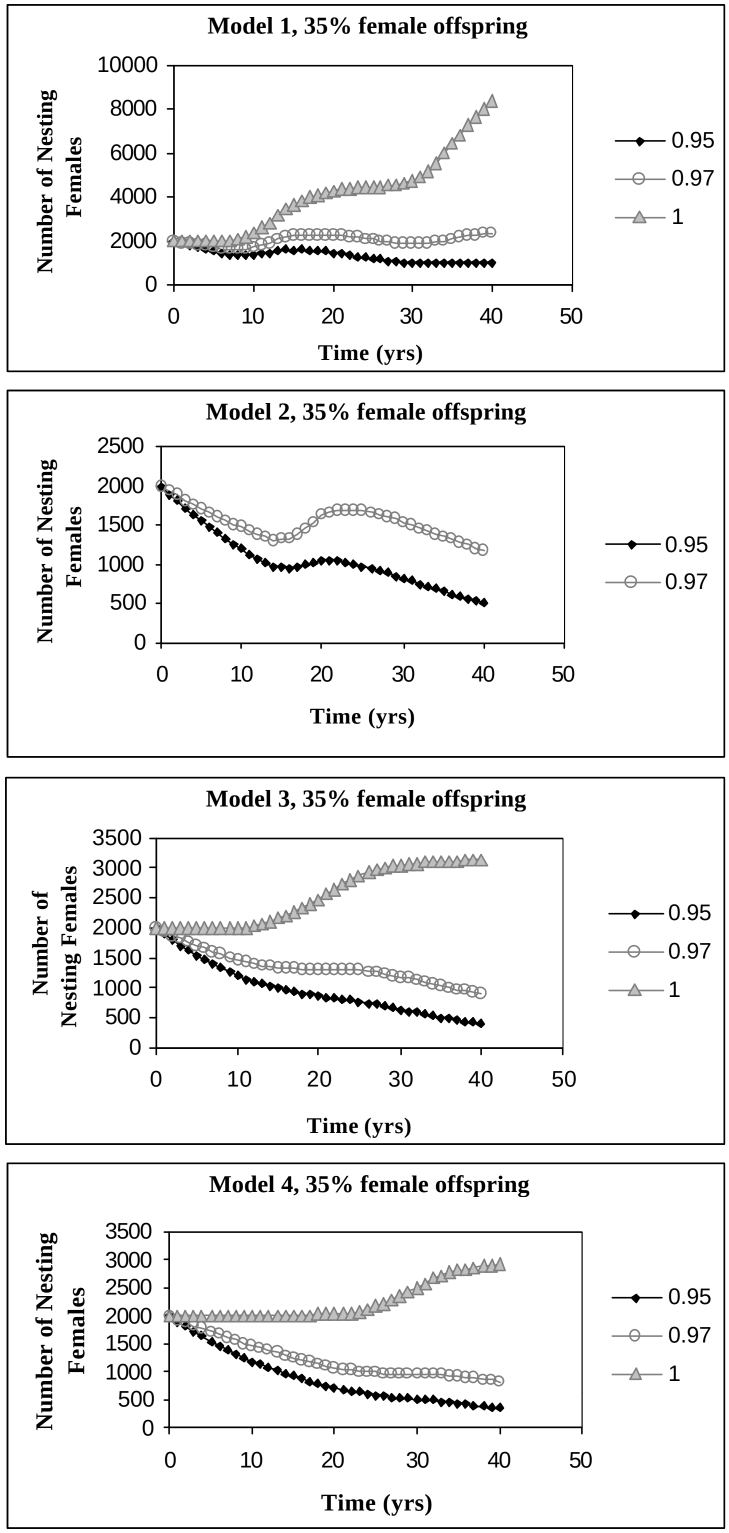

Figure 15. Population trajectories for the 4 models. Model runs were initialized with a population at stable age distribution for the appropriate combination of model and λ, assuming 2000 nesting females. Small benthic juvenile mortality was decreased by 30% and the population projected based on the new survival rates.

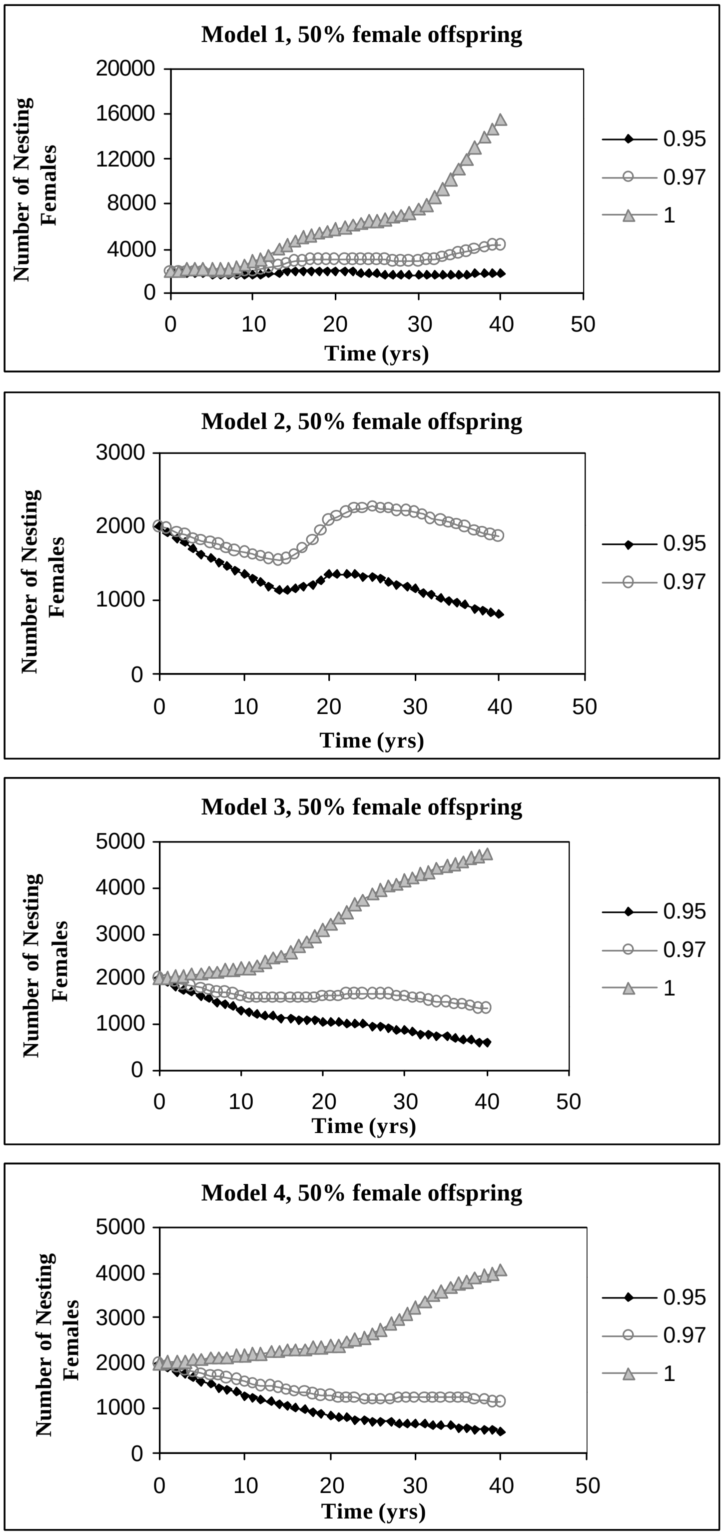

Figure 16. Population trajectories for the same 4 models as in Fig. 14 but with the proportion of female offspring now set to 0.50 in the fecundity function. Model runs were initialized with a population at stable age distribution for the appropriate combination of model and λ, assuming 2000 nesting females. Small benthic juvenile mortality was decreased by 30% and the population projected based on the new survival rates.

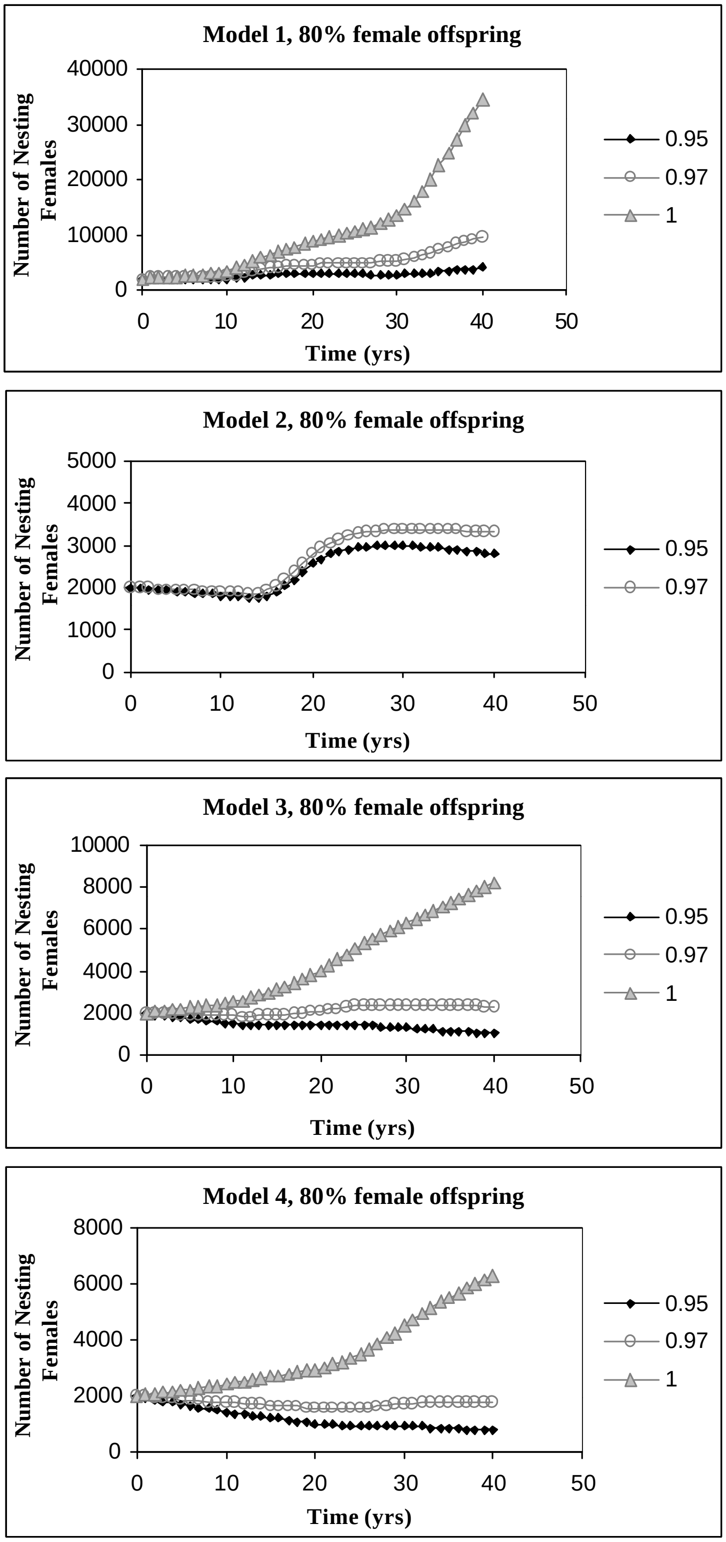

Figure 17. Population trajectories for the same 4 models as in Fig. 14 but with the proportion of female offspring now set to 0.80 in the fecundity function. Model runs were initialized with a population at stable age distribution for the appropriate combination of model and λ, assuming 2000 nesting females. Small benthic juvenile mortality was decreased by 30% and the population projected based on the new survival rates.

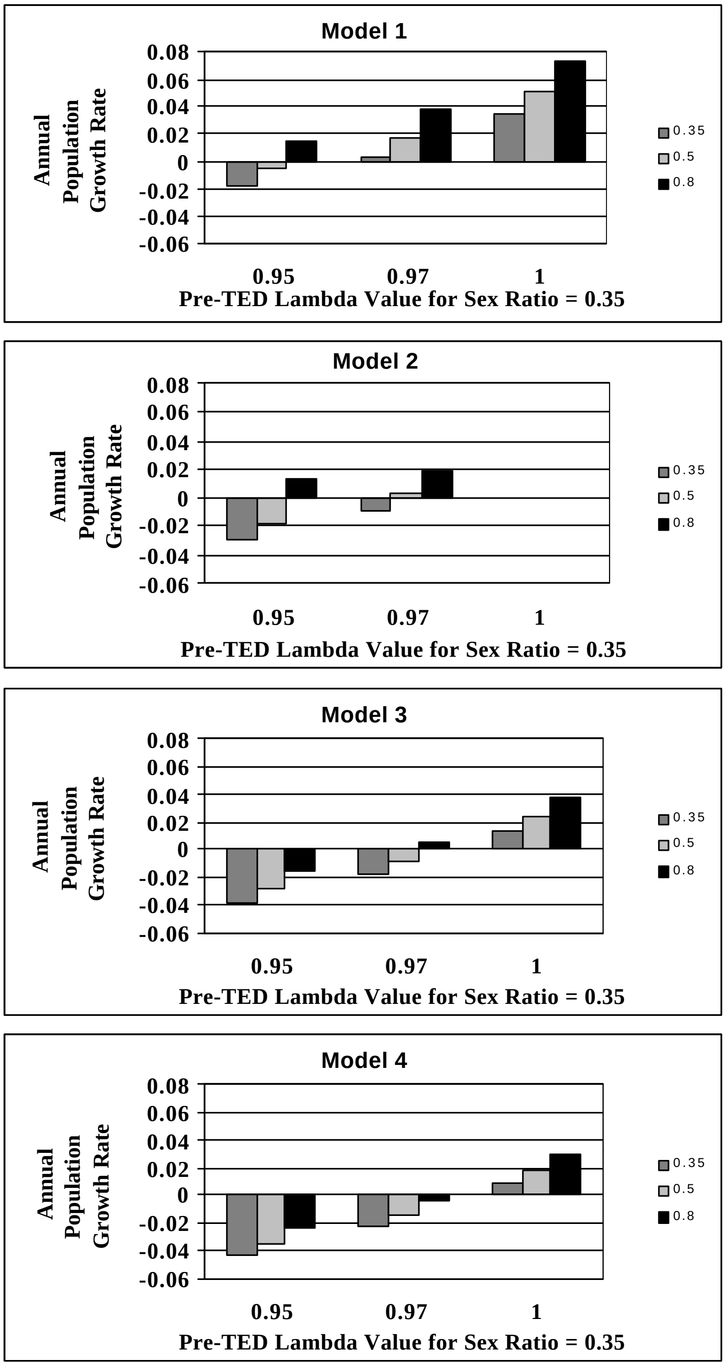

Figure 18. Population growth rates following a 30% reduction in mortality in the small benthic stage. Each model (1-4) was run at 3 initial values of λ (equal to 0.95, 0.97 and 1.0 for proportion of female offspring = 0.35) and at three values for proportion of female offspring (0.35, 0.50 and 0.80).

PART II

STOCK ASSESSMENT OF LEATHERBACK SEA TURTLES OF THE WESTERN NORTH ATLANTIC

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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.

<u>Seasonal Distributions</u>

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

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[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

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[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).

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[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

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[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

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[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

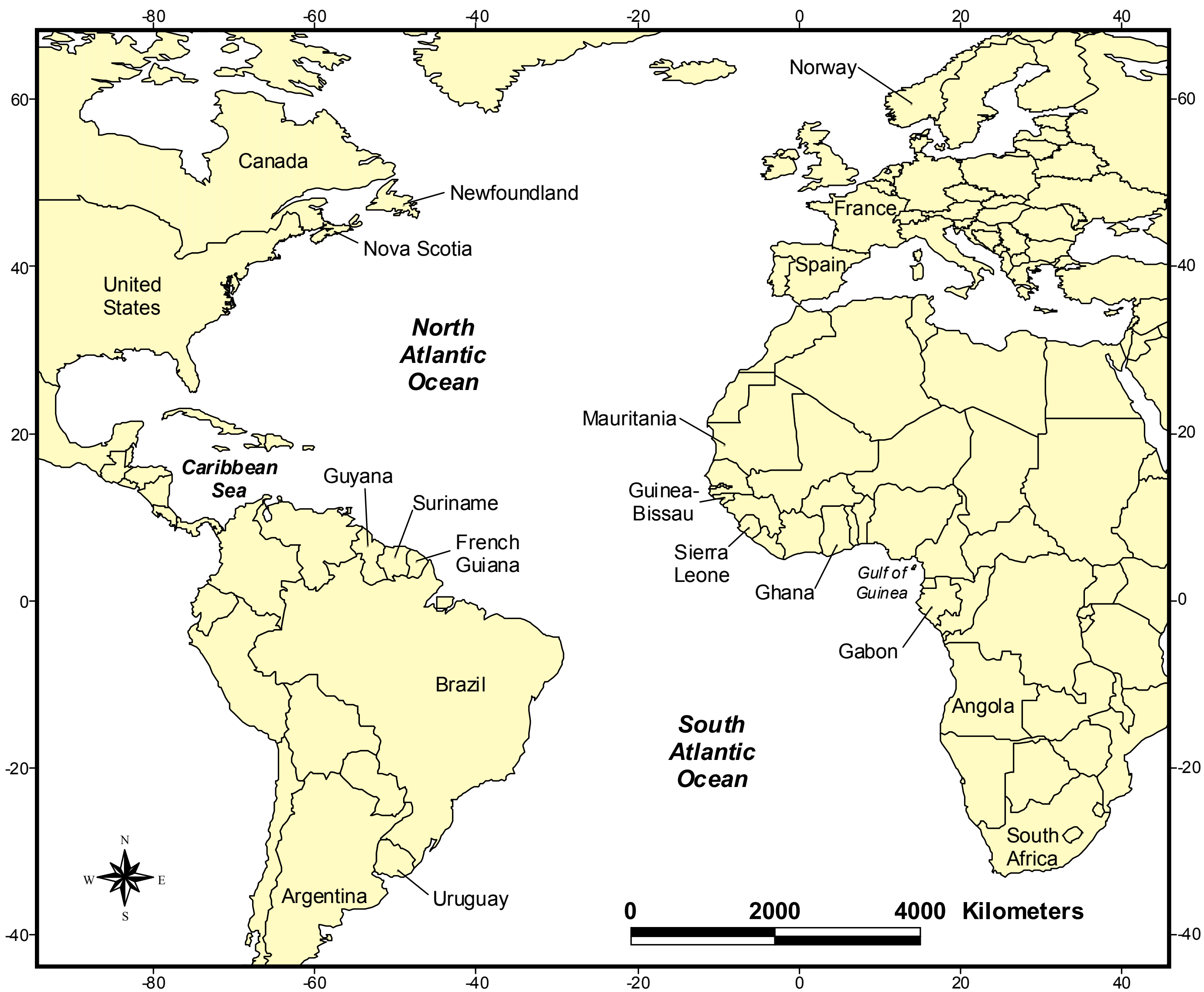


Figure 1. Map of Atlantic Ocean basin and localities for leatherback distribution.

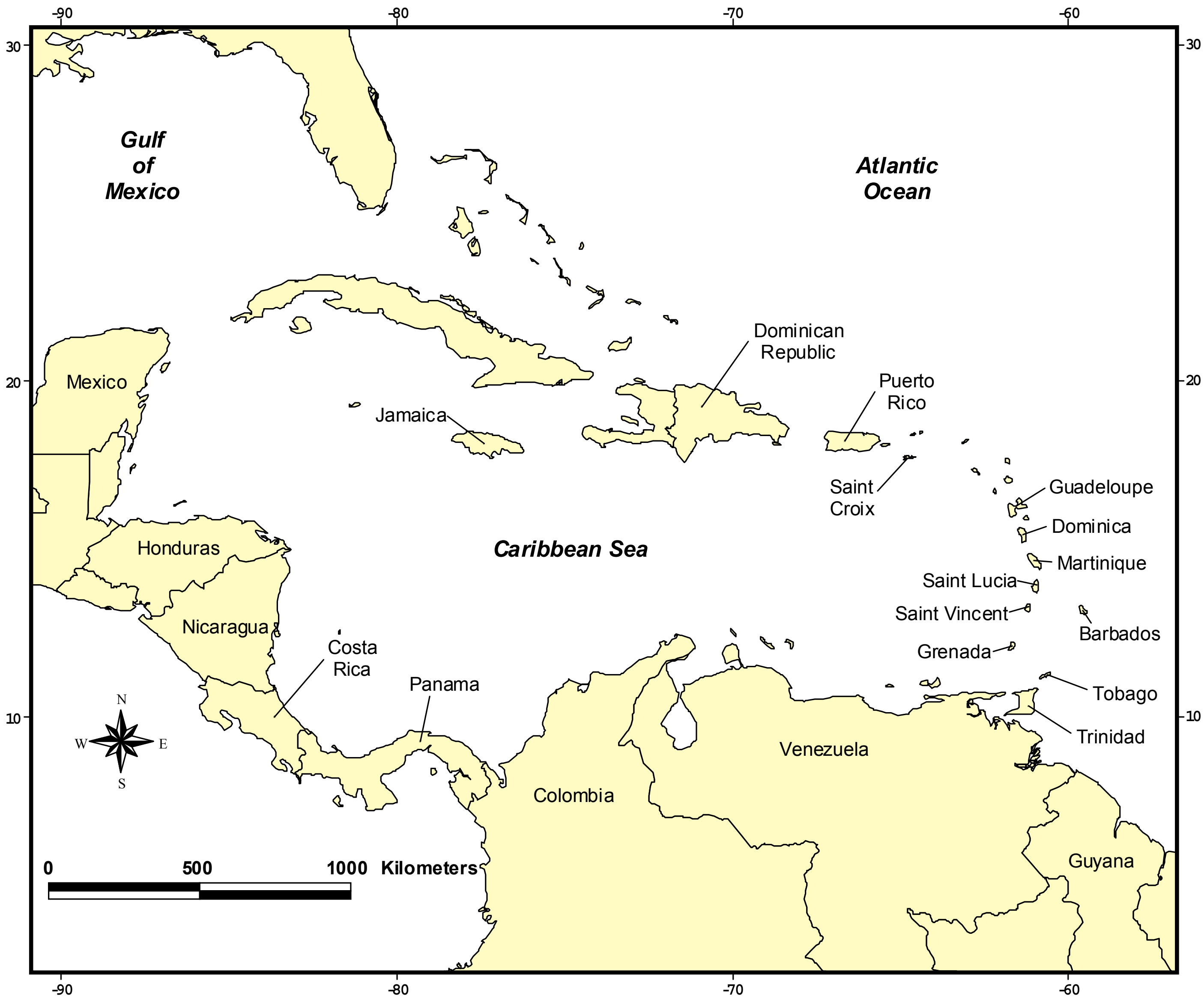
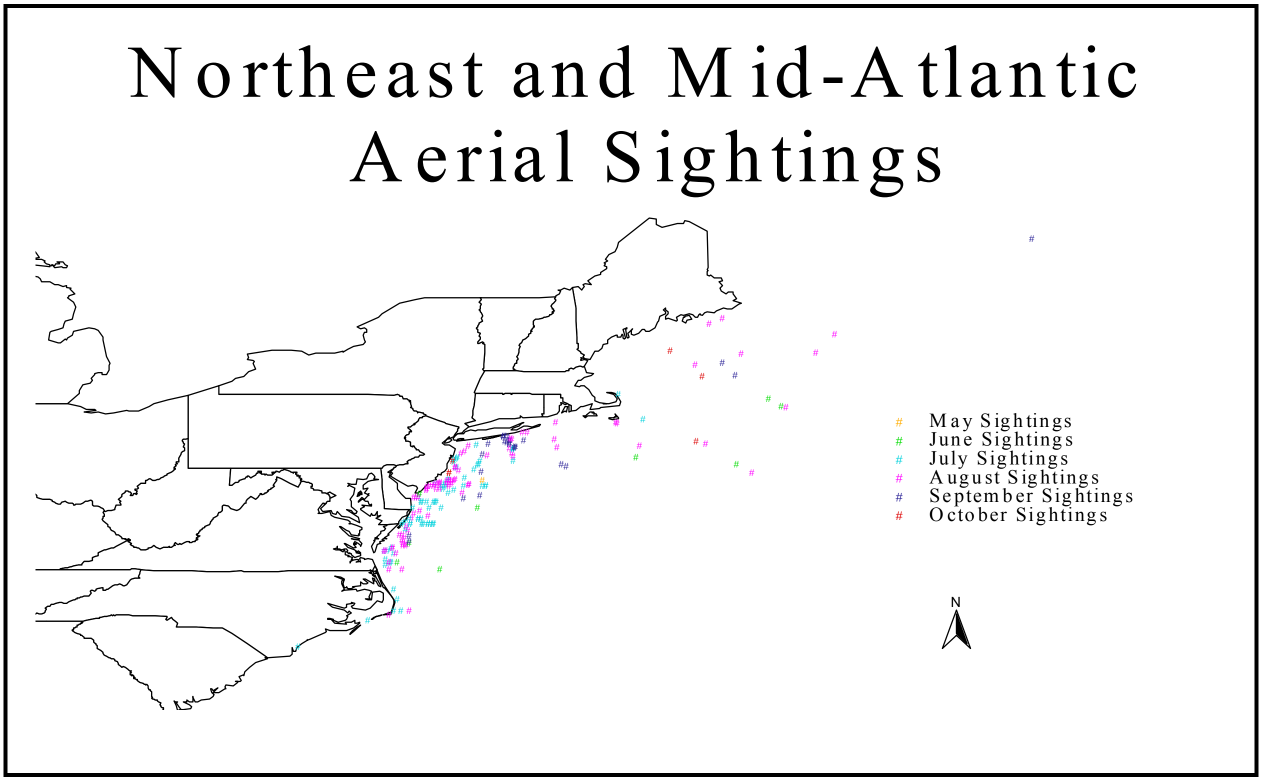


Figure 2. Map of Caribbean Sea basin and localities for leatherback distribution.



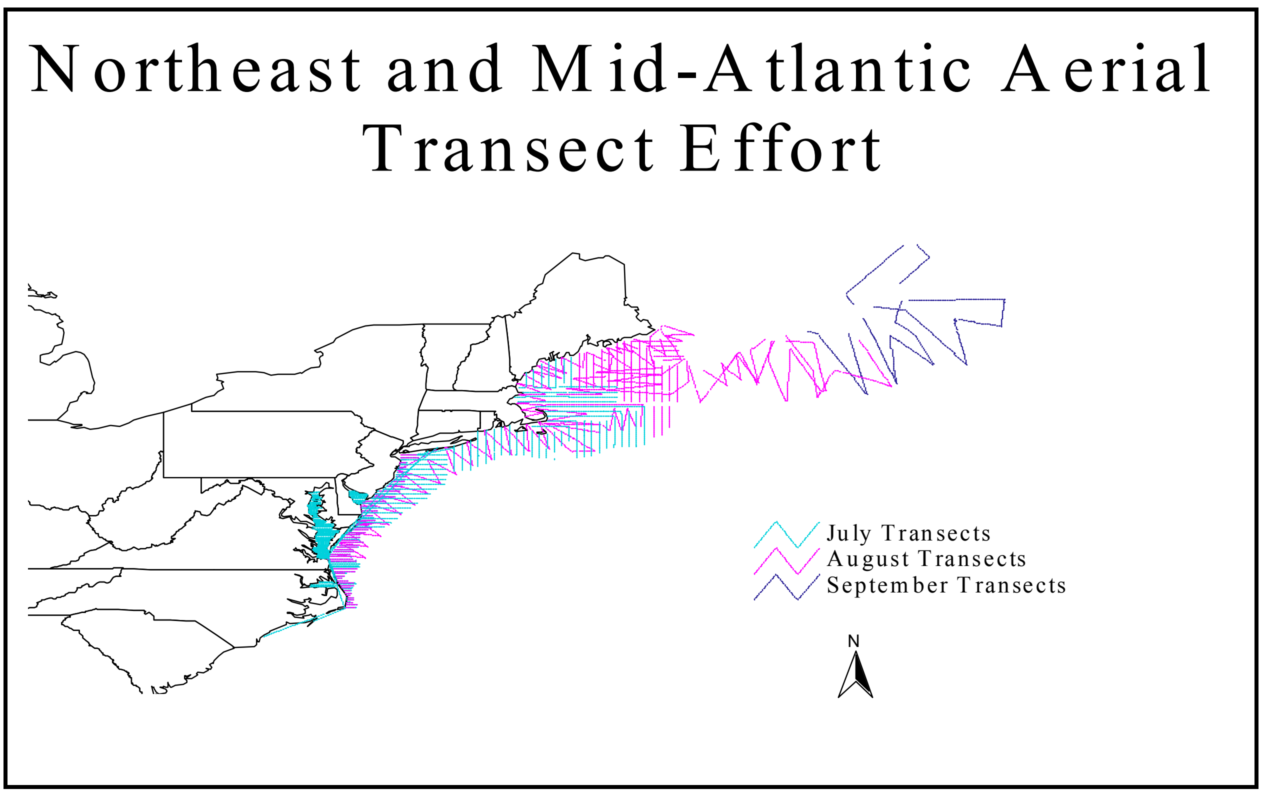


Figure 3. Leatherback sightings and transect effort in aerial surveys of the Northeast U.S. and Mid-Atlantic, 1994-1998. Some sightings may be obscured by others. Transect effort of Shoop and Kenney (1992) is not included, while sightings are.

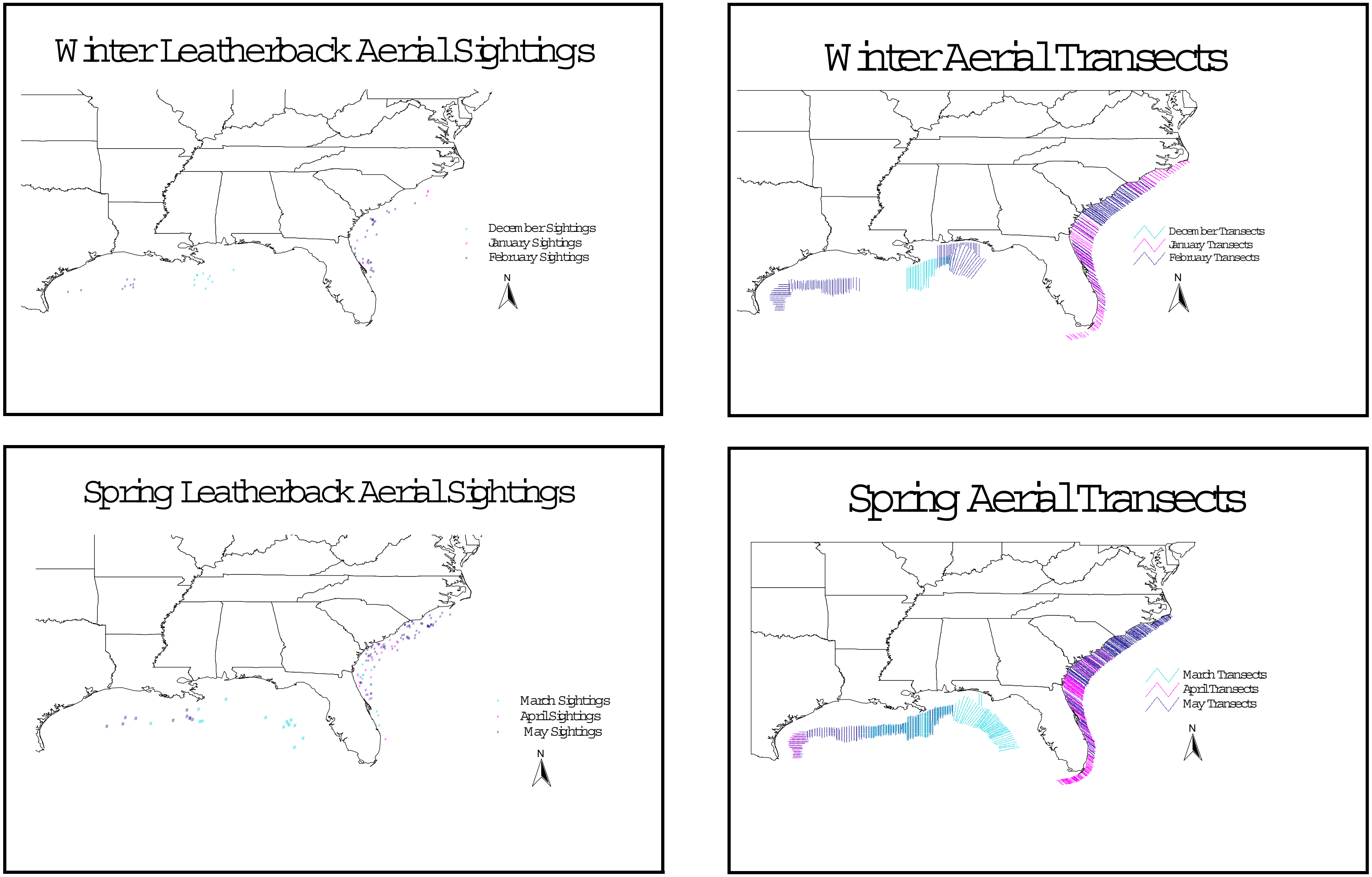
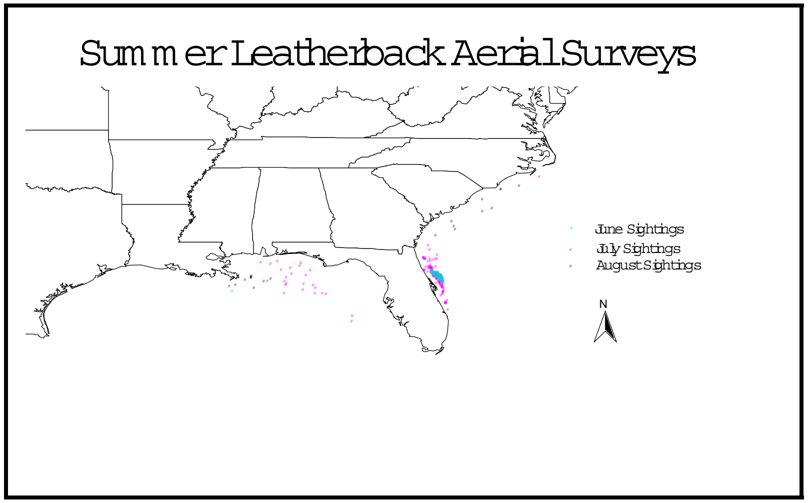
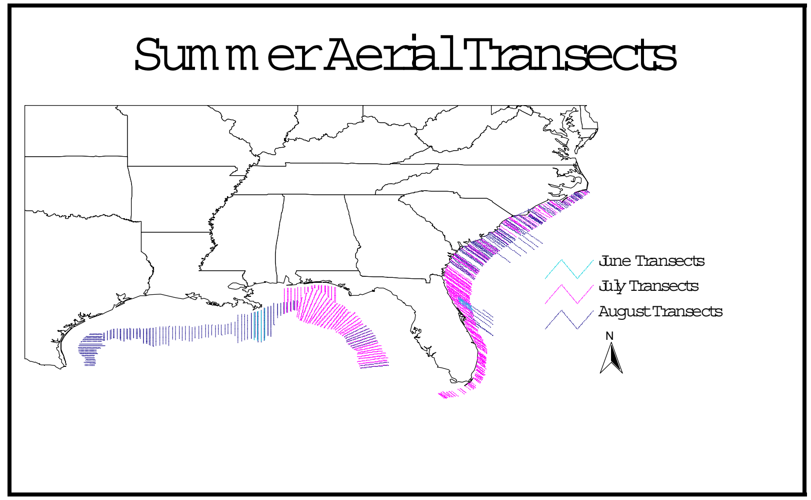
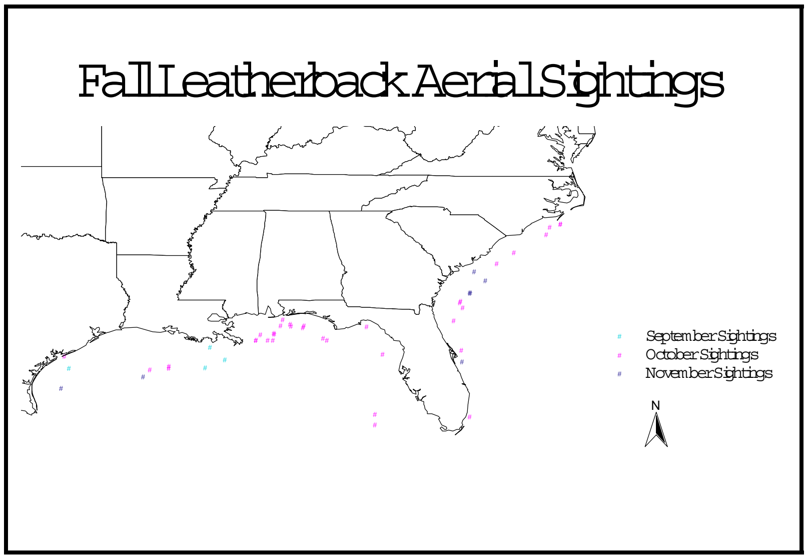


Figure 4. Leatherback sightings and transect effort in aerial surveys of the Southeast U.S. and Gulf of Mexico, 1982 – 1997.







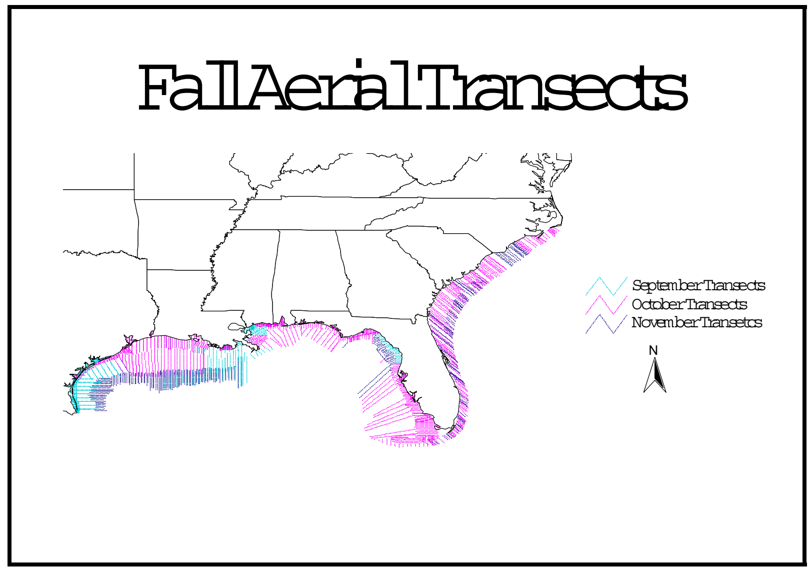


Figure 4. (continued)

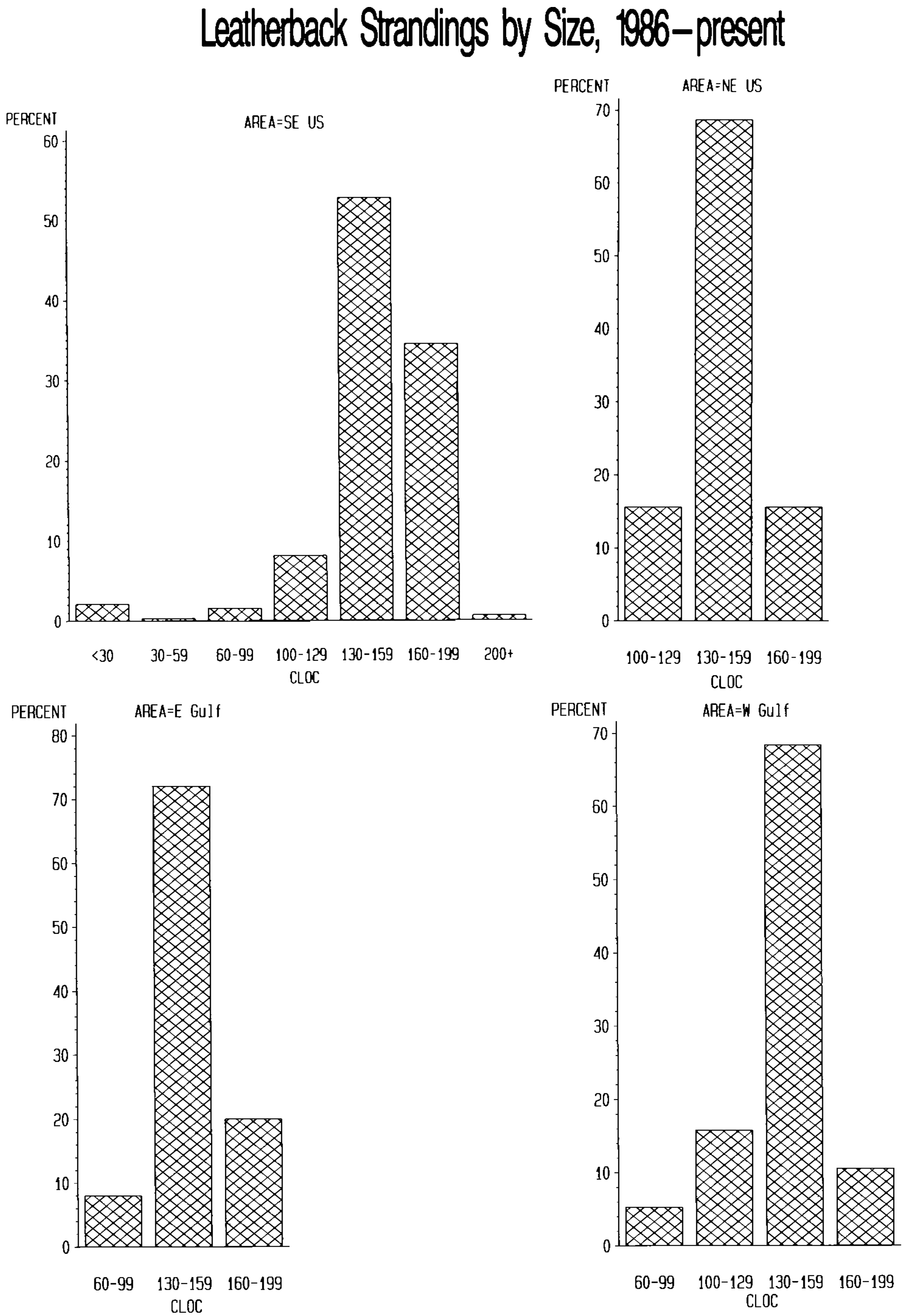


Figure 5. Size distribution of leatherback strandings by region, 1986-1999[7].

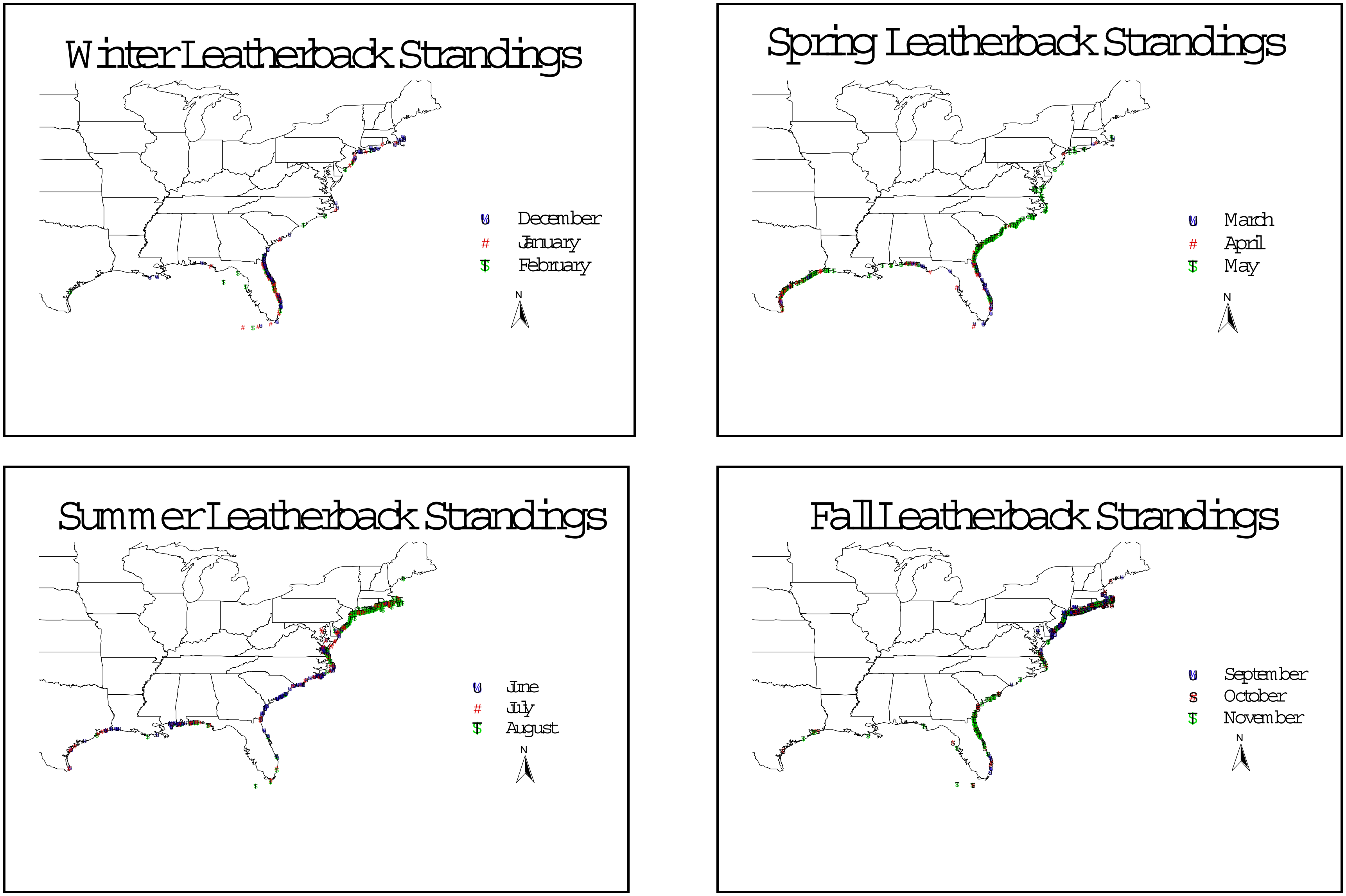


Figure 6. Seasonal leatherback strandings along the U.S. Atlantic and Gulf of Mexico coasts, 1980-1999[7].

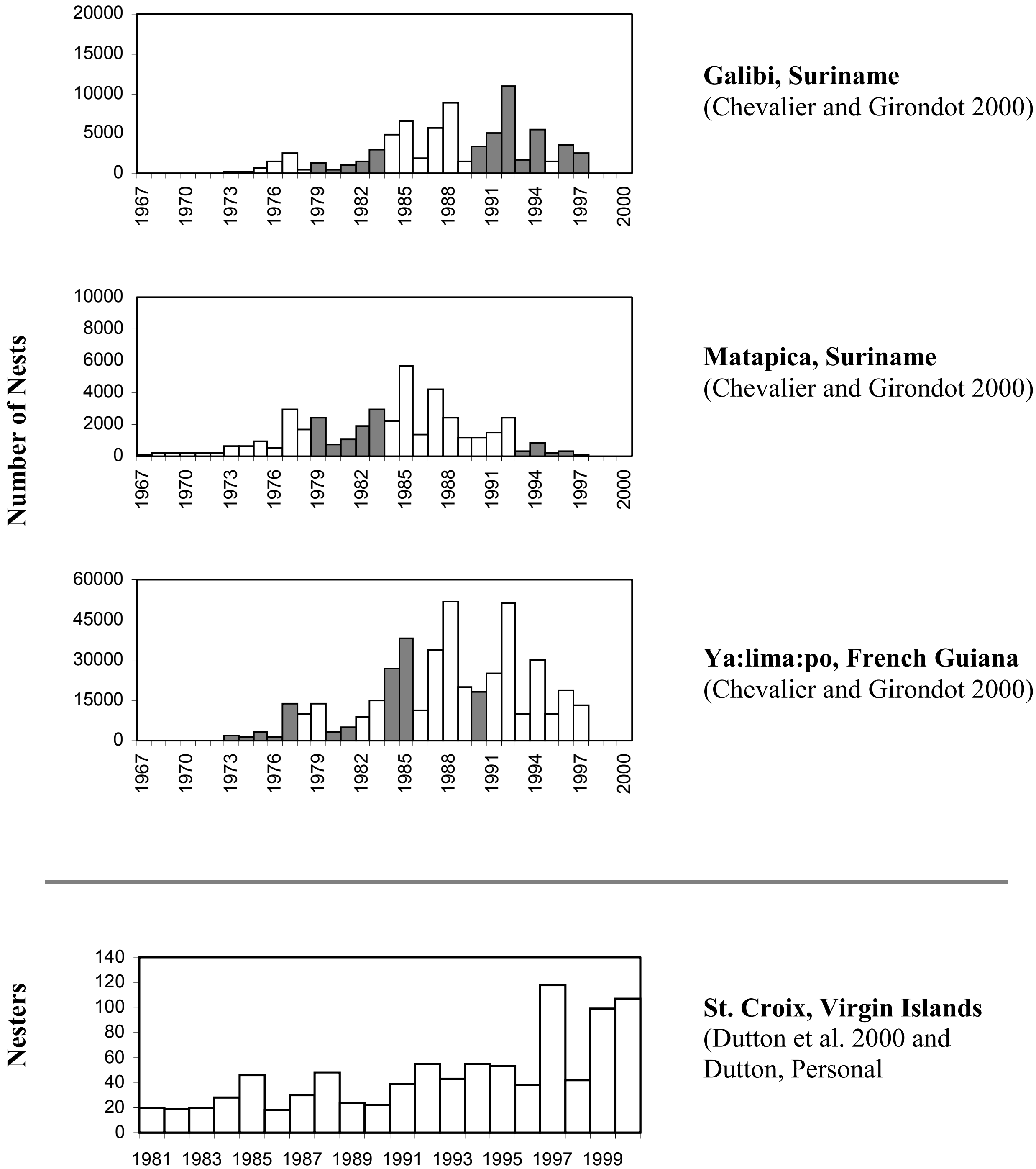


Figure 7. Nesting activity in the Guianas and St. Croix, U.S. Virgin Islands. Shaded bars are extrapolated values.

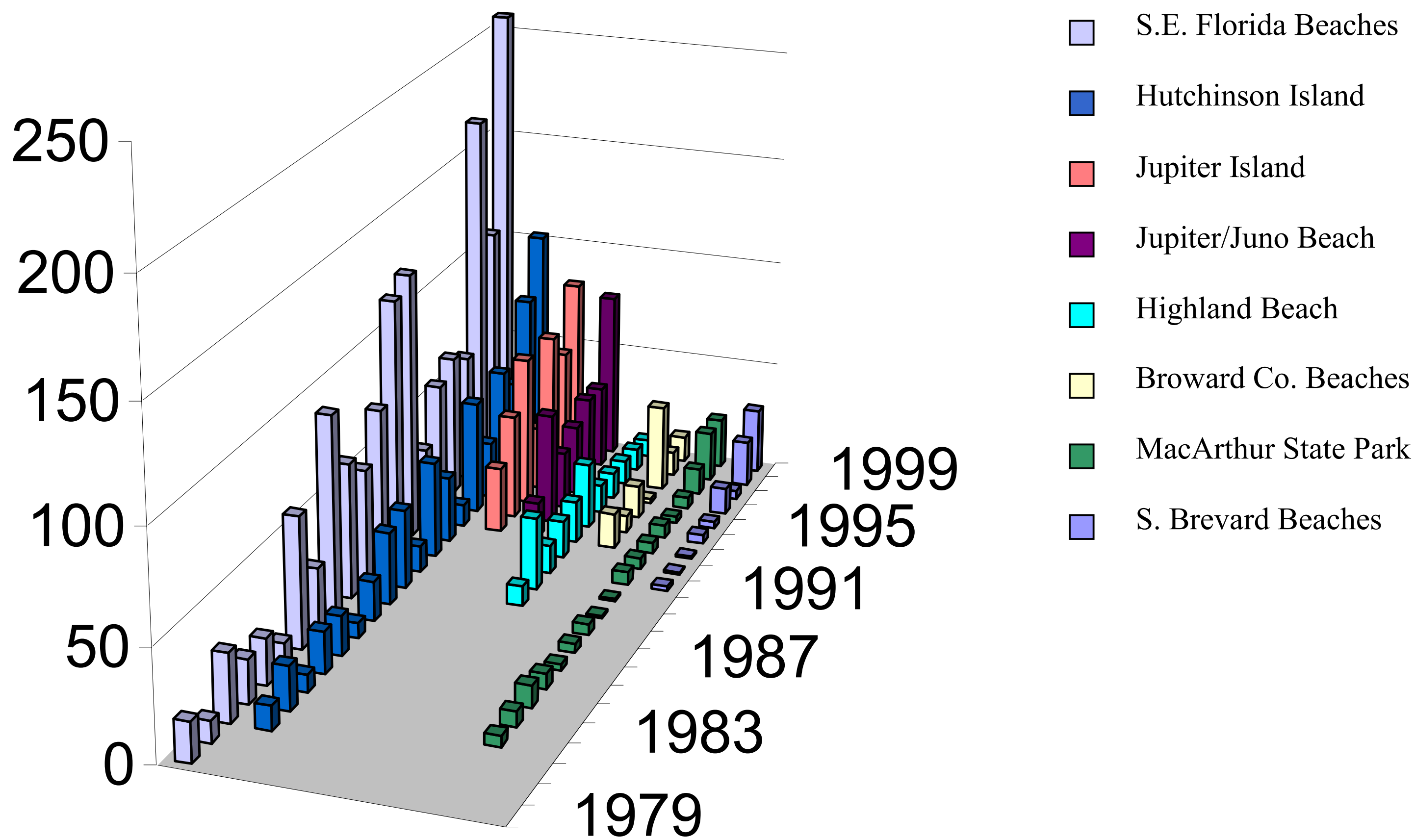


Figure 8. Leatherback nesting activity (number of nests) on selected Southeast Florida beaches that have consistent survey effort (Meylan *et al.* 1995, FWC 2000[26]).

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

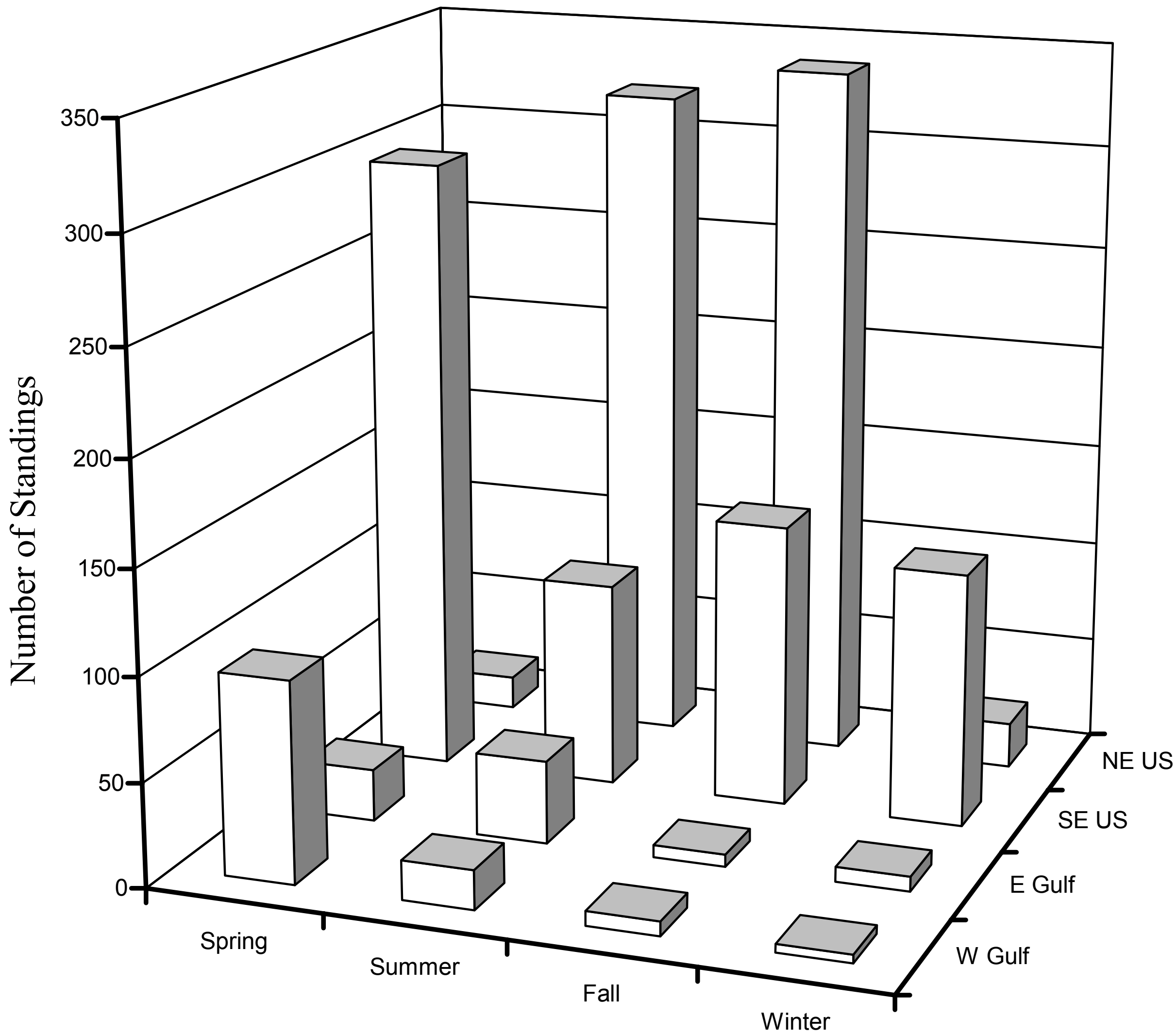

Figure 9. Seasonal leatherback stranding totals by region, 1986-1999[7].

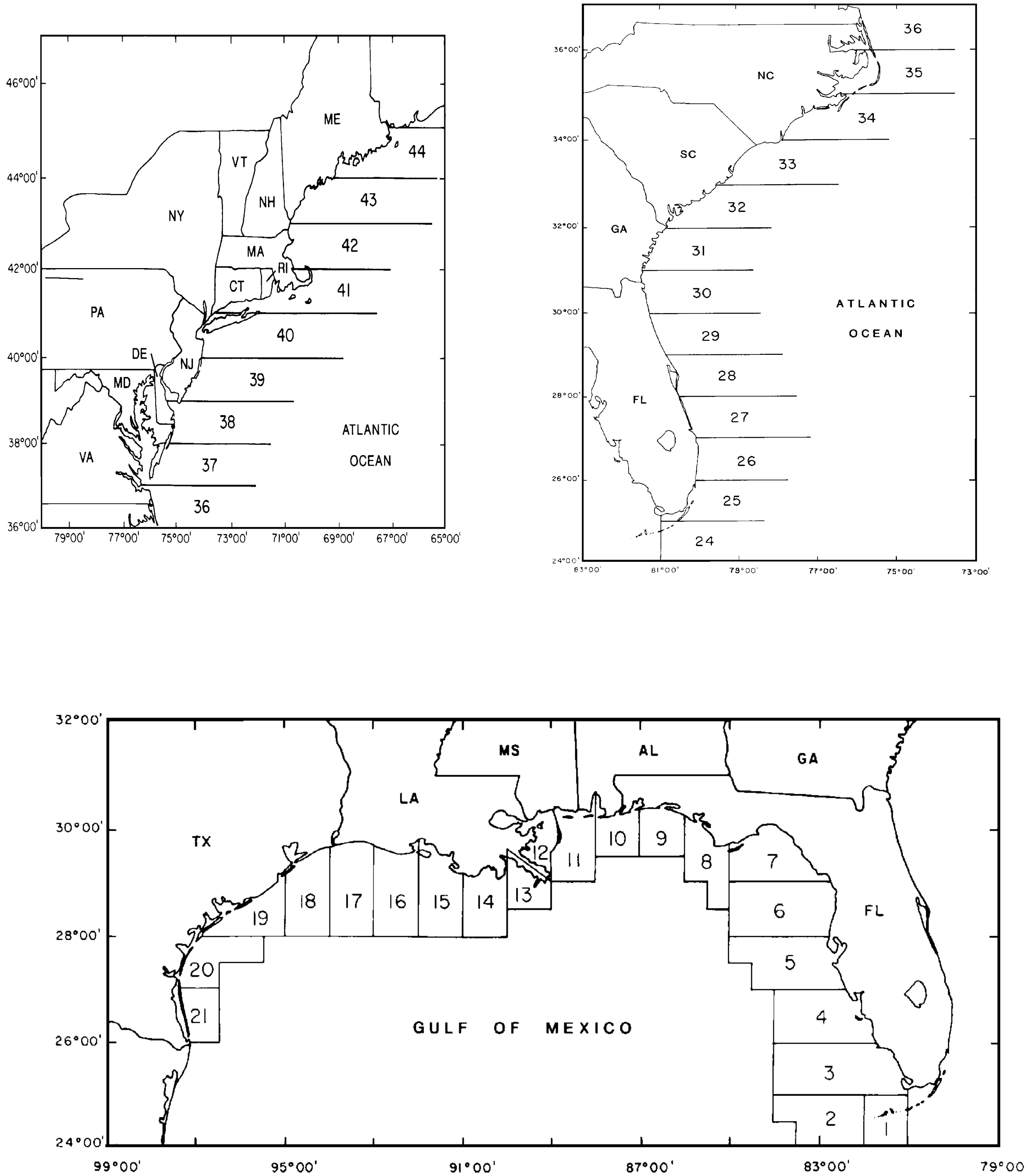

Figure 10. Statistical zones along the U.S. Atlantic and Gulf of Mexico coasts.

Part III

ASSESSMENT OF THE IMPACT OF THE PELAGIC LONGLINE FISHERY ON LOGGERHEAD AND LEATHERBACK SEA TURTLES OF THE NORTH ATLANTIC

Table of Contents

CHAPTER 1. DESCRIPTION OF THE ATLANTIC OCEAN AND MEDITERRANEAN SEA PELAGIC LONGLINE FISHERIES

Wayne N. Witzell, Sheryan P. Epperly, and Lisa A. Csuzdi

The United States is one of at least 23 other countries that fished in the Atlantic Ocean and Mediterranean Sea with pelagic longlines during 1990-1997 (Carocci and Majowski 1998). The Atlantic pelagic longline fisheries typically consist of a free floating mainline that supports multiple baited gangions. Pelagic longline vessels target sharks (*Carcharinus spp*.), swordfish (*Ziphias gladius*), and various tunas (*Thunnus spp*.), particularly yellowfin, bigeye, and albacore, depending on season and geographic location. The various swordfish fisheries in the Atlantic Ocean and Mediterranean Sea have recently been described by Folsom (1997*a,b*, Folsom *et al*. 1997, Brewster-Geisz *et al*. 1997, Barrett *et al*. 1998, Weidner and Arocha 1999, Weidner *et al*. 1999*a*,*b*). The fisheries are extensive, diverse, and dynamic and are economically important. The fishermen are able to change gear configurations and fishing strategies, depending on target species, location, and time of year. Domestically, the U.S. pelagic longline fishery has been described from a mandatory logbook system implemented and managed by the National Marine Fisheries Service (NMFS), Southeast Fisheries Science Center (SEFSC) in Miami, Florida (Cramer and Adams 2000). Additional information on the U.S. longline fleet is from the NMFS, SEFSC pelagic observer program (Lee and Brown 1998). Hoey and Moore (1999[1]) also provide a summary description of the U.S. pelagic longline fishing gear, fishing strategy, and catch composition using observer data and Witzell (1999) provided a description of distribution and relative abundance sea turtle takes by the U.S. longline fleet using NMFS, SEFSC 1992-1995 logbook data.

Most of the foreign high seas fisheries in the Atlantic Ocean are basically similar to those of the United States, in that they fish multiple days and fish many miles of line per day. However, the Mediterranean longline fisheries of Italy, Greece, and Malta, apparently fish smaller vessels than the larger oceanic fleets. They set once per night, relatively close to shore, and return to port between sets (Argano *et al*. 1992, De Metrio *et al*. 1983, Gramentz 1989, Panou *et al*., 1991[2], 1992[3]).

Most nations that fish pelagic longline gear in the North and South Atlantic Oceans, Gulf of Mexico, Caribbean Sea, and Mediterranean Sea belong to the International Commission for

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[1] Hoey, J.J. and N. Moore. 1999. Captain's report: multi-species catch characteristics for the U.S. Atlantic pelagic longline fishery. MARFIN Grant – NA77FF0543 and SK Grant – NA86FD113 from National Marine Fisheries Service, Silver Spring, MD to National Fisheries Institute, Inc., Arlington, VA., 78 pp.

[2] Panou, A., S. Moschonas, L. Tselentis, and N. Voutsinas. 1991. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Unpublished Report. Institute of Zoology University of Munich, Federated Republic of Germany, Munich, 6 pp.

[3] Panou, A., G. Antypas, Y. Giannopoulos, S. Moschonas, D. Mourelatos, G. Mourelatos, Ch. Mourelatos, P. Toumazatos, L. Tselentis, N. Voutsinas, and V. Voutsinas. 1992. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Unpublished Report. Institute of Zoology University of Munich, Federated Republic of Germany, Munich, 8 pp.

the Conservation of Atlantic Tunas (ICCAT). This is the international research and management organization that manages the tuna and billfish species affected by longlines in the Atlantic Ocean. Fisheries data such as yield (landings), catch per unit effort (CPUE), individual sizes and weights are collected by ICCAT countries and used in stock assessments and for regulatory considerations. There are many countries that fish pelagic longlines in the Atlantic and Mediterranean Sea, and other countries may move from one geographic area to another, changing target species depending on fishing success and ICCAT regulations. Some fishing vessels operate under another nation's flag or otherwise do not report landings under any particular country. These landings are designated NEI (Not Elsewhere Included).

The reported longline yields of swordfish and tunas were tabulated from the ICCAT data base (CATDIS, found at www.iccat.org or www.iccat.es under the Statistics and Monitoring Section). These data are sent to the United Nations Food and Agricultural Organization (FAO) for inclusion in the Atlas of Tuna and Billfish Catches (Carocci and Majkowski 1998). The CATDIS data were summarized by region, year (1990-1997) and species group (tunas and swordfish) for the U.S. and for all other nations combined. Regions were defined as Mediterranean Sea, North Atlantic (data coded north of 9° N) and tropics (data coded as 10° south of the equator to 9° north of the equator). Note that data are coded for 1° square cells and are labeled with the degree latitude of its southern boundary. Thus, data coded as 9°N represents yield attributed to fishing between 9° and 10°N. Consequently, although we refer to the Tropics as 10°S to 9°N, that represents fishing between 10°S and 10°N. Similarly the North Atlantic, labeled as >9°N, represent fishing at and north of 10°N.

Swordfish and tuna landings were summarized by nation for the years 1990-1997 combined (Figures 1-3). Countries with relatively little yield were eliminated for graphics clarity. However, these countries will be listed in descending order of yield value. The United States pelagic longline fleet is a major producer of swordfish and tuna in the north Atlantic. The U.S. fleet is of less importance in the tropics, and is not a component of the Mediterranean Sea fishery.

North Atlantic (Fig. 1):

The top three countries landing swordfish were Spain, United States, and Canada, and the top producers of tunas were Japan, Taipei, and United States. The following countries landed less than 1,800 mt of swordfish: Taipei, Brazil, NEI, Trinidad, Morocco, Cyprus, Venezuela, Korea, Mexico, Cuba, United Kingdom, Bermuda, Peoples Republic of China, and Grenada. The following countries landed less than 1,800 mt of tunas: Canada, Belize, Grenada, Brazil, Peoples Republic of China, Cuba, France, and Ireland.

Tropics (Fig. 2):

The top producers of swordfish were Spain, Japan, and Taipei, and the top producers of tunas were Japan, Taipei, and Honduras. The following countries landed less than 2,500 mt of swordfish: Brazil, United States, Korea, Portugal, Cuba, Peoples Republic of China, and Equatorial Guinea. The countries that landed less than 2,500 mt of tunas were Spain, Libya, United States, Cuba, Venezuela, Peoples Republic of China, USSR, Portugal, and Equatorial Guinea.

Mediterranean Sea (Fig. 3):

The top producers of swordfish were Italy, Greece, and Morocco, and the top producers of tunas were Italy, NEI (Not Elsewhere Included), and Spain. Those countries reporting less than 500 mt for swordfish were Malta and Japan, and those countries reporting less than 500 mt of tunas were NEI, Cyprus, Peoples Republic of China, Croatia, and Taipei.

The U.S. portions of the total catches are shown in Figures 4 and 5. It is unclear how well yields of one target species will reflect the relative efficiency of a fleet at catching other species, *e.g*. sea turtles. To examine the indications of U.S. fishing efficiency relative to swordfish and tunas, sample CPUE data from ICCAT were examined for 1990-1996. Catch in that data set were primarily recorded in number of fish. The sampled CPUE data (Figures 6-9) indicates that the U.S. accounted for less than 10% (5%-8%) of the sampled hooks fished in the North Atlantic Ocean. If total numbers of hooks (effort) data were available for all nations, it is expected that the U.S. proportion would be lower. This is because a large fraction of the total U.S. pelagic longline effort is included in the sample, while other nations do not report sampled effort and, of those nations that do report samples, it is not known what fraction of fishing effort is actually reported.

In the North Atlantic, the U.S. fleet was roughly 4-8 times more efficient (proportion catch/proportion hooks) than the other fleets at catching swordfish and about 2-3 times more efficient at catching tunas (Figure 6). There was less information on U.S. fishing in the Tropics (Figure 8) because of less effort, but the calculated efficiencies were generally lower for swordfish (from equally efficient to 12 times more efficient with all but 2 years at roughly equal efficiency to 3 times more efficient.), and lower for tunas (about 1.5-2 as efficient). Examination of a subsection of the North Atlantic (Caribbean) revealed markedly different efficiencies. The U.S. fleet was about 3-5 times more efficient at catching swordfish, but less efficient than other sampled fleets at catching tunas (from about 0.1 to about 0.3 times as efficient). In summary, it appears that:

1. The U.S. longline fleet accounts for a relatively small proportion of total hooks fished in the Atlantic Ocean.

2. The relative fishing efficiency of the U.S. fleet at catching swordfish and tunas varies spatially, and probably temporally.

3. There likely are differences that occur in fishing efficiencies at catching non-target species (including sea turtles) between fleets both temporally and spatially.

Literature Cited

Argano, R., R. Basso, M. Cocco, and G. Gerosa. 1992. Nouvi dati sugli spostamenti di tartaruga marine comune (*Caretta caretta*) in Mediterraneo. Bollettino Musel Istitiuti Universita Genova 56-57:137-163.

Barret, I., O. Soas-Nishizaki, and N. Bartoo, eds. 1998. Biology and fisheries of swordfish, *Ziphias gladius*. U.S. Department of Commerce NOAA Technical Report NMFS-142, 276 pp.

Brewster-Geisz, K., D.M. Crory, and W.B. Folsom. 1997. World swordfish fisheries. An analysis of swordfish fisheries, market trends, and trade patterns. Past-Present-Future. Vol. V, North America. NOAA Technical Memorandum NMFS-F/SPO-28, 136 pp.

Carocci, F. and J. Majkowski. 1998. Atlas of tuna and billfish catches. CD-ROM version 1.0. FAO, Rome, Italy.

Cramer, J. and H. Adams. 2000. Large pelagic logbook newsletter – 1998. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-433, 25 pp.

De Metrio, G., G. Petrosino, A. Matarrese, A. Tursi, and C. Montanaro. 1983. Importance of fishery activities with drift lines on the populations of *Caretta caretta* (L.) and *Dermochelys coriacea* (L.) (Reptilia, Testudines), in the Gulf of Taranto. Oebalia 1983, Vol. IX (N.S.):43-53.

Folsom, W.B. 1997*a*. World swordfish fisheries, market trends, and trade patterns. Past-Present-Future. Vol. II, Africa and the Middle East. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-24, 235 pp.

Folsom, W.B. 1997*b*. World swordfish fisheries. An analysis of swordfish fisheries, market trends, and trade patterns. Past-Present-Future. Vol. VI, Western Europe. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-29, 324 pp.

Folsom, W.B., D.M. Weidner, and M.R. Wildman. 1997. World swordfish fisheries. An analysis of swordfish fisheries, market trends, and trade patterns. Past-Present-Future. Vol. I. Executive Overview. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-23, 53 pp.

Gramentz, D. 1989. Marine turtles in the central Mediterranean Sea. Centro 1(4): 41-56.

Lee, D.W. and C. Brown. 1998. SEFSC pelagic observer program data summary for 1992-1996. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-408, 21 pp.

Weidner, D.M. and F. Arocha. 1999. World swordfish fisheries. An analysis of swordfish fisheries, market trends, and trade patterns. Past-Present-Future. Vol. IV, Latin America. Part A, South America. Section 2, Atlantic. Segment B, Brazil. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-35:237-628.

Weidner, D.M., F.J Fontes, and J.A. Serrano. 1999*a*. World swordfish fisheries. An analysis of swordfish fisheries, market trends, and trade patterns. Past-Present-Future. Vol. IV, Latin America. Part A, South America. Section 2, Atlantic. Segment C, Uruguay, Paraguay. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-36:631-916.

Weidner, D.M., F. Arocha, F.J. Fontes, W.J. Folsom, J.A. Serrano, and D.R. Starks. 1999*b*. World swordfish fisheries. An analysis of swordfish fisheries, market trends, and trade patterns. Past- Present- Future. Vol. IV, Latin America. Part A, South America. Sec. 2, Atlantic. Segment A, Venezuela, Guyana, Suriname, and French Guiana. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-34, 235 pp.

Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. Fishery Bulletin 97:200-211.

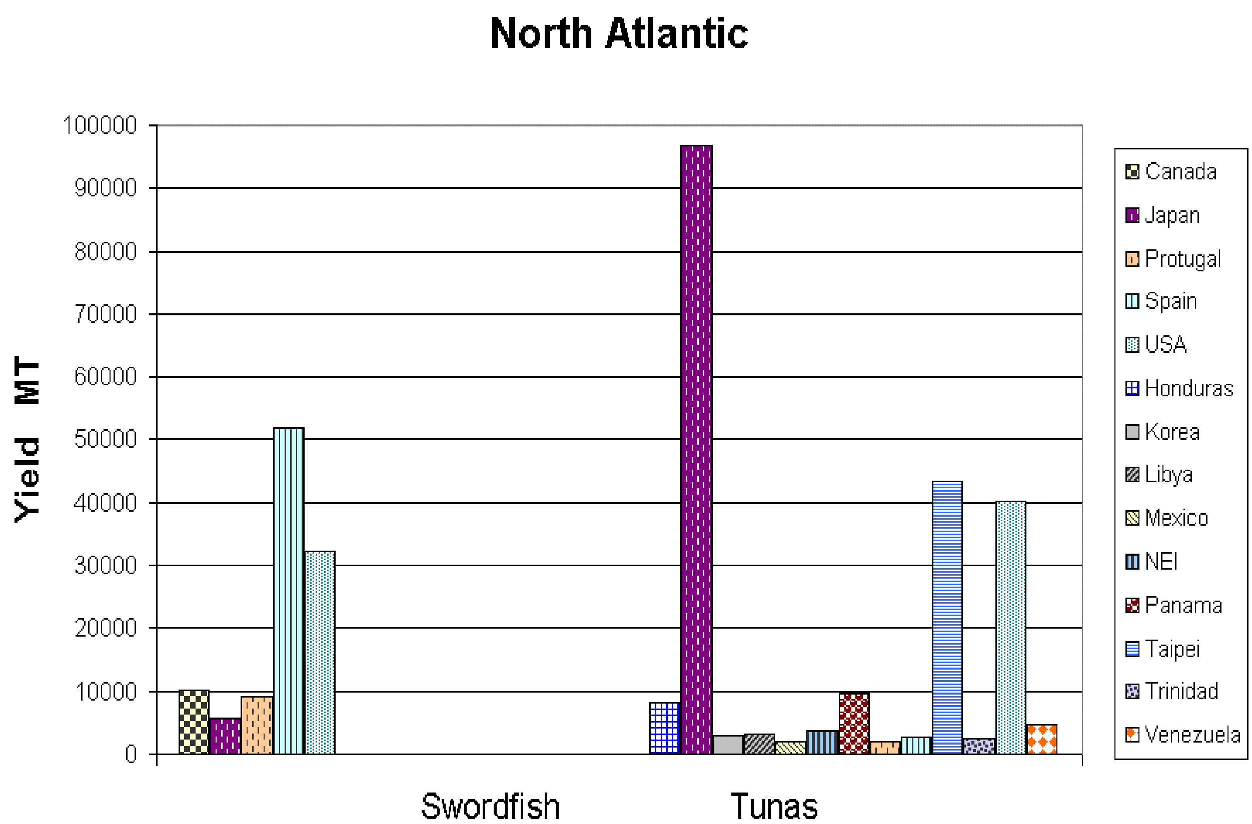


Figure 1. Yield of swordfish and tunas from the North Atlantic Ocean (Data from Carocci and Majkowski 1998).

Nations with yields <1800 MT were not included in this graph. Listed in descending order for swordfish these include Taipei, Brazil, NEI, Trinidad, Morocco, Cyprus, Venezuela, Korea, Mexico, Cuba, UK, Bermuda, Peoples Republic of China, and Grenada. For tunas these include Canada, Belize, Grenada, Brazil, Peoples Republic of China, Cuba, France, and Ireland.

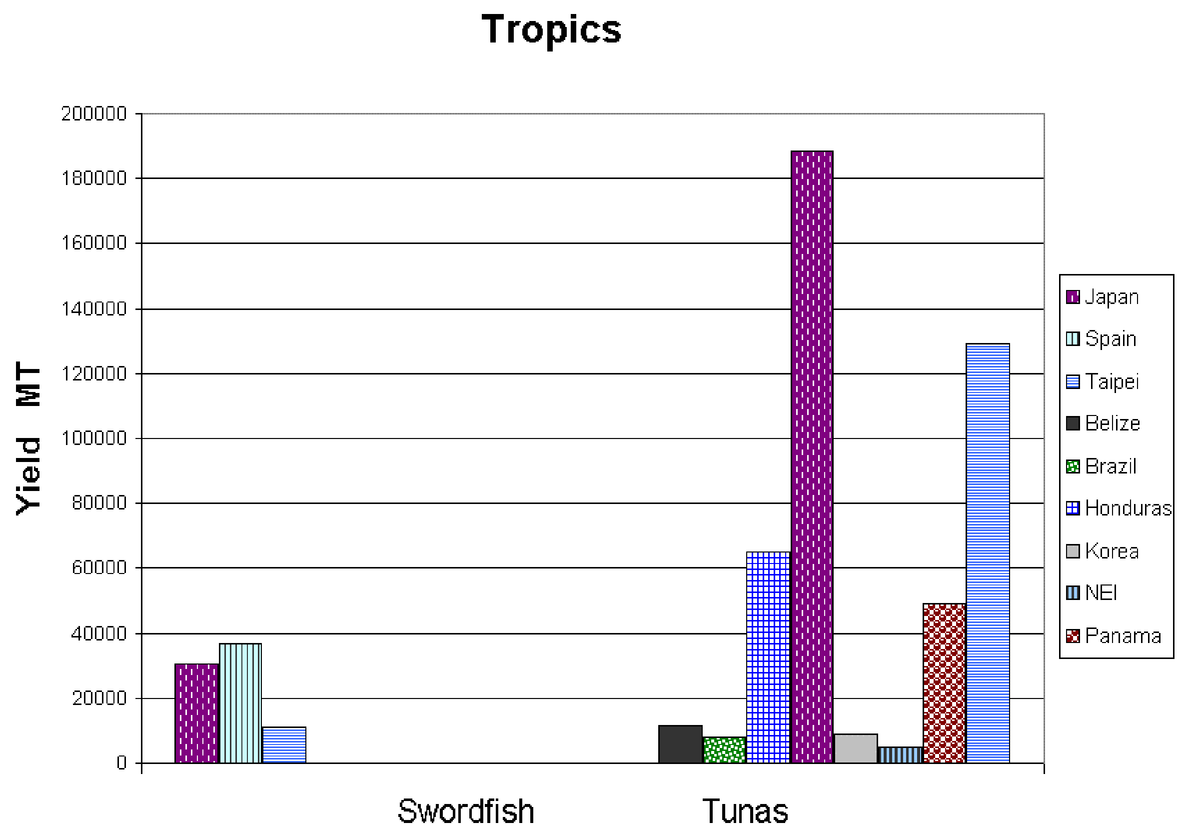


Figure 2. Yield of swordfish and tunas from the Tropical Atlantic Ocean (Data from Carocci and Majkowski 1998).

Nations with yields < 2500 MT were not included in this graph. Listed in descending order for swordfish these include Brazil, U.S.A, Korea, Portugal, Cuba, Peoples Republic of China, and Equatorial Guinea. For tunas these include Spain, Libya, U.S.A, Cuba, Venezuela, Peoples Republic of China, USSR, Portugal, and Equatorial Guinea.

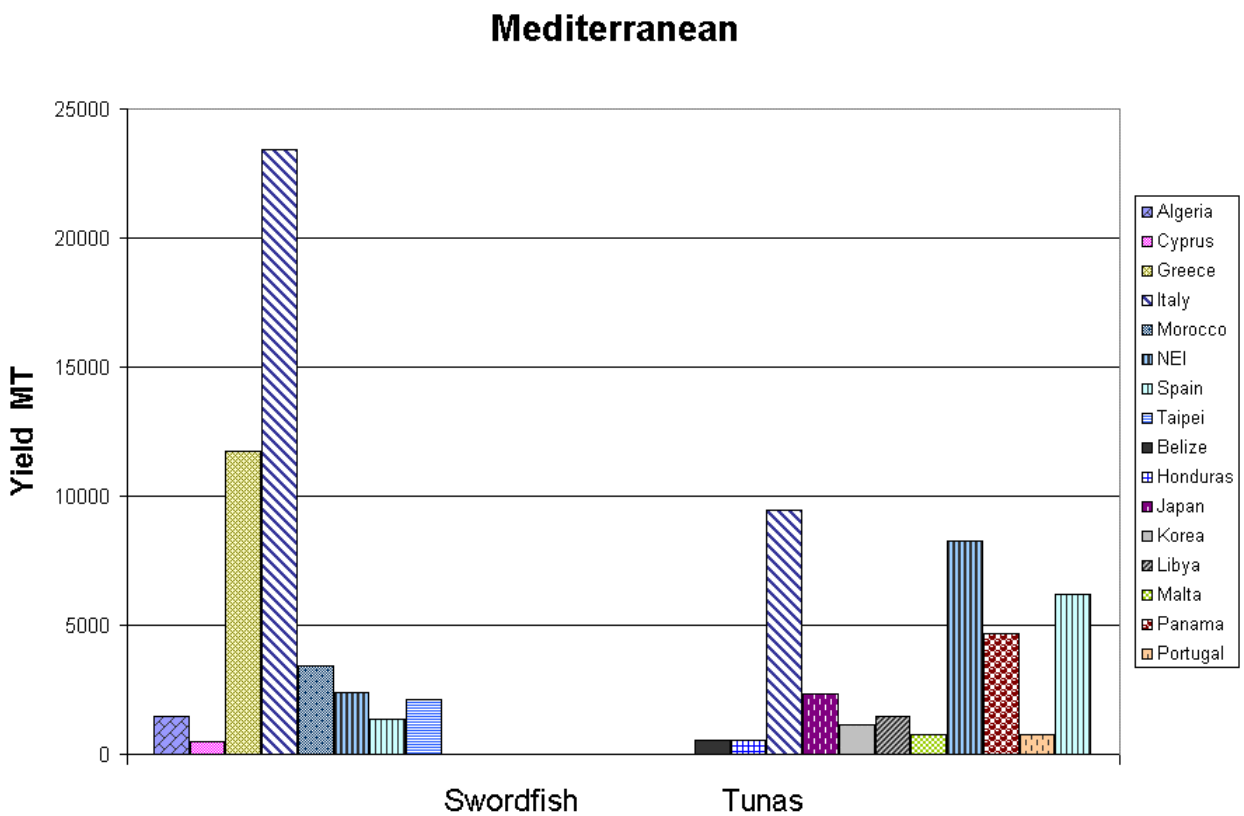


Figure 3. Yield of swordfish and tunas from the Mediterranean Sea (Data from Carocci and Majkowski 1998).

Nations with yields < 500 MT were not included in this graph. Listed in descending order for swordfish these include Malta and Japan. For tunas these include NEI, Cyprus, Peoples Republic of China, Croatia, and Taipei.

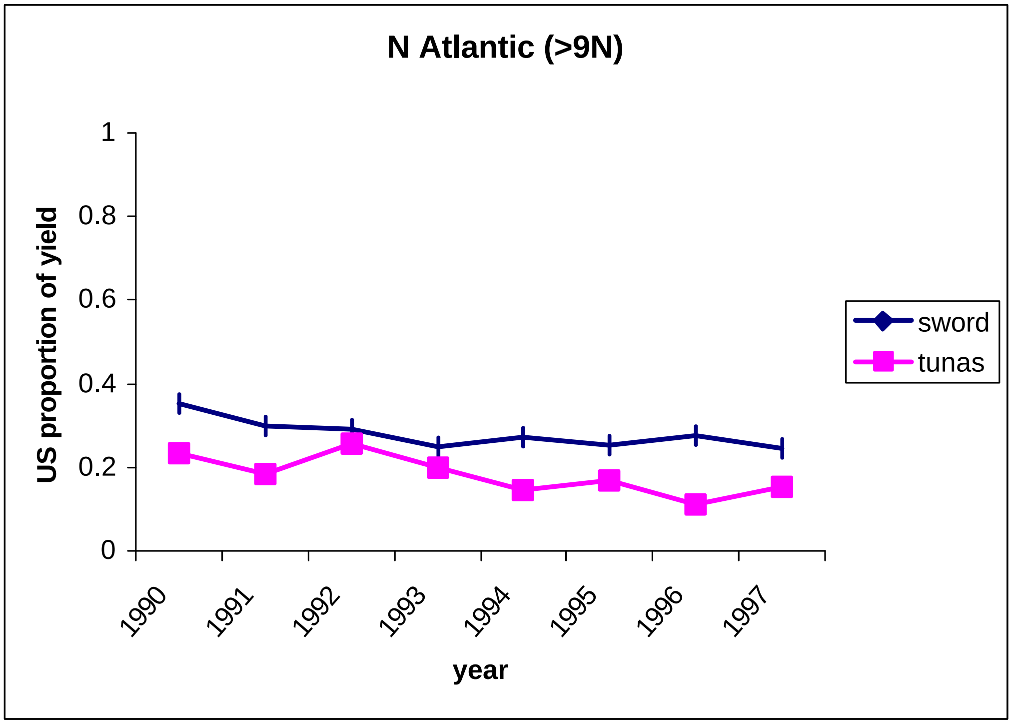


Figure 4. Proportion of the total yield of swordfish and tunas taken from the North Atlantic by the U.S. pelagic longline fleet.

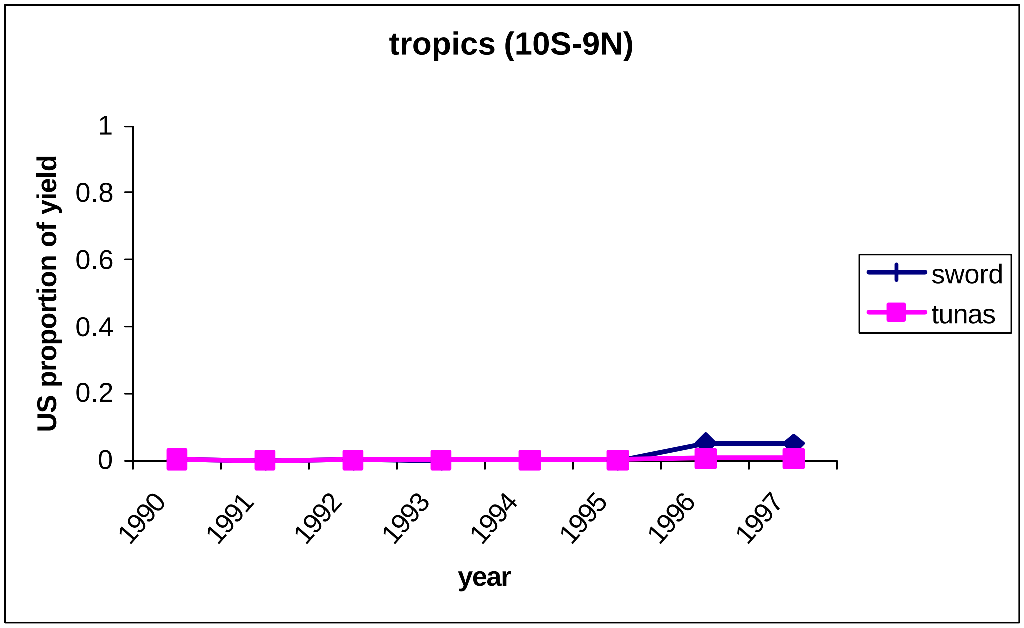


Figure 5. Proportion of the total yield of swordfish and tunas taken from the Tropical Atlantic by the U.S. pelagic longline fleet.

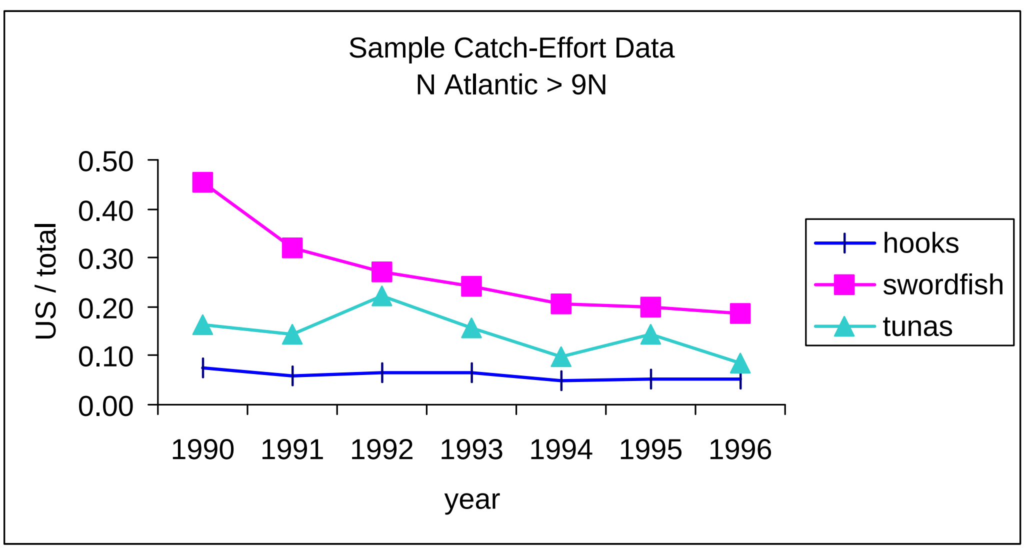


Figure 6. Proportion of total hooks, swordfish and tunas (in numbers of fish) in ICCAT catch/effort samples from the North Atlantic accounted for by the U.S. pelagic longline fleet.

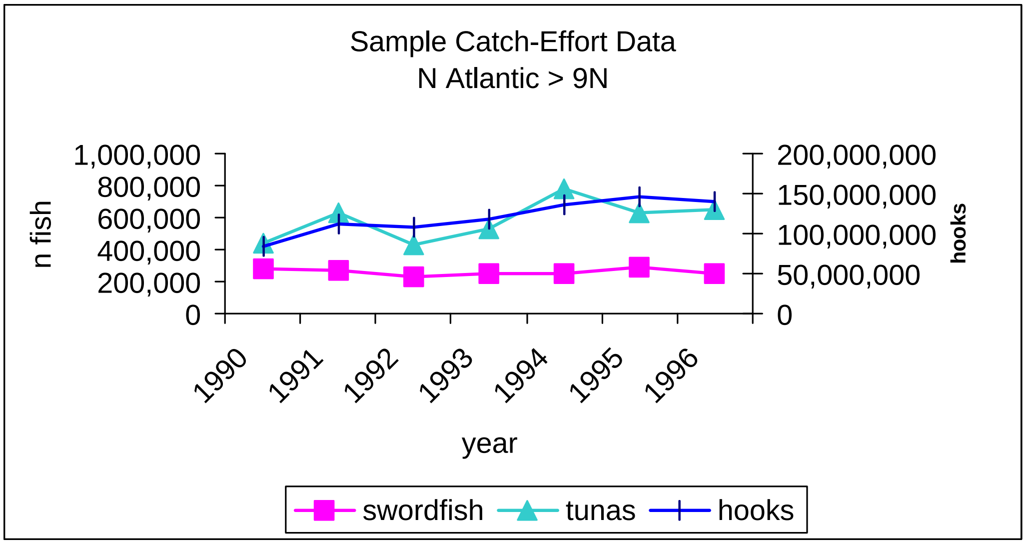


Figure 7. Numbers of hooks, swordfish and tunas, from ICCAT catch/effort samples from pelagic longliners in the North Atlantic.

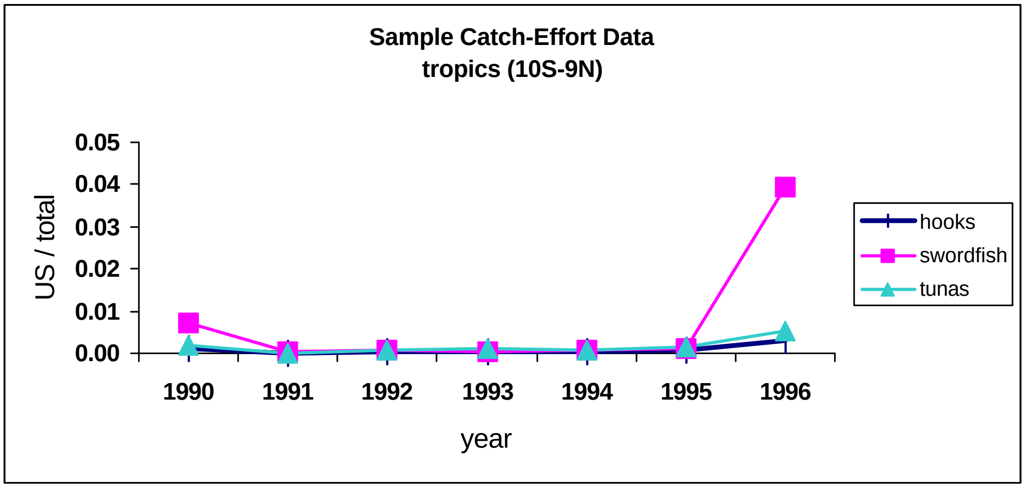


Figure 8. Proportion of total hooks, swordfish and tunas, (in number of fish) in ICCAT catch/effort samples from the Tropical Atlantic accounted for by the U.S. pelagic longline fleet.

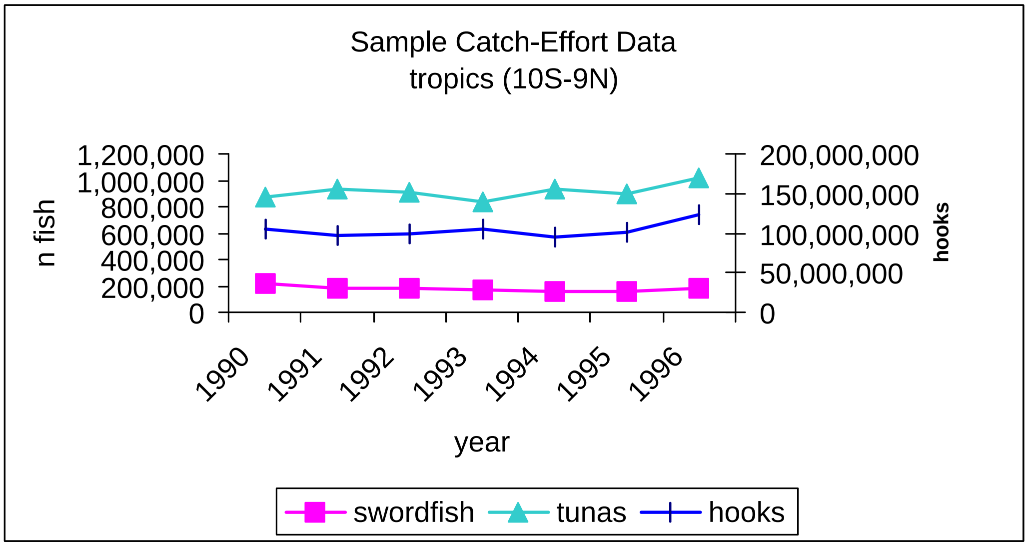


Figure 9. Numbers of hooks, swordfish and tunas, recorded in ICCAT catch/effort samples from pelagic longliners in the Tropical Atlantic.

CHAPTER 2. ANALYSIS OF MARINE TURTLE BYCATCH BY THE U.S. ATLANTIC PELAGIC LONGLINE FLEET

Cynthia Yeung

Introduction

The U.S. pelagic longline fleet targeting tuna (*Thunnus spp.*) and swordfish (*Xiphias gladius*) in the North Atlantic (including the Caribbean Sea and the Gulf of Mexico) occasionally interacts with marine turtles (Berkeley *et al*. 1981; Hoey and Bertolino 1988). Turtles are hooked or entangled, resulting inevitably in injury or in extreme cases, death. In this paper, the bycatch of marine turtle by the said fleet in 1992-1999 is estimated and factors that influenced bycatch rates are examined.

The bycatch of marine turtles by the U.S. pelagic longline fishery in 1992-1997 and 1998 has been estimated previously using the delta-lognormal method (Pennington 1983). The bycatch estimates were based on a random sample of the longline fishing vessels on which trained observers were placed. Due to the random nature of the sampling and relatively low sampling fractions, not all time-area strata have been observed. Thus, pooling observations between strata is necessary to estimate fleet-wide bycatch. In several previous reports (Johnson et al. 1999; Yeung 1999*a*,*b*), the robustness of the bycatch estimates from several different pooling schemes for bycatch rates were examined, from the lowest level of pooling (stratified estimates by year-quarter-grouped fishing area (NAREA)) to the highest level of pooling (stratified estimates by year-large fishing region (MAREA), where MAREA is the result of pooling NAREA). For those analyses, however, no estimates were made for strata that remained without observed effort after pooling, even though there was unobserved effort reported by the fishing fleet.

Here, the delta-lognormal method is again used to obtain estimates of the mean and variance of longline turtle bycatch for 1992-1999, but a criterion of a minimum number of observed sets (N_{min}) is used to determine the level of pooling from which to estimate bycatch rates for a time-area stratum. By this approach, estimates are made for all strata. This method was applied effectively to the estimation of tuna and swordfish catches by the U.S. Atlantic pelagic longline fleet (Brown, in press). A preliminary report on the estimated bycatch of marine turtles and mammals based on this method has been prepared earlier (Yeung *et al*. 2000[4]). According to this pooling method, the levels of 1) quarter, 2) year and 3) NAREA are successively pooled in that order until the criterion is met. The order of pooling followed the increasing order of significance of these three factors in an ANOVA model on bycatch rate. With this dynamic pooling method, if observer effort is adequate according to N_{min} in a basic year-quarter-NAREA

[4] Yeung, C., S. Epperly, and C. A. Brown. 2000. Preliminary revised estimates of marine mammal and marine turtle bycatch by the U.S. Atlantic pelagic longline fleet, 1992-1999 National Marine Fisheries Service Miami Laboratory PRD Contribution Number 99/00-13, SEFSC Miami, Fla. Revised tables with estimates through 1999 are in Appendix 3 and data on turtles observed in 1999 and 2000 are in Appendix 3 and turtles and observers comments are detailed in Appendix 4.

stratum, then an estimate is obtained based on the observed bycatch rate of the stratum and the data independence of the basic stratum is maintained; otherwise, bycatch rate will be extrapolated from some other strata that ideally should have similar characteristics. The main objective is to avoid leaving empty cells with no estimates available. Results from this delta-lognormal-N_{min} method are compared with an alternative estimation method using generalized linear modeling (GLM) with the delta approach (Stefánsson 1996). GLM and regression trees methods are also used to shed light on the factors that influence the bycatch rates of marine turtles.

Methods

Data Sets

Systematic sampling by scientific observers on board U.S. pelagic longline vessels in the Atlantic permitted to land and sell swordfish was implemented in 1992, under the mandate of the 1991 amendments to the U.S. Fishery Management Plan (FMP) for Atlantic Swordfish. The estimated bycatch rates of marine turtles in the pelagic longline fishery are based on observer sampling data collected and maintained by the NMFS Southeast Fisheries Science Center (SEFSC) (Lee and Brown 1998).

The Atlantic Large Pelagic Logbook database, also maintained by the SEFSC, contains daily fishing effort reported by all U.S. Atlantic longline vessels landing swordfish and tuna as required under the Atlantic Swordfish Fishery Management Plan since 1986 (Cramer and Adams 2000). Not withstanding errors due to misreporting, fishery-reported effort from the logbook (reported effort) is taken to represent the actual permitted effort expended by the U.S. pelagic longline fleet in the North Atlantic.

Observed bycatch rates are raised to the amount of reported effort in the logbook for estimating total bycatch. The unit of effort is an individual set (gear deployment) that fished at least 100 hooks and included tunas and/or swordfish among the declared target species – application of this criterion results in reported effort about 10% higher compared to effort reported to target only tunas and/or swordfish. Effort is grouped by fishing area, the smallest area grouping is AREA (Fig. 1). The eleven AREAs are further grouped into six NAREAs, which are the areal strata used here for bycatch analysis. Effort missing location data are proportionally distributed among AREAs based on the distribution of known set locations for the pertinent year and calendar quarter. Effort missing calendar quarter data within a fishing area are proportionally distributed among quarters based on the distribution of effort across quarters within the area. Only aabout 1% of the effort data are missing time and/or area information.

Apart from systematic revisions to the data sets since the previous reports that may have led to changes, the effort data are treated slightly differently compared to previous reports. The fishing location was previously defined by where the longline was set to begin fishing, but here is defined by the location where the haul-back of the longline began after fishing. Also, the parts of a set that were interrupted (*e.g.*, when the main line was severed) previously were defined as separate sets, but now are combined as a single set.

In addition to the essential time-area information on the fishing set, gear and effort information are also recorded on observed trips. Some gear and effort characteristics are potentially influential on bycatch of marine turtles (Kleiber 2000[5]). A subset of these gear-effort variables (Table 1) is selected for exploratory analysis, including GLM and regression tree analysis conducted with the S-PLUS software (MathSoft 1997), to identify significant factors that may be incorporated into models for predicting bycatch rates.

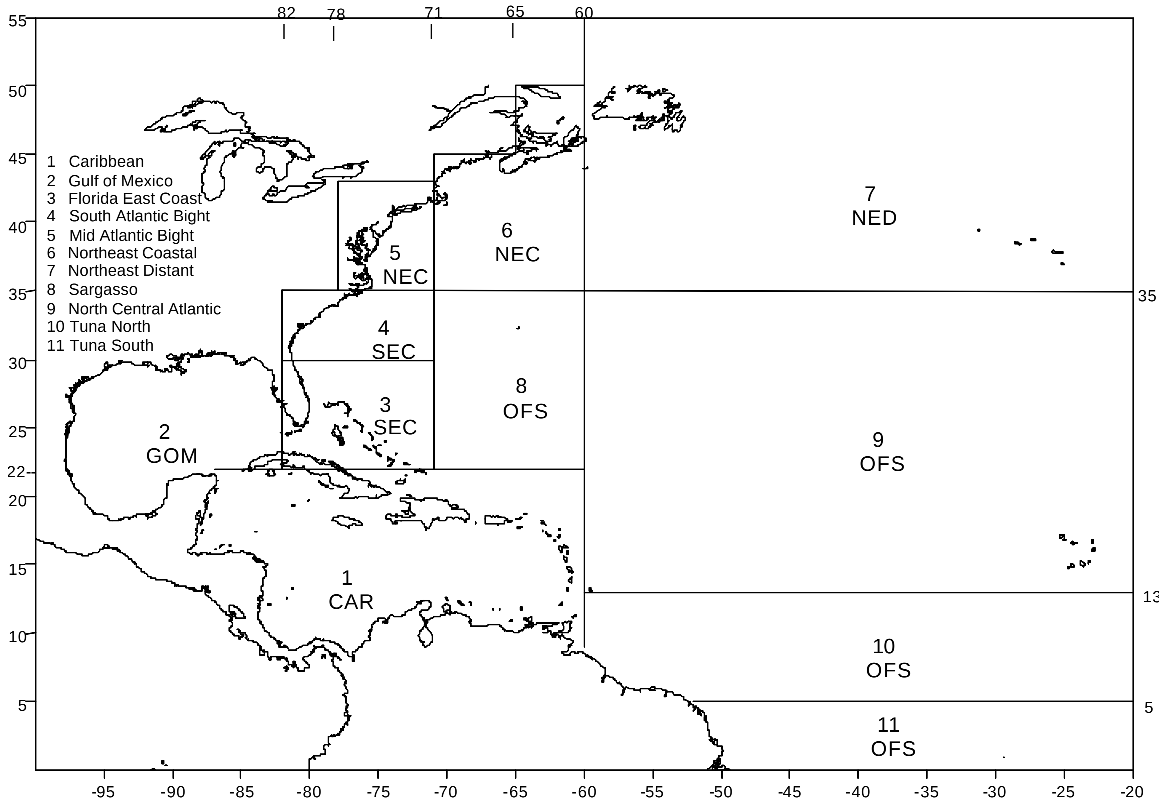


Figure 1. The eleven geographical areas (AREA) used to classify U.S. Atlantic pelagic longline fishing effort. AREAs are further arranged into 6 grouped strata (NAREA): 1) Southeast Coastal (SEC) = AREAs 3 and 4; 2) Northeast Coastal (NEC) = AREAs 5 and 6; 3) the Offshore South (OFS) = AREAs 8, 9, 10, and 11. Each one of the AREAs: 4) Caribbean (CAR), 5) Gulf of Mexico (GOM), and 6) Northeast Distant (NED), is also a distinct NAREA.

[5] Kleiber, P. 2000. Working group on reducing turtle bycatch in longline fisheries. Report of First Meeting. September 12 –13, Los Angeles, U.S.A. Unpublished report. National Marine Fisheries Service, SWFSC, Honolulu, Hawaii, 11 pp.

Table 1. Time-area and gear-effort variables considered for predictors in the GLM approach. Strikeover variables are omitted from consideration because of any combination of the following reasons: 1) insufficient data, 2) collinearity with other selected variables, 3) insignificant effect on the catch rate in exploratory analysis.

Variable type: E=effort G=gear C=catch c=categorical q=quantitative

	VARIABLE	**DESCRIPTION**	
	set		
Cc	year		
Cc	area		
Cc	month		
	target catch		
Cq	~~srkn~~	number of shark caught	
Cq	swfn	number of swordfish caught	
Cq	~~tunn~~	number of tuna caught	
	longline length		
Eq	~~MAINLEN~~	mainline length (nm)	
Eq	HOOKSET	number of hooks set	
Eq	SOAKDUR	soak duration (hrs)	
Eq	~~FLOATNUM~~	number of floats used	
Eq	LITENUM	number of light sticks used	
Eq	~~RATLRNUM~~	number of rattlers used	
Eq	~~SRFLTNUM~~	number of surface lights used	
Gq	~~HKSBFLT~~	max hooks between floats	
Gq	~~GANGDIS~~	gangion distance	
Gq	~~GANGCNT~~	gangion count	
	longline depth		
Gq	GANGLEN	gangion length (ft)	
Gq	~~LEADLEN~~	leader length (in)	
Eq	~~HKDEPMIN~~	max hook depth (fm)	
Eq	~~HKDEPMAX~~	min hook depth (fm)	
	bait		
Eq	~~BAITNUM~~		
Ec	BAITKND	01-Mackerel, 02-Herring, 03-Squid, 04-Artificial, 05-Sardine, 06-Scad, 99-Other	
Ec	~~BAITTYP~~	1-Whole, 2-Cut, 3-Live, 9-Other	
Ec	BAITCON	1-Frozen, 2-Semi-frozen, 3-Thawed, 4-Fresh, 5-Salted, 9-Other	
	temperature		
Eq	TEMP	mean of begin/end set/haul temp (F)	
	hook		
Gc	~~HKBRAND~~	hook brand	
Gc	HKPATRN	hook pattern	
~~Gc~~	~~HKSIZE~~	hook size	
	auxiliaries		
Gc	~~LITECOLR~~	light stick color	
Gc	GANGCOLR	gangion color	
Gc	LEAD	leader used?	
Ec	~~LITESTX~~	light sticks used?	1=yes, 2=no
Ec	~~SRFLITE~~	surface lights used?	
Ec	~~RATLR~~	rattlers used?	

Catch Estimation

Delta lognormal bycatch estimation with pooling criterion N_{min}=5

The delta-distribution or delta-lognormal method (Pennington 1983) provides minimum variance unbiased (MVU) estimators of means and variances for sampling data that contain many zero observations and the non-zero observations are lognormally distributed. The sample mean as an estimator in that case may overestimate the population mean, and the variance of the sample mean can be very large. The robustness of the delta-lognormal estimators depends on the assumption of lognormal distribution of the non-zero (positive) observations (Myers and Pepin 1990; Syrjala 2000).

The delta-lognormal method is a possible approach for estimating the observed bycatch rates of turtles. The observation unit is a longline fishing set, and the observed response is the bycatch rate = number caught per 1000 hooks (*cph*). A quantile-quantile plot of the distribution function of the ln-transformed positive bycatch rates (*lcph*:{*lcph*>0}) for all species and the normal distribution shows departures from linearity at the tail ends that is not unexpected of small to moderate sample sizes (Fig. 2a), and it appears unlikely that any other parametric distribution will fit the sample data substantially better (Fig. 2b). The lognormal distribution may thus be an “acceptable” approximation for all practical purposes. The same trends apply whether for all species combined (n=429), loggerheads (n=198), or leatherbacks (n=201). The rare turtle species in the bycatch - green, hawksbill, and Kemp’s Ridley, cannot be tested separately because of the extremely low sample sizes (total n=30).

a b

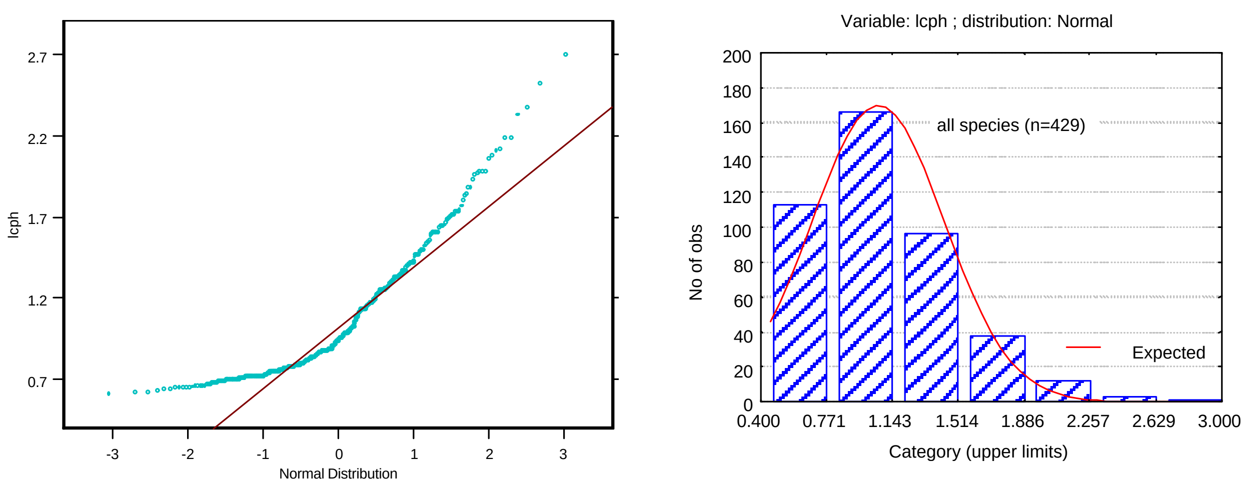


Figure 2. a) Quantile-quantile plot of the distribution function of observed ln-transformed positive bycatch rates {*lcph*>0} for all species and the normal distribution; b) frequency comparison of the same observed data and the fitted distribution.

The bycatch estimates are constructed as a product of the proportion of positive sets and the average bycatch rate of the positive sets (Pennington 1983). Estimated bycatch for a basic time-area stratum (year-quarter-NAREA), C, is estimated as:

$$C = H\frac{m_c}{N}e^{L}G_{m_c}(\frac{s_L^2}{2}), \tag{1}$$

H = reported number of hooks set, divided by 1000,
m_c= number of sets in which a non-zero bycatch was observed (positive sets),
N = total number of sets observed,
$L = \sum L_i / m_c$,

$s_L^2 = \frac{\sum (L_i - L)^2}{m_c - 1}$, where

L_i = ln(bycatch$_i$/hooks$_i$ ×1000) = $lcph_i$, ln-transformed bycatch rate for the i^{th} positive set, i=1,...,m_c,
L = mean of L_i,
s_L^2 = sample variance of L_i;

and the function $G_{m_c}(\frac{s_L^2}{2})$ is:

$$G_{m_c}(\frac{s_L^2}{2}) = 1 + \frac{m_c - 1}{m_c}(\frac{s_L^2}{2}) + \sum_{j=2}^{\infty}\frac{(m_c - 1)^{2j-1}}{m_c^{\,j}(m_c + 1)(m_c + 3)...(m_c + 2j - 3)} \times \frac{(\frac{s_L^2}{2})^j}{j!}. \tag{2}$$

Numerically, the series is computed over j terms, until a convergence criterion of <0.001 change in the function is achieved (usually less than 10 terms are required). The estimate of variance of the bycatch takes the form:

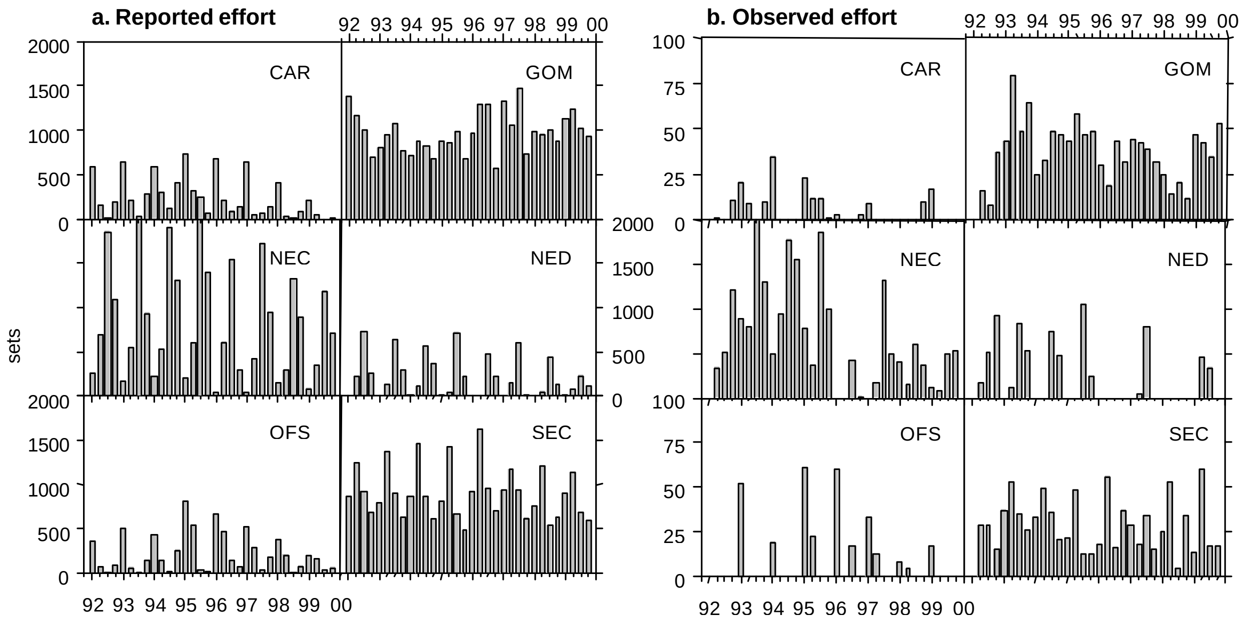
$$V(C) = \frac{m_c}{N}(He^{L})^2[\frac{m_c}{N}G_{m_c}^{\;2}(\frac{s_L^2}{2}) - (\frac{m_c - 1}{N - 1})G_{m_c}(\frac{m_c - 2}{m_c - 1}s_L^2)]. \tag{3}$$

Bycatch estimates by stratum are assumed independent, and the proportion of positive sets (m_c/N) and reported number of hooks (H) are treated as constants within a stratum and thus uncorrelated with the bycatch rate. The coefficient of variation for the stratum-wise estimate of bycatch is:

$$CV = \frac{\sqrt{V(C)}}{C}. \tag{4}$$

In the previous reports (Johnson *et al.* 1999; Yeung 1999*a*; 1999*b*), when there was no observer effort (= fishing set) for a particular analytical stratum, *i.e.*, N=0, the mean bycatch rate L and the proportion of positive sets, m_c/N were not estimated. Thus, no estimate of bycatch was made for the stratum even though there was reported fishing effort (H>0) in the logbook. Quarters lacking observed effort occurred mainly in the NAREAs of CAR, NED, and OFS, all relatively far from the continental U.S. coast (Fig. 1) and where U.S. pelagic longline fishing effort is typically low (Fig. 3). When observed effort is pooled across quarters within a NAREA-year stratum, cells lacking observed effort only occur in OFS in 1992, and NED in 1996 and 1998 (Fig. 3).

Figure 3. Quarterly a) reported sets and b) observed sets by NAREA, 1992-1999.



Pooling allows extrapolation of bycatch rate to a basic time-area stratum that has no observed effort using data from related strata. A possible disadvantage of pooling is that it may smooth out the inherent heterogeneities among time-area strata and distort bycatch patterns and trends. Pooling is therefore applied only when necessary by assessing whether a criterion of a minimum number of observed sets (N_{min}) is met for a basic stratum. To determine the order of factors to pool, the effect of year, quarter, and NAREA on the bycatch rate was evaluated with the ANOVA model

$$L_j = \text{year} + \text{quarter} + \text{NAREA},$$

where $L_j = \ln(\text{bycatch}_j/\text{hooks}_j + 1)$, $j = 1, 2,..., N$ is the bycatch rate (including zeros) in the j^{th} observed set. The model was assessed for 1) all turtle species combined, 2) leatherbacks, and 3) loggerheads. In each case, NAREA is responsible for the greatest model effect, followed by year and then quarter (Table 2). The standard pooling priority order of quarter, year, and NAREA is established according to the increasing order of variance explained attributed to the effect, i.e. pooling similar levels first. Next, a low N_{min} of 5 sets and a high of 30 sets observed are arbitrarily chosen to be tested, emulating what have been used in bluefin tuna assessment (Brown, in press). Both produced bycatch estimates of similar magnitudes, which indicates both criteria resulted in similar amount of pooling (Yeung *et al*. 2000[4]). The criterion of $N_{min} = 5$ was chosen to potentially minimize the necessity to pool in most cases. The stepwise pooling procedure is thus: in the absence of observer data for a stratum, data are first pooled across quarters to obtain a minimum sample size of 5 observed sets. Should the pooling across quarters not suffice to achieve the N_{min}, data are then pooled across years, and if still failing the criterion, data are lastly pooled across NAREAs to obtain an estimate of L and m_c/N, for the stratum. The variance for the bycatch $V(C)$ is then estimated over the pooled stratum.

Table 2. ANOVA of time-area effects on ln-transformed bycatch rate (*lcph*) of marine turtles

Model: *lcph* = year + NAREA + quarter

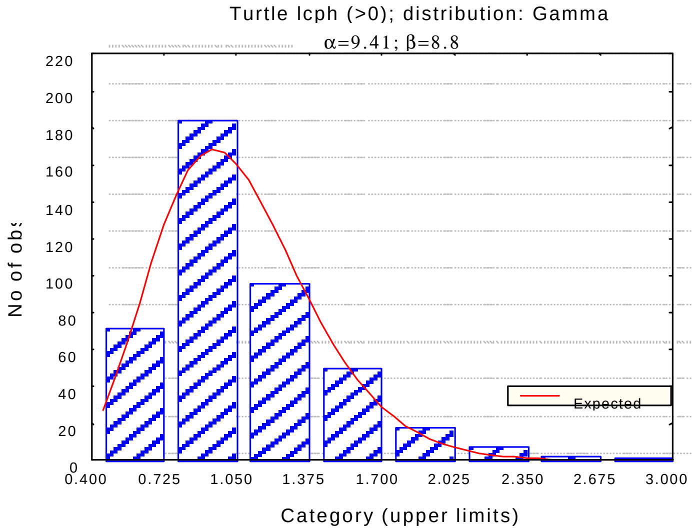
```
         *** Analysis of Variance Model ***
              Type III Sum of Squares
1) All species
            Df Sum of Sq  Mean Sq  F Value      Pr(F)
       yr    7    6.4282  0.91831   9.1049 0.00000000
    narea    5   68.8221 13.76443 136.4712 0.00000000
   quartr    3    1.0619  0.35396   3.5094 0.01465468
Residuals 4016  405.0520  0.10086

2) Leatherback
       yr    7    0.9559 0.136559  2.67591 0.00918291
    narea    5    7.7804 1.556083 30.49174 0.00000000
   quartr    3    0.4050 0.135015  2.64565 0.04747834
Residuals 4016  204.9482 0.051033

3) Loggerhead
       yr    7    5.3014 0.757339 12.78133 0.00000000
    narea    5   28.8476 5.769524 97.37008 0.00000000
   quartr    3    0.4804 0.160132  2.70249 0.04398371
Residuals 4016  237.9623 0.059254
```

Bycatch estimation by delta-GLM approach

There is concern that delta-lognormal estimators are not robust to seemingly small departures of the distribution of the positive observations from lognormal, in which case the delta-lognormal estimators may be positively-biased (Syrjala 2000). For comparison, an alternative method of estimating bycatch is used that combines the delta approach with GLMs to predict bycatch rate from predictor variables. Stefánsson (1996) described this maximum likelihood estimation method that calls for the fitting of a GLM to 0/1 binary observations, and another GLM to the positive observations.

Two models are fitted with the observed bycatch and effort data. The probability of a positive set is modeled as a random response variable, *bcatch*, (= 1 if *lcph*>0, = 0 if *lcph*=0) using a binomial model with a logit link function. The fitted response is the expected probability of a positive set Pr(*bcatch*=1) = *p*. A separate GLM relates the expected bycatch rate of positive sets (*lcph*>0) to the linear predictor by the gamma distribution and a log link function. The gamma distribution fit to the positive bycatch rates (Fig. 4) is similar to lognormal fit (Fig. 2), and models with gamma-log and gaussian-identity link functions produced similar results. The gamma distribution has been suggested to be preferable in fisheries data in some cases where there is a considerable probability of small observations, though the gain may be minor (Stefánsson 1996). It is used here mainly as a comparison with the delta-lognormal distribution. Analysis of deviance is used to evaluate significant predictor variables and select the final models.

Figure 4. Frequency comparison of the observed ln-transformed positive bycatch rate {*lcph*>0} of all turtle species and the fitted gamma distribution (parameters: $\boldsymbol{a}$–shape; $\boldsymbol{b}$-scale).



The fitted $\log_e$-transformed bycatch rate *lcph* from the gamma model is back-transformed by

$$cph = exp(lcph)\text{-}1,$$

where *cph* = bycatch per 1000 hooks = *m*, the expected bycatch rate for positive sets. The estimated overall catch rate at a time-area stratum, $\hat{X}$, is then

$$\hat{X} = pm, \tag{5}$$

where p = expected probability of a positive set from the binomial model. The variance of the estimated overall catch rate is calculated as

$$V(\hat{X}) = p\,s^2 + m^2 p(1\text{-}p) = m^2[p(1+1/\boldsymbol{a})\text{-}p^2], \tag{6}$$

where $\boldsymbol{a}$ = shape parameter and $\boldsymbol{s}^2 = m^2/\ \boldsymbol{a}$ = variance of the estimated gamma function (Stefánsson 1996). The coefficient of variation of the estimate is

$$CV = \frac{\sqrt{V(\hat{X})}}{\hat{X}}$$

Finally, the total estimated bycatch per stratum, $\hat{C}_g$, is calculated as

$$\hat{C}_g = \hat{X} \times H,$$

where H = total reported number of hooks set for the stratum, divided by 1000, as defined in eq. (1) (the subscript g distinguishes the delta-GLM model bycatch estimate from the delta-lognormal catch estimate).

There are no prior assumptions of homogeneity in the structure of zero or non-zero observations in this estimation approach, but a parametric function has to be assumed nonetheless to link the mean and variance of the predicted response to the linear predictor, and thus like the delta-lognormal method it is not distribution-free. In this method, missing cell values are estimated based on factor level averages, an alternative to the pooling used in the delta-lognormal method. The GLM approach can serve to evaluate the effect of different factors on the bycatch rate and incorporate multiple significant factors to model bycatch rate. However, the fit of GLMs can be hampered by unbalanced data structure and missing cells. It may not a superior method to delta-lognormal for sparse data as in this case, but an alternative. Maximum likelihood estimations for GLMs in this analysis are made with available routines in the S-PLUS software (MathSoft 1997).

Results And Discussion

Delta-lognormal bycatch estimates

Reported nominal effort (number of fishing sets) in 1992-1999 shows that fishing effort and trends varied among NAREAs (Fig. 3a). Intra-annually, effort in the northern NAREAs of NEC and NED peaked in the 3rd quarter, and was lowest in the 1st quarter. The reverse annual trend is apparent in the southern NAREAs of OFS and CAR, where effort peaked in the 1st quarter and was lowest in the 3rd quarter. SEC had peak effort in the 2nd quarter, whereas effort in GOM was distributed relatively evenly among quarters. Average effort was highest in GOM, NEC, and SEC in the coastal zone of continental U.S. With the exception of GOM, annual nominal effort was somewhat lower in other NAREAs in recent years. For the coastal NAREAs of GOM, NEC, and SEC, annual observed effort was ≤5% of reported effort, and the quarterly distribution of observed effort approximated the reported trend. The distant NAREAs of CAR, NED, and OFS received more sporadic observer coverage and often none at all (Fig. 3b).

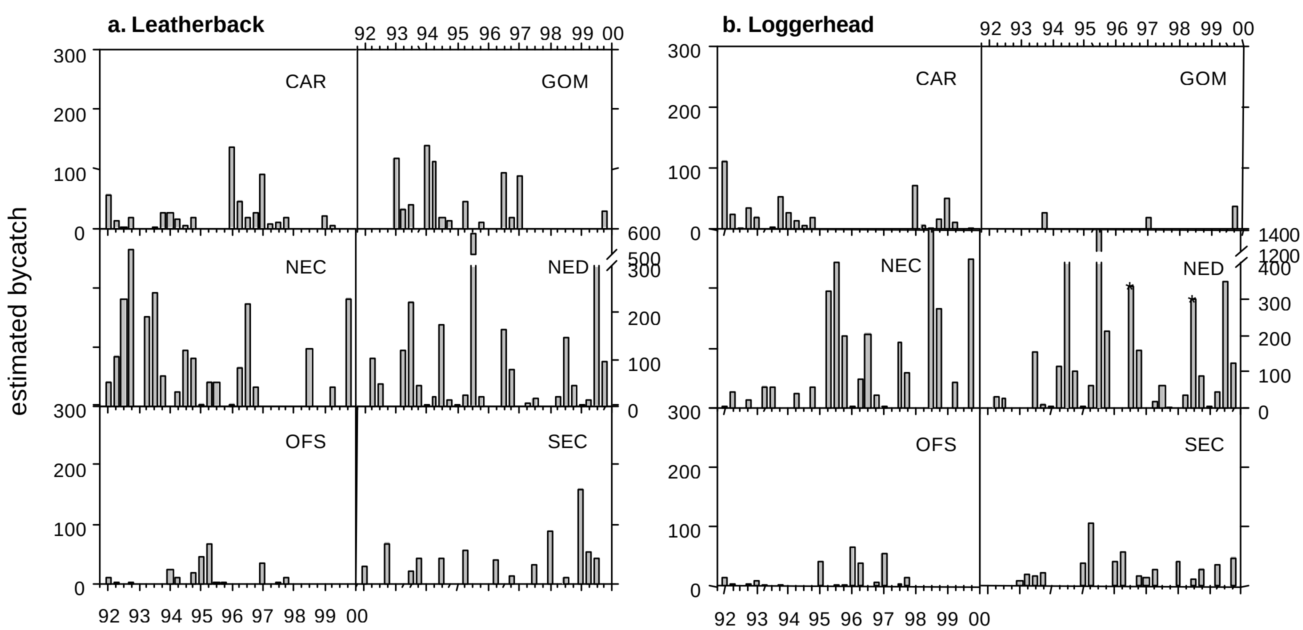
Between 1992-1999, 4032 longline sets were observed, of which 429 (~11%) caught turtles. Most of the turtles caught in the longline were either loggerheads or leatherbacks (Table 3). It is likely that the green, hawksbill, and Kemp's Ridley takes were mis-identifications, and were in fact loggerheads, the most common hard-shelled turtle taken in the fishery (Hoey 1998; Witzell 1999). Of the turtles caught, rarely were any observed to be dead (Table 3), but this does not discount the possibility that those observed to be released alive might have sustained serious or fatal injuries. The results of expanding observed bycatch rates estimated by the delta-lognormal method to the level of reported effort show that estimated mean bycatch ($CV \leq 1$) of loggerheads and leatherbacks were highest in NED and NEC (Fig. 5), and peaked generally in the 3rd quarter in accordance with the quarterly trend in fishing effort. An estimated 100-200 leatherbacks were caught in the peak quarter in the NEC and NED (Fig. 5a). Exceptionally high estimated bycatch of leatherbacks occurred in NEC 1992 (265, CV=0.28), NED 1995 (580, 0.17) and NED 1999 (384, 0.31).

Estimated mean bycatch of loggerheads were generally higher in NED than NEC (Fig. 5b). High bycatch years in NEC were 1995, 1998, and 1999 with 200-300 loggerheads estimated caught in the 3rd quarter. For NED, estimated mean bycatch of loggerheads exceeded 300 in the 3rd quarter of 1994-1996, and 1998-1999 - extreme highs occurred in 1994 (1001, 0.17) and 1995 (1413, 0.2). Note that in 1996 and 1998 there was no observed effort in NED (Fig. 3), therefore the bycatch estimates were based on pooled bycatch rates for all the other years combined. Considering that the reported effort in NED was a factor of 3-4 lower than in NEC, the comparable bycatch estimates between the two areas distinguish NED as the area of highest catch rates of leatherbacks and loggerheads.

Table 3. Numbers and species of marine turtles caught in longline sets observed between 1992-1999. The number observed as dead is a subset of the total number caught.

species	caught	dead	sets
loggerhead	355	4	198
leatherback	263	1	201
green	15	2	11
hawksbill	3	0	3
Kemp's Ridley	2	0	2
unidentified	14	0	14

Figure 5. Estimated quarterly bycatch of a) leatherback and b) loggerhead turtles by the delta-lognormal method. The asterisks in loggerhead-NED indicate where there was no actual observed effort for the quarter. Note change in y-axis scale for NED.



Bycatch Factors

Of the available gear-effort factors in the observer data set, many were eliminated from consideration for predictors of bycatch rate because of too much missing data, collinearity with other predictors, or having insignificant effect on the bycatch rate. The remaining subset of factors (Table 1) was evaluated closely and further screened before entering GLM and regression tree models. The time-area factors were analyzed in greater detail as month and AREA instead of as the quarter and NAREA factors that were actually used in bycatch estimation.

In swordfish longlining, the use of light sticks is standard and has a significant positive effect on the turtle bycatch rate (Witzell 1999). Seventy percent of the observed sets used light sticks. The number of light sticks used in a set (LITENUM) is significantly correlated with the bycatch rate, as well as with other variables such as the number of surface lights, rattlers, floats, mainline length, and gangion distance. Obviously, the number of light sticks used is a function of the length of the longline set. However, the number of hooks set (HOOKSET), hooks between floats (HKSBFLT), and soak duration (SOAKDUR) have negative correlations with the number of light sticks. HKSBFLT can be dropped since it is highly correlated HOOKSET. LITENUM, HOOKSET, and SOAKDUR in the "longline length" class of factors (Table 1) are retained for further analysis.

Other significant factors retained are gangion length (GANGLEN), which represents the class of depth-related factors, hook pattern (HKPATRN), the condition of the bait (BAITCON), and the kind of bait (BAITKND). Of the miscellaneous auxiliary factors in Table 1, those that are significant and are not correlated with other already selected factors are gangion color (GANGCOLR) and whether leaders were used (LEAD). The bycatch rate of turtles (*lcph*) is highly correlated with the numbers of swordfish caught (swfn) ($r=0.30$, $Pr<0.0001$). The numbers of sharks (srkn) and tunas caught (tunn) are also significantly correlated with swfn (srkn: $r=0.19$, $Pr<0.0001$; tunn: $r= -0.15$, $Pr<0.0001$), but their correlations with *lcph* are not as strong as that of swfn. The reduced subset of factors is shown in Table 1 as the ones that are not strikeouts.

An initial GLM with bycatch rate as the response was fitted using the reduced subset of factors with no interaction terms (Table 4a). The time-area factors of year, month, AREA, with their two-factor interactions, and the significant gear-effort factors of BAITCON, swfn, HKPATRN, and LEAD from the initial GLM are retained for input into another GLM (Table 4b). In the second GLM, only swfn among the gear-effort factors remains significant, as are all time-area factors and their interactions (Table 4b).

Due to the unbalanced nature of the data and the sparse observations particularly of gear-effort variables, GLM results could be somewhat misleading. Regression tree modeling is a robust and flexible method, and can handle nonlinear relationships, high order interactions, and missing values (De'ath and Fabricus 2000). It gives visual and easily interpretable results directly on the levels of the factors. It is thus applied to the reduced subset of factor (Table 1) for another attempt at identifying key factors influencing turtle bycatch rates.

The resultant full regression tree model (size = 96 terminal nodes) is of *lcph* for all turtle species combined using the reduced subset of factors in Table 1. The first four nodes are based on the factors AREA, year, and surface temperature (temp), which account for the largest proportional reduction (~30%) in deviance (Fig. 6a). Subsequent branching only reduces small proportions of deviance at a high cost of model complexity. Compare to the full tree of 96 nodes, the pruned tree of 4 nodes only has an increase of residual mean deviance of +0.029 (Fig. 6). The pruned tree in Fig. 6b identifies the terminal nodes and their respective fitted response (*lcph*). The length of the vertical branch is roughly proportional to the deviance explained by the node from which it is grown. The first and most important split is between NED (g) to the right branch and the other AREAs to the left. The second split is among years within NED – between

1992, 1993, 1997 to the left and 1994, 1995, 1999 to the right (no observed data for 1996, 1998). The left group has already been identified before as the low bycatch years, and the right group as the high bycatch years (Fig. 3). The third split is by temperature under the years 1994, 1995, 1999 years, with lower temperatures accounting for a lower *lcph*. The substitution of temperature in the tree model for month in GLM as one of the three significant predictors of bycatch rate is not contradictory, as both month and temperature are indicators of seasonality.

Table 4. GLMs of bycatch rate with time-area factors and reduced subset of gear-effort factors.

a. GLM with reduced subset of factors with no interaction terms

NOTE: Due to missing values, only 2026 of 4032 observations can be used in this analysis.

Dependent Variable: *lcph*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	69	20.5252181	0.2974669	3.98	<.0001
Error	1956	146.0204001	0.0746526		
Corrected Total	2025	166.5456182			

R-Square	Coeff Var	Root MSE	*lcph* Mean
0.123241	341.1795	0.273226	0.080083

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	7	0.83073132	0.11867590	1.59	0.1339
month	11	1.42537395	0.12957945	1.74	0.0603
AREA	10	4.08954806	0.40895481	5.48	<.0001*
BAITCON	4	2.02694385	0.50673596	6.79	<.0001*
BAITKND	5	0.29753419	0.05950684	0.80	0.5516
LITENUM	1	0.11588307	0.11588307	1.55	0.2129
HOOKSET	1	0.00787284	0.00787284	0.11	0.7454
SOAKDUR	1	0.02239024	0.02239024	0.30	0.5840
swfn	1	0.39373659	0.39373659	5.27	0.0217*
temp	1	0.11558896	0.11558896	1.55	0.2135
HKPATRN	21	3.31880536	0.15803835	2.12	0.0022*
GANGCOLR	5	0.38701935	0.07740387	1.04	0.3941
LEAD	1	0.23100816	0.23100816	3.09	0.0787*

* significant effect at $\alpha=0.1$

b. GLM repeating 1. less insignificant factors and with year-month-area interactions

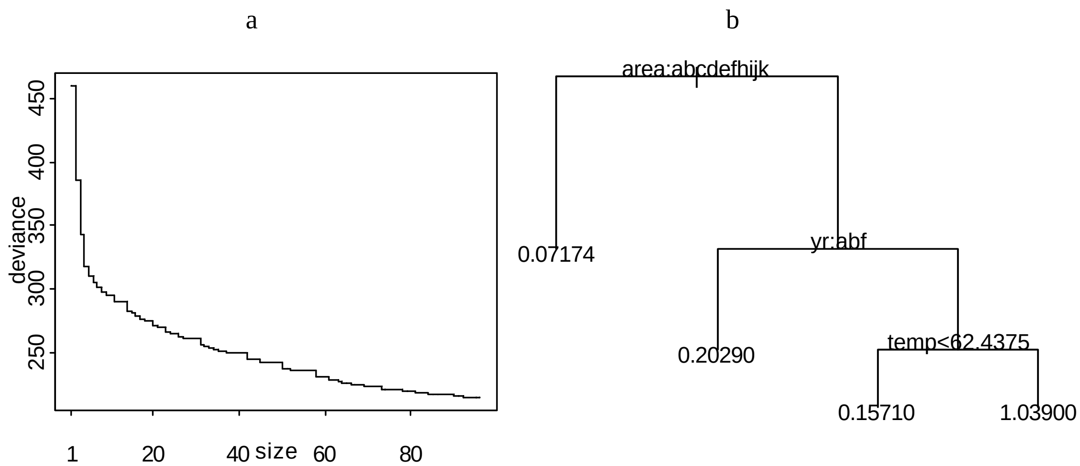
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	290	47.0281703	0.1621661	2.36	<.0001
Error	1764	121.0550384	0.0686253		
Corrected Total	2054	168.0832087			

R-Square	Coeff Var	Root MSE	*lcph* Mean
0.279791	329.2710	0.261964	0.079559

Source	DF	Type III SS	Mean Square	F Value	Pr > F
year	7	1.13290782	0.16184397	2.36	0.0213*
month	11	2.45835156	0.22348651	3.26	0.0002*
AREA	10	3.42810423	0.34281042	5.00	<.0001*
BAITCON	4	0.46219792	0.11554948	1.68	0.1511
swfn	1	0.26045106	0.26045106	3.80	0.0516*
HKPATRN	17	1.65370565	0.09727680	1.42	0.1185
LEAD	1	0.07761345	0.07761345	1.13	0.2877
year*month	66	7.05860717	0.10694859	1.56	0.0031*
year*AREA	40	5.11287667	0.12782192	1.86	0.0009*
month*AREA	53	6.50548469	0.12274499	1.79	0.0005*
year*mon*AREA	72	4.96852382	0.06900728	1.01	0.4662

Figure 6. Regression tree model of time-area and gear-effort factors on the response of bycatch rate (*lcph*) of all turtle species combined. The mean residual deviance of the full and pruned models are given. a) the plot of the deviance against the number of terminal nodes (size) of the tree model grown, b) shows the pruned model with the fitted response at each node. The length of the vertical branch is roughly proportional to the deviance explained by the node from which it is grown.

```
Full model: lcph = year + month + AREA + BAITCON + BAITKND + LITENUM + HOOKSET +
       SOAKDUR + swfn + temp + HKPATRN + GANGCOLR + LEAD
Number of terminal nodes:  96    Residual mean deviance:  0.0652 = 215.1 / 3299

Pruned model: lcph = AREA + year + temp
Number of terminal nodes:  4     Residual mean deviance:  0.09392 = 318.5 / 3391
```



<u>Key to 6b</u>:
area: a-CAR b-GOM c-FEC d-MAB e-NCA f-NEC g-NED h-SAB I-SAR j-TUN k-TUS
yr: a-92 b-93 c-94 d-95 e-96 f-97 g-98 h-99

Regression trees constructed separately for loggerheads and leatherbacks gave similar results as for all species combined. Both first split into NED and the other AREAs. For leatherbacks, the subsequent branches are year, month, and temperature, in order of importance. For loggerheads, it is year, temperature, and month. However, lower temperature accounts for a slightly higher catch rate of leatherback, but the opposite is true for loggerhead, so temperature as a factor may be possibly be species-specific. Given that the intra-annual distribution of observed effort emulates reported effort and tends to be concentrated in one specific quarter, the month and temperature factors have to be cautiously interpreted. For NED, fishing peaked in the 3rd quarter, which is likely to have a higher average temperature than the average temperature of the other quarters combined. GLM and the regression tree model analysis both essentially indicate that area and time of fishing as the most important predictors of bycatch rate, and temperature a possible covariate.

Delta-GLM bycatch estimates

Probability of a positive set

Several binomial models were compared by analysis of deviance and the AIC statistic in a stepwise regression procedure, beginning with the full model that includes time-area factors (year, quarter, NAREA) and all gear-effort factors in the reduced subset as in Table 4a. None of the gear-effort factors nor the time factor of quarter contributes significantly to the model. The "best" model involves only year and NAREA:

bcatch=NAREA+ year + year*NAREA.

The predictors in the model are listed in decreasing order of importance (according to mean deviance = deviance/df), which has been tested valid for each species (Table 5). NAREA is again confirmed as the most important factor.

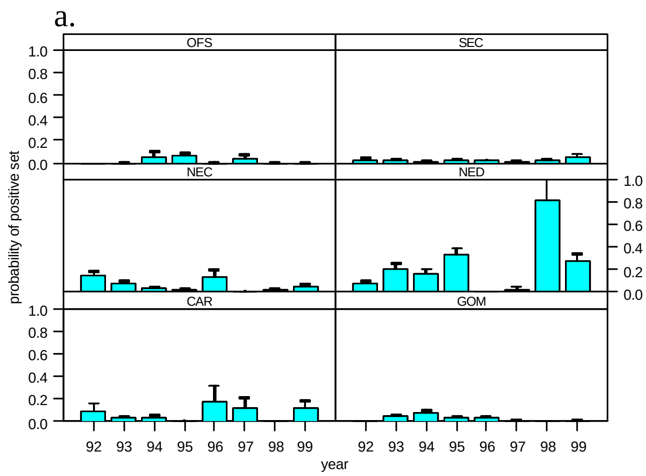
This model was fitted to each species. Leatherbacks and loggerheads, which were most common in the bycatch and have the most positive sets, share a similar fitted pattern showing that the expected probability of a positive set (*p*) is highest in NED, particularly the years 1995 and 1999, and 1994 as well for loggerheads (Fig. 7). The apparent peaks in years 1996 (loggerhead: $p = 0.99 \pm 0.11$ s.e.) and 1998 (leatherback: 0.81 ± 1.74; loggerhead: 0.77 ± 2.39) in NED, however, are not based on any actual observations in these years (Fig. 3) and carry very high uncertainty. Other NAREA of moderate probability of bycatch are CAR and NEC. Fitted *p* is mostly zero for each year-NAREA for the rare greens, hawksbills, and Kemp's Ridleys. These results are in strong agreement with the delta-lognormal estimates and regression tree analysis.

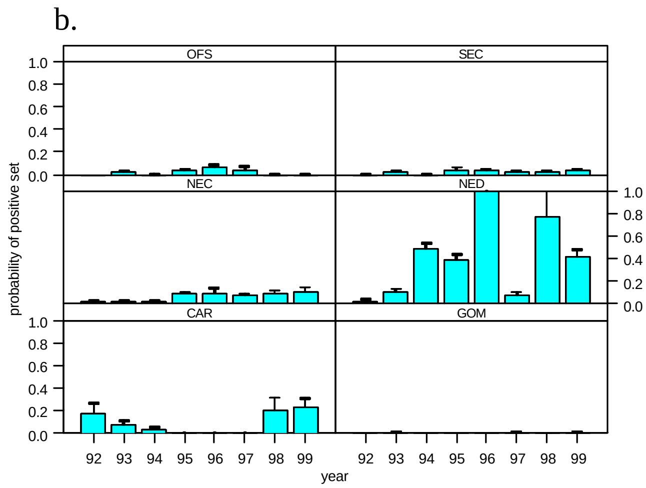
Table 5. Analysis of deviance of the binomial model for the probability of positive set, *bcatch*= year+NAREA+year*NAREA.

Response: *bcatch*
Terms added sequentially (first to last)

	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
a. Leatherback						
NULL			4031	1597.292		
yr	7	45.4679	4024	1551.824	7.29440	1.020363e-008
narea	5	117.0881	4019	1434.736	26.29813	0.000000e+000
yr:narea	32	100.5779	3987	1334.158	3.52968	8.915000e-011
b. Loggerhead						
NULL			4031	1579.559		
yr	7	47.3457	4024	1532.213	8.70338	1.199050e-010
narea	5	312.9231	4019	1219.290	80.53281	0.000000e+000
yr:narea	32	81.4260	3987	1137.864	3.27430	1.632598e-009

Figure 7. The expected probability of a positive set (+ s.e.) modeled on year, NAREA, and their interaction in a binomial model for a) leatherbacks; b) loggerheads.





Bycatch rate of positive sets

A similar selection process for the binomial model is applied for the gamma model for a) all species combined, b) leatherbacks and c) loggerheads. Due to sparse data, separate gamma models cannot be fitted to rare species such as greens, hawksbills and Kemp's ridley. Instead the all species fitted model is used for those species. The most important factors remain the time-area factors for each of these three categories, with slight variations on the order and degree of significance, although NAREA is invariably the most important. A "best" model for all species, which includes year*NAREA interaction,

$$lcph = \text{year} + \text{NAREA} + \text{quarter} + \text{year*NAREA}, \quad \{lcph>0\},$$

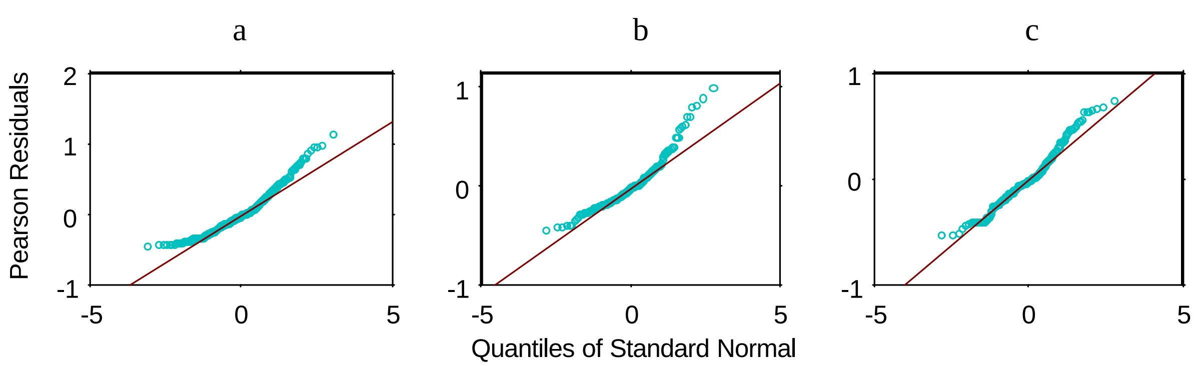
is suitable for the two single species also (Table 6). The residuals of each of the three fitted models approximate the normal distribution, showing reasonable model fits (Figure 8).

Table 6. Analysis of deviance of the gamma log-link models for bycatch rate for positive sets, {*lcph*>0}, of a) all species; b) leatherbacks; c) loggerheads.

```
Response: lcph
Terms added sequentially (first to last)
```

	Df	Deviance	Resid. Df	Resid. Dev	F Value	Pr(F)
a. All species						
NULL			428	46.35774		
yr	7	3.369571	421	42.98817	5.184267	0.00001165
narea	5	4.483531	416	38.50464	9.657414	0.00000001
quartr	3	1.197666	413	37.30697	4.299571	0.00532184
yr:narea	27	3.554925	386	33.75204	1.418004	0.08322637
b. Leatherbacks						
NULL			200	17.65148		
yr	7	1.459332	193	16.19215	2.641661	0.0130186
narea	5	1.349223	188	14.84292	3.419279	0.0057858
quartr	3	0.713974	185	14.12895	3.015657	0.0316335
yr:narea	23	2.550594	162	11.57836	1.405188	0.1149731
c. Loggerheads						
NULL			197	24.97021		
yr	7	3.842434	190	21.12778	6.076786	0.0000026
narea	5	3.463001	185	17.66478	7.667400	0.0000017
quartr	3	0.440150	182	17.22463	1.624221	0.1857846
yr:narea	19	2.220263	163	15.00436	1.293649	0.1938116

Figure 8. Pearson residuals of the gamma model *lcph*=year+NAREA+quarter+year*NAREA, {*lcph*>0}, fitted to a) all species; b) leatherbacks; c) loggerheads.



Delta-GLM bycatch estimates for leatherbacks and loggerheads are derived from their respective species-specific fitted binomial and gamma models. The bycatch estimates for each of the other species are derived from their respective species-specific fitted binomial models and the all-species gamma model.

The quarterly delta-GLM bycatch estimates for leatherbacks and loggerheads are plotted in Fig. 9 for a comparison with the delta-lognormal estimates in Fig. 5. In terms of general trends and magnitudes, the point estimates derived from the two methods are quite similar. The quarterly estimates for leatherbacks in NED 1998, where there was no actual observed effort, are exceptions. The extremely high leatherback bycatch estimates for the 3rd and 4th quarters of NED 1998 are affected by the aforementioned high uncertainty in the predicted probability of positive set (p), low number of observations, and the status of NAREA as a high bycatch area, and therefore should be interpreted conservatively. The NED 1995 3rd quarter peak for leatherbacks in the delta-lognormal estimates is also present in the delta-GLM estimates, but at ~400 animals compared to the ~600 animals estimated by the delta-lognormal method. For both leatherbacks and loggerheads in CAR, NEC, NED, and OFS, the patterns of bycatch from both methods match very well visually (Figs. 5 and 9), especially in the characteristic 3rd quarter peaks. The GLM method eliminated many of the zero cells of the lognormal estimates, most obviously in GOM and SEC for leatherbacks, but annual sums of the bycatch estimates in each NAREA are of similar magnitudes.

The GLM method produced much higher and probably more realistic *CV*s for the estimates (≤13 for loggerheads and leatherbacks, higher still for rare species, see Table 7) than the delta-lognormal method (≤1, with *CV*=1 where there is no measure of variability due to lack of data). This partly reflects that the fits of the GLMs may not optimal, and the linear predictors do not adequately explain the observed bycatch rates. The main problem may be the sparse data in combination with the low bycatch rates. The bycatch estimates, *CV*s, and annual sums of the rare species by the two methods are tabulated for comparison in Table 7.

Figure 9. Estimated quarterly mean bycatch of a) leatherback and b) loggerhead turtles by the delta-GLM method. Note change in y-axis scale for second-row panels.

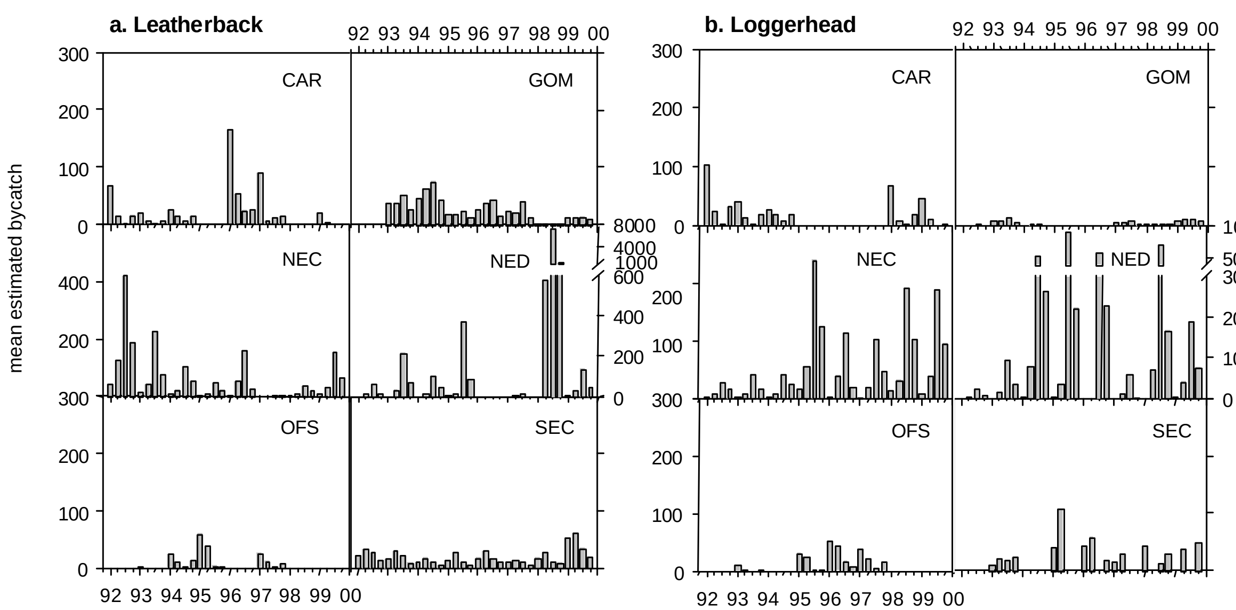


Table 7. Comparison of the quarterly bycatch estimates and associated coefficient of variation (*CV*) from the delta-lognormal and delta-GLM methods for rare species. The extremely high *CV*'s from the delta-GLM method resulted from extrapolation to strata with no observed data, and some of these estimates are so out of range that they are not presented (empty cells).

	yr	qtr	narea	delta-lognormal estimated catch	delta-lognormal cv	delta-GLM estimated catch	delta-GLM cv
KEMPS RIDLEY	94	1	NEC			1	16
	94	2	NEC			2	16
	94	3	NEC	26	1	10	16
	94	4	NEC			6	16
	97	1	OFS	17	1	14	6.96
	97	2	OFS			7	6.96
	97	3	OFS	1	0.98	1	6.96
	97	4	OFS	4	0.98	6	6.96
	92	1	OFS	1	0.98	NA	NA
Total				49		47	
UNIDENTIFIED	95	1	CAR			3	280.8
	95	2	CAR			1	280.8
	95	3	CAR			2	280.8
	93	1	GOM			4	15.86
	93	2	GOM	10	1	4	15.86
	93	3	GOM			6	15.86
	93	4	GOM			4	15.86
	94	1	GOM	20	1	4	12.83
	94	2	GOM			5	12.83
	94	3	GOM			6	12.83
	94	4	GOM			4	12.83
	97	1	GOM	23	1	10	12.95
	97	2	GOM			9	12.95
	97	3	GOM			17	12.95
	97	4	GOM			8	12.95
	99	1	GOM	24	1	15	9.7
	99	2	GOM			16	9.7
	99	3	GOM			17	9.7
	99	4	GOM	14	1	13	9.7
	92	1	NEC	1	0.98	2	10.58
	92	2	NEC	24	1	6	10.58
	92	3	NEC	21	1	20	10.58
	92	4	NEC			11	10.58
	93	1	NEC			1	16.85
	93	2	NEC			2	16.85
	93	3	NEC			10	16.85
	93	4	NEC			4	16.85
	99	1	NEC			1	8.23
	99	2	NEC	4	0.98	5	8.23
	99	3	NEC			28	8.23
	99	4	NEC	24	1	15	8.23
	94	2	NED	1	0.98	2	8.49
	94	3	NED	13	0.99	14	8.49
	94	4	NED			7	8.49
	96	3	NED	1	0.98		
	96	4	NED	1	0.98		
	98	3	NED	1	0.98		
	92	1	OFS	1	0.98		
	97	1	OFS	18	1	14	6.96
	97	2	OFS			7	6.96
	97	3	OFS	1	0.98	1	6.96
	97	4	OFS	5	1.01	6	6.96
	95	1	SEC	86	0.69	34	4.9
	95	2	SEC	85	0.7	68	4.9
	95	3	SEC			30	4.9
	95	4	SEC			18	4.9
Total				378		454	

	yr	qtr	narea	delta-lognormal estimated catch	delta-lognormal cv	delta-GLM estimated catch	delta-GLM cv
GREEN	95	1	CAR			1	462.9
	95	2	CAR			0	462.9
	95	3	CAR			1	462.9
	95	4	CAR			0	462.9
	93	1	GOM	19	1	4	15.86
	93	2	GOM			4	15.86
	93	3	GOM			6	15.86
	93	4	GOM			4	15.86
	92	1	NEC	3	0.68	4	7.44
	92	2	NEC	48	0.69	12	7.44
	92	3	NEC			40	7.44
	92	4	NEC			22	7.44
	94	1	NEC			2	11.29
	94	2	NEC	7	1	4	11.29
	94	3	NEC	26	1	20	11.29
	94	4	NEC			13	11.29
	92	2	NED			11	4.59
	92	3	NED			48	4.59
	92	4	NED	36	0.52	15	4.59
	93	2	NED			2	8.98
	93	3	NED	12	1	12	8.98
	93	4	NED			5	8.98
	96	3	NED	11	0.75		
	96	4	NED	5	0.77		
	98	2	NED	1	0.81		
	98	3	NED	10	0.75		
	98	4	NED	3	0.74		
	95	1	SEC			9	9.95
	95	2	SEC			17	9.95
	95	3	SEC	40	1	7	9.95
	95	4	SEC			5	9.95
Total				221		268	
HAWKSBILL	92	1	NEC	2	0.98	2	10.58
	92	2	NEC			6	10.58
	92	3	NEC			20	10.58
	92	4	NEC	18	1	11	10.58
	98	1	NEC	17	1	2	8.98
	98	2	NEC			5	8.98
	98	3	NEC			31	8.98
	98	4	NEC			18	8.98
	96	3	NED			83	10.05
	96	4	NED			30	10.05
	97	1	SEC	16	1	6	10.05
	97	2	SEC			7	10.05
	97	3	SEC			6	10.05
	97	4	SEC			3	10.05
Total				53		230	

Summary

The delta-lognormal method is used to estimate bycatch of marine turtle in the U.S. Atlantic pelagic longline fishery in 1992-1999. Estimates are based on quarterly observed effort and grouped by six fishing areas or NAREAs. To avoid missing or poor estimates where there are no or very few observation units (set) in a basic year-quarter-NAREA stratum, a criterion is set so that if a basic stratum has less than 5 (=N_{min}) observed sets, the levels of quarter, year, and then NAREA will be pooled successively in that order until N_{min} is achieved. Pooling is necessary only in the offshore NAREAs of CAR, OFS, and NED and only up to the level of quarters with rare exceptions. The N_{min} of five is selected in an attempt to balance the need for reasonable estimates and preserving inherent variability among strata. A similar pooling method was used to estimate retained catch of commercial species from the U.S. Atlantic pelagic longline fishery with results similar to values reported in the commercial landings reporting system (Brown *et al*. 2000). Where there is a paucity of actual observations, this method may be an acceptable alternative when applied with a consideration of its limitations. The choice of N_{min}, for example, should be subjected to further analysis. The annual summed observed bycatch and the estimated bycatch obtained by the delta-lognormal method are presented in Table 8. The *CV*s for the annual summed estimates are based on the assumption of independence of estimates among basic strata.

The delta-GLM approach to bycatch estimation is analogous to the delta-lognormal in that it separately accommodates zero and non-zero observations, which both yield important information on bycatch. One of advantages offered by the delta-GLM method over the delta-lognormal is that it avoids the complication of pooling strata and provides explicit models for the probability of a set resulting in turtle bycatch in a stratum and the mean bycatch rate for those positive sets (Stefánsson 1996). GLM also allows the testing of factors influential to bycatch and the incorporation of those factors in the prediction of bycatch. In terms of bycatch estimates, however, there is no considerable gain in using the delta-GLM over the delta-lognormal method, and both are based on the tenuous assumption of a parametric distribution of a rather small sample data set. Quarterly patterns and trends in the bycatch of each NAREA correspond well between the two methods (Figs. 5 and 9). Although the delta-GLM method in some cases resulted in a more even distribution of bycatch intra-annually, the annual summed bycatch estimates are reasonably close to those of the delta-lognormal (Table 7). The delta-GLM method is more cumbersome than the delta-lognormal, and the GLM models are by no means optimally fitted. The binomial models fitted only accounted for approximately 20-30% of the total deviance or variation explained (Table 5), while the gamma models are slightly better with 30-40% (Table 6). The *CV*s of the bycatch estimates from the delta-GLM method may suffer from poor model fits, but may actually be more realistic than those of the delta-lognormal estimates. The primary reason for high *CV*s, however, is the sparseness of the data and also the nature of the data, in which the probability of a positive set tends to be extremely low.

Loggerheads and leatherbacks are the marine turtle species most often caught in pelagic longline. Results of the bycatch analysis show that NEC and NED are the two areas of highest bycatch of these species (Fig. 5), and peak bycatch occurred in the 3rd quarter of the year at the height of fishing effort (Fig. 3). Considering the relatively low effort in NED compared to NEC, their comparable magnitude of estimated bycatch marks NED as an area of extraordinarily high bycatch rate. There is no distinguishable monotonic trend in bycatch, but that may be affected by the lack of observed effort in some quarters and for the entire 1996 and 1998 for NED.

Analysis of the observed data show that time-area factors are far more influential on bycatch than gear-effort factors. The task remains the unraveling of the biological and physical factors that are masked by time and space.

Table 8. Annual summed observed and delta-lognormal estimates of total marine turtle bycatch and the subset that were dead when released in the U.S. pelagic longline fishery (CL= confidence limit; CV =coefficient of variation).

species	year	observed catch	estimated catch	upper 95% CL	lower 95% CL	CV	estimated dead	upper 95% CL	lower 95% CL	CV
loggerhead	92	6	293	1149	78	0.79	0			
loggerhead	93	23	417	1414	142	0.69	9	46	2	1
loggerhead	94	88	1344	2392	859	0.3	31	158	6	1
loggerhead	95	129	2439	4542	1405	0.33	0			
loggerhead	96	13	917	2713	322	0.6	2	10	0	0.98
loggerhead	97	17	384	1281	124	0.68	0			
loggerhead	98	15	1106	3225	395	0.59	1	5	0	0.98
loggerhead	99	64	991	2089	510	0.39	23	117	5	1
leatherback	92	28	914	2716	353	0.6	88	449	17	1
leatherback	93	66	1054	2603	463	0.49	0			
leatherback	94	42	837	2433	328	0.59	0			
leatherback	95	61	934	2093	520	0.43	0			
leatherback	96	10	904	2074	231	0.44	0			
leatherback	97	7	308	1498	66	0.96	0			
leatherback	98	4	400	1411	120	0.72	0			
leatherback	99	45	1012	2786	410	0.55	0			
green	92	10	87	266	29	0.62	30	154	6	1
green	93	2	31	158	6	1	0			
green	94	2	33	169	6	1	0			
green	95	1	40	205	8	1	0			
green	96	0	16	60	4	0.76	2	10	0	0.98
green	98	0	14	52	4	0.75	1	5	0	0.98
hawksbill	92	1	20	102	4	1	0			
hawksbill	97	1	16	82	3	1	0			
hawksbill	98	1	17	87	3	1	0			
Kemp's Ridley	92	0	1	5	0	0.98	0			
Kemp's Ridley	94	1	26	133	5	1	0			
Kemp's Ridley	97	1	22	112	4	1	0			
unidentified	92	1	26	133	5	1	0			
unidentified	93	2	31	158	6	1	0			
unidentified	94	2	34	173	7	1	0			
unidentified	95	4	171	587	50	0.7	0			
unidentified	96	0	2	10	0	0.98	0			
unidentified	97	2	47	241	9	1	0			
unidentified	98	0	1	5	0	0.98	0			
unidentified	99	3	66	338	14	1	0			

Literature Cited

Berkeley, S., E. Irby, and J. Jolley. 1981. Florida's commercial swordfish fishery: longline gear and methods. Florida Sea Grant Marine Advisory Bull. MAP-14, 23 pp.

Brown, C.A. In press. Revised estimates of bluefin tuna dead discards by the U.S. Atlantic pelagic longline fleet, 1992-1999. International Commission for the Conservation of Atlantic Tunas, Collected Volume of Scientific Papers Working Document SCRS/2000/97.

Brown, C.A., J. Cramer, and A. Bertolino. 2000. Estimates of bycatch by the U.S. Atlantic pelagic longline fleet during 1993-1998. U.S. Department of Commerce NOAA Technical Memorandum NMFS-F/SPO-46:17.

Cramer, J. and H. Adams. 2000. Large pelagic logbook newsletter – 1998. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-433, 25 pp.

De'ath, G. and K. E. Fabricus. 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology 81: 3178-3192.

Hoey, J. 1998. NEFSC pelagic longline data review & analysis of gear, environmental, and operating practices that influence pelagic longline interactions with sea turtles. Final contract report NOAA Contract - 50EANA700063, National Fisheries Institute, Inc., Arlington, Va., 32 pp.

Hoey, J. and A. Bertolino. 1988. Review of the U. S. fishery for swordfish, 1978 to 1986. International Commission for the Conserververation of Atlantic Tunas (ICCAT), Collected Volume of Scientific Papers 27:230-239.

Johnson, D. R., C. Yeung, C. A. Brown 1999. Estimates of marine mammal and marine turtle bycatch by the U.S. Atlantic pelagic longline fleet in 1992-1997. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-418, 70 pp.

Lee, D. W. and C. J. Brown. 1998. SEFSC pelagic observer program data summary for 1992-1996. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-408, 21 pp.

MathSoft, 1997. S-PLUS 4 Guide to Statistics. Data Analysis Products Division, MathSoft, Inc. Seattle, WA.

Myers, R. A. and P. Pepin. 1990. The robustness of lognormal-based estimators of abundance. Biometrics 46:1185-1192.

Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. Biometrics 39:281-286.

Stefánsson, G. 1996. Analysis of groundfish survey abundance data: combining the GLM and delta approaches. ICES Journal of Marine Science 53:577-588.

Syrjala, S. E. 2000. Critique on the use of the delta distribution for the analysis of trawl survey data. ICES Journal of Marine Science 57:831-842.

Witzell, W. N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic Ocean, 1992-1995. Fishery Bulletin 97:200-211.

Yeung, C. 1999*a*. Revised mortality estimates of marine mammal bycatch in 1992-1997 based on serious injury guidelines. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-429, 23 pp.

Yeung, C. 1999*b*. Estimates of marine mammal and marine turtle bycatch by the U.S. Atlantic pelagic longline fleet in 1998. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-430, 26 pp.

CHAPTER 3. SIZES OF SEA TURTLES INCIDENTALLY CAPTURED IN ATLANTIC AND MEDITERRANEAN PELAGIC LONGLINE FISHERIES AND THEIR NATAL ORIGINS

Wayne N. Witzell and Sheryan P. Epperly

Pelagic longline fisheries may impact several species of sea turtle. However, it is unlikely that the U.S. Atlantic fleet encounters substantial numbers of hard-shell turtles other than loggerheads. Witzell (1999) edited the U.S. pelagic logbook to include only leatherback and loggerhead turtles. This was based on the known distribution, abundance, and biology of sea turtles in the areas fished, and the fact that some vessel captains and observers were unable to accurately identify turtles encountered[6]. There is the possibility hard shell turtles other than loggerheads could occasionally be taken, but there have been no photographs taken to date or green, ridley, or hawksbill turtles taken by the U.S. Atlantic fleet.

Sizes

There is little data on the sizes of sea turtles incidentally captured in various Atlantic Ocean and Mediterranean Sea longline fisheries. Data for loggerhead sea turtles are summarized in Table 1. No information was found on incidentally caught leatherback turtle sizes in any Atlantic or Mediterranean Sea longline fishery.

The most pertinent published study is by Witzell (1999) who summarized observer data from the U.S. Grand Banks swordfish fishery. These data indicate that immature loggerhead turtles (41-70 cm CCL) are captured, with a mean size of 55.9 cm. Bolten *et al*. (1993) reported that turtles from an eastern Atlantic tuna fishery ranged in size form 42-82 cm CCL. The Witzell (1999) data and the Bolten *et al*. (1993) data are very similar and are presented in Fig. 1.

Bolten *et al*. (1993) reported that dip net caught turtles were significantly smaller (12.5-62.5 CCL) than the longline caught turtles (42.5-67.5 CCL) from the same area, indicating that the longlines selectively harvest larger immature turtles than the dip nets. Conclusions drawn from results of expanded sample sizes of the Azores dip net (Bjorndal *et al.* 2000) and longline caught turtles (Bolten *et al.* 2001[7]) remain unchanged (Fig. 2).

The loggerhead turtles caught in the Mediterranean Sea also appear to be immature turtles. The largest sample size (N=856) is reported by Aguilar *et al*. (1995) from the western Mediterranean. These animals averaged 48.1 cm (27-76 cm). Turtles from the central

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[6] Dr. Molly Lutcavage, New England Aquarium, Boston, MA. Personal Communication (phone) to Wayne Witzell, National marine Fisheries Service, SEFSC, Miami, Fla., January 30, 2001.

[7] Bolten, A.B., H. Martins, E. Isidro, R. Ferreira, M. Santos, A. Giga, B. Riewald, and K. Bjorndal. Preliminary results of an experiment to evaluate effects of hook type on sea turtle bycatch in the swordfish longline fishery in the Azores. Bolten, A.B., University of Florida, E-mail to Nancy Thompson and Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., Jan. 14. 2001.

Mediterranean Sea ranged from 35-75 cm (Argano *et al*. 1992, Panou *et al.* 1992[8]) and averaged 57.0 cm (Argano *et al*. 1992).

Loggerheads of the sizes reported above captured in the open ocean most likely are pelagic juveniles, although this size range also represents the overlap in sizes of pelagic and small benthic juveniles (Bjorndal *et al*. 2000). Laurent *et al*. (1998) proposed that between the strict oceanic pelagic stage and the benthic stages, immature turtles may live through an intermediate neritic stage in which they switch between pelagic and benthic foods and habitats. Furthermore, it is likely that some animals are not pelagic juveniles, as adults are known to make migrations between foraging grounds and nesting beaches across open ocean waters (see Part I.) and benthic juveniles have been reported to migrate well offshore seasonally (Epperly *et al*. 1995, Shoop and Kenney 1992, Mullin and Hoggard 2000[9]).

<u>Natal Origins</u>

There is no information about the natal origins of loggerheads captured by the Atlantic fleets. However, studies of foraging ground animals on the North American continental shelf and estuarine waters and of stranded animals in the western North Atlantic indicate that animals of different origins mix on the foraging grounds, with the large South Florida subpopulation dominating everywhere, but with decreasing contribution northward (see Part I and TEWG 1998, 2000). Studies of pelagic animals captured in the vicinity of the Azores indicated that 71-72% of the animals originated from the South Florida subpopulation, with 17-19% of the animals originating from the northern subpopulation and 10-11% from the Quintana Roo, Mexico subpopulation (Bolten *et al*. 1998). The Azores samples, dipnetted from the ocean's surface, represent an admixture of pelagic animals. The size distribution of these animals is significantly different (smaller) than animals taken on the longlines (Fig. 2). If there is no sorting by natal origin in the pelagia and these smaller animals represent the same genetic mix as would be found in the larger animals taken by the longline, we can assume that these results also represent the natal origins of animals caught by the U.S. domestic longline fleet on the high seas in the eastern Atlantic.

In the Mediterranean Sea, 45-47% of the loggerheads captured in pelagic longlines (presumably pelagic stage animals) originate from western North Atlantic rookeries (Laurent *et al*. 1998) whereas none of the animals captured in trawls (presumably benthic stage animals) were from the western North Atlantic. Of the animals from the Western North Atlantic, 2% were from the northern subpopulation, the remainder were attributed to the South Florida subpopulation. Thus, it appears that both the eastern and western basins of the Mediterranean

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[8] Panou, A., G. Antypas, Y.Giannopoulos, S. Moschonas, D.G., D. Mourelatos, G. Mourelatos, Ch. Mourelatos, P. Toumazatos, L. Tselentis, N.Voutsinas, and V.Voutsinas. 1992. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Unpublished Report. Institute of Zoology, University of Munich, Germany, 8 pp

[9] Mullin, K.D. and W. Hoggard. 2000. Visual surveys of cetaceans and sea turtles from aircraft and ships, p. 111-322. <u>In</u> R.W.Davis, W.E. Evans, and B. Würsig, eds. Cetaceans, sea turtles and seabirds in the 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.

Sea are utilized by pelagic loggerheads originating from the western North Atlantic but these animals leave the Mediterranean before switching to their benthic life stage.

In fall 2000, 18 genetic samples were taken from loggerhead turtles captured on the Grand Banks and 16 of them have been sequenced[10]. Two haplotypes were discerned: A (56.3%) and B (43.7%). Haplotypes A and B have been found in all 3 nesting assemblages in the United States and B also has been found in the nesting population of Mexico and Greece (Encalada *et al.* 1998). The sample size is too small to yet determine the proportions of the subpopulations represented.

[10] Peter Dutton, National Marine Fisheries Service, SWFSC, La Jolla, Calif. Personal Communication (E-Mail) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., January 20, 2001.

Literature Cited

Aguilar, R., J. Mas, and X. Pastor. 1995. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the western Mediterranean. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-361:1-6.

Argano, R. R. Basso, M. Cocco, G.Gerosa. 1992. Nouvi dati sugli spostamenti di tartaruga marine comune (*Caretta caretta*) in Mediterraneo. Bollettino Musel Istitiuti Universita Genova 56-57:137-163.

Bjorndal, K.A., A.B. Bolten, and H.R. Martins. 2000. Somatic growth model of juvenile loggerhead sea turtles *Caretta caretta*: duration of pelagic stage. Marine Ecology Progress Series 202:265-272.

Bolten, A.B., H.R. Martins, K.A. Bjorndal, J. Gordon. 1993. Size distribution of pelagic-stage loggerhead sea turtles (*Caretta caretta*) in the waters around the Azores and Madeira. Arquipelago 11A:49-54.

Bolten, A.B., K.A. Bjorndal, and H.R. Martins. 1994. Life history model for the loggerhead sea turtle (*Caretta caretta*) population in the Atlantic: Potential impacts of a longline fishery. U.S. Department of Commerce NOAA Technical Memorandum. NMFS-SWFSC-201:48-55.

Bolten, A.B., K.A. Bjorndal, H.R. Martins, T. Dellinger, M.J. Biscoito, S.E. Encalada, and B.W. Bowen. 1998. Transatlantic developmental migrations of loggerhead sea turtles demonstrated by mtDNA sequence analysis. Ecological Applications 8:1-7.

Encalada, S.E., K.A. Bjorndal, A.B. Bolten, J.C. Zurita, B. Schroeder, E. Possardt, C.J. Sears, and B.W. Bowen. 1998. Population structure of loggerhead turtle (*Caretta caretta*) nesting colonies in the Atlantic and Mediterranean as inferred from mitochondrial DNA control region sequences. Marine Biology 130:567-575.

Epperly, S.P., J. Braun, A.J. Chester, F. A Cross, J.V. Merriner, and P.A. Tester. 1995. Winter distribution of sea turtles in the vicinity of Cape Hatteras and their interactions with the summer flounder trawl fishery. Bulletin of Marine Science 56:547-568.

Laurent, L., P. Casale, M.N. Bradai, B.J. Godley, G. Gerosa, A.C. Broderick, W. Schroth, B. Schierwater, A.M. Levy, D. Freggi, E.M. Abd El-Mawla, D.A. Hadoud, H.E. Gomati, M. Domingo, M. Hadjichristophorou, L. Kornaraky, F. Demirayak, and Ch. Gautier. 1998. Molecular resolution of marine turtle stock composition in fishery bycatch: a case study in the Mediterranean. Molecular Ecology 7:1529-1542.

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.

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, 96pp.

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.

Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by the U.S. pelagic longline fleet in the western North Atlantic ocean, 1992-1995. Fishery Bulletin 97:200-211.

Table 1. Documented loggerhead sea turtle sizes incidentally captured by various longline fleets.

		Mean (cm)	Range	StDev	N
Atlantic Ocean					
Location fished	Grand Banks	55.9	41-70	6.5	98
Vessel Flag	U.S.A.				
Target Species	Swordfish				
Reference	Witzell (1999)				
Location fished	Azores	--	42-82	--	224
Vessel Flag	Spain				
Target Species	Tuna, Swordfish, Blue Sharks				
Reference	Bolten *et al.* (1993, 1994, 2001[11])				
Mediterranean Sea					
Location Fished	Western Med. Sea	48.1	27-76	-	856
Vessel Flag	Spain				
Target Species	Swordfish				
Reference	Aguilar *et al*. (1995)				
Location Fished	Ionian Sea	35-75	20-100	-	59
Vessel Flag	Greece				
Target Species	Swordfish				
Reference	Panou *et al*. (1992)[12]				
Location Fished	Central Med. Sea	57.0	35-69.5	9.9	38
Vessel Flag	Italy				
Target Species	Swordfish				
Reference	Argano *et al.* (1992)				

[11] Bolten, A.B., H. Martins, E. Isidro, R. Ferreira, M. Santos, A. Giga, B. Riewald, and K. Bjorndal. Preliminary results of an experiment to evaluate effects of hook type on sea turtle bycatch in the swordfish longline fishery in the Azores. Bolten, A.B., University of Florida, E-mail to Nancy Thompson and Sheryan Epperly, NMFS/SEFSC/Miami, FL, January 14. 2001.

[12] Panou, A., G. Antypas, Y.Giannopoulos, S. Moschonas, D. Mourelatos, G. Mourelatos, Ch. Mourelatos, P. Toumazatos, L.Tselentis, N.Voutsinas, and V.Voutsinas. 1992. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Unpublished Report. Institute of Zoology, University of Munich, Germany, 8 pp

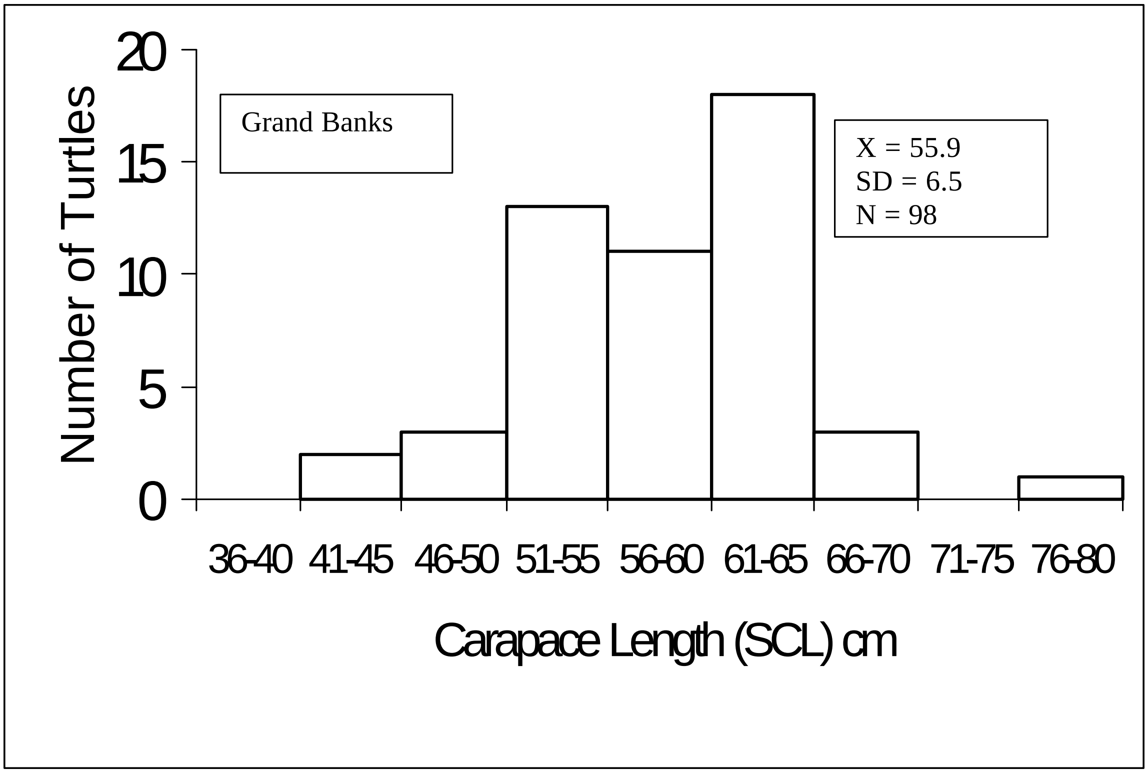


Figure 1. Sizes of longline caught loggerhead (*Caretta caretta*) turtles from the U.S. Grand Banks swordfish fishery (above) (original data from Witzell 1999) and the Spanish Azores tuna fishery (below) (Bolten *et al*. 1993; data from Figure 2).

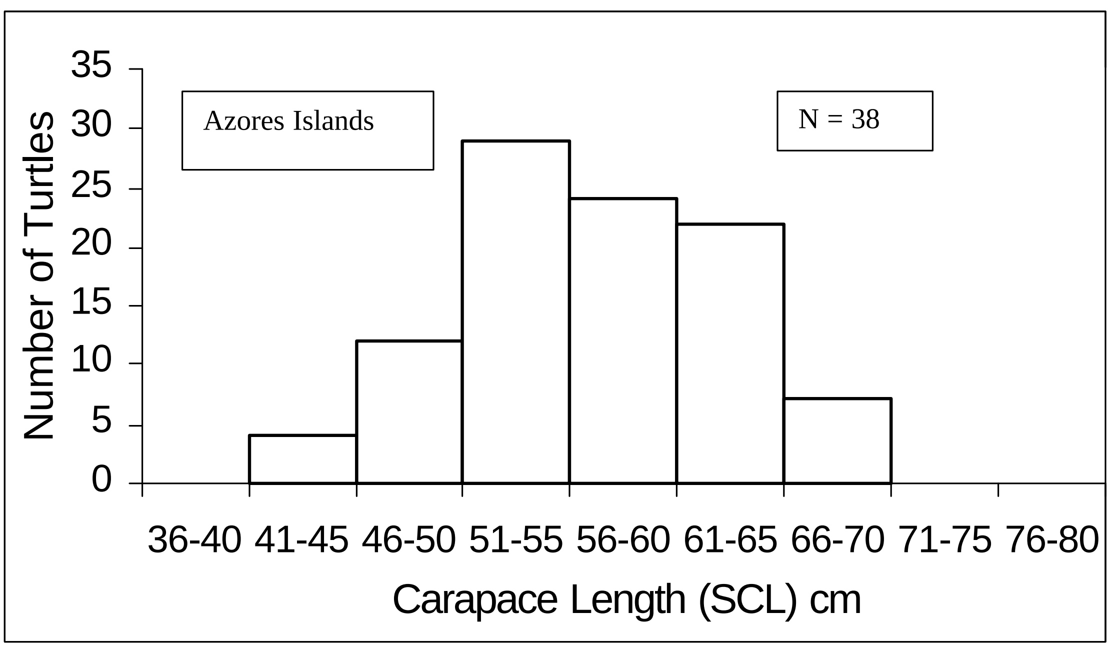


Figure 2. Length frequency histogram of dip netted and longline caught loggerhead turtles near the Azores (reproduced from Bolten *et al.* 1993).

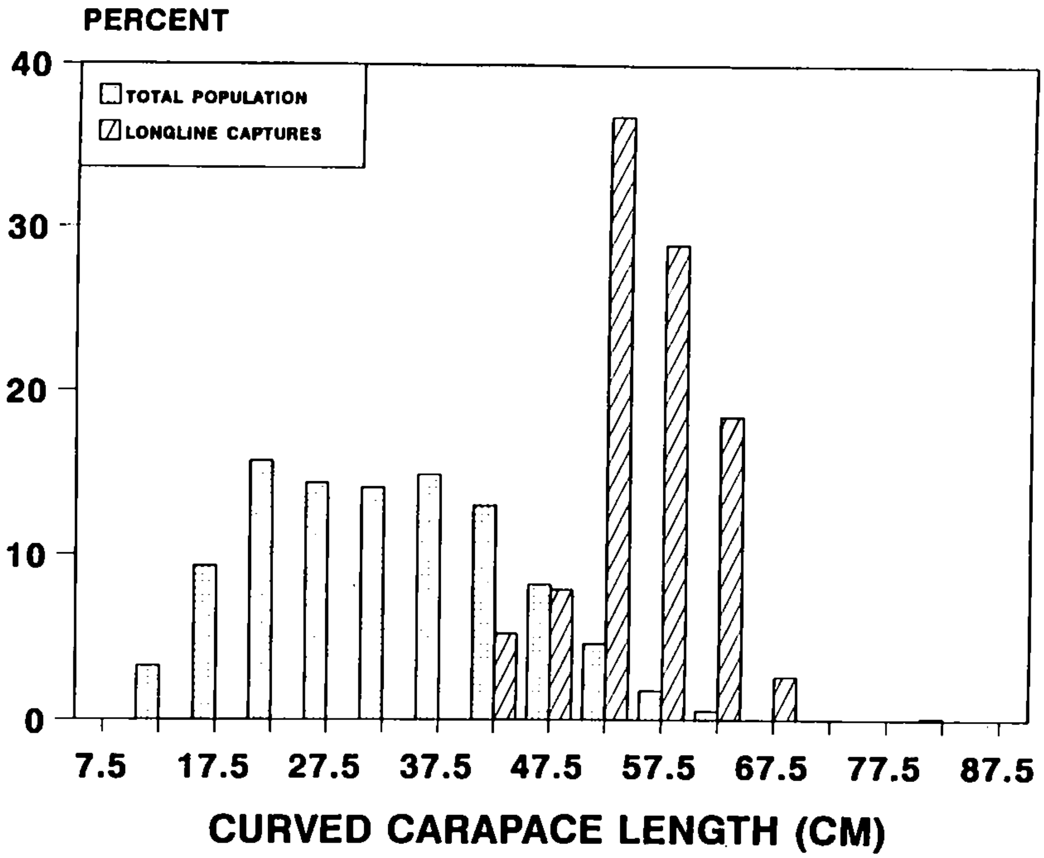
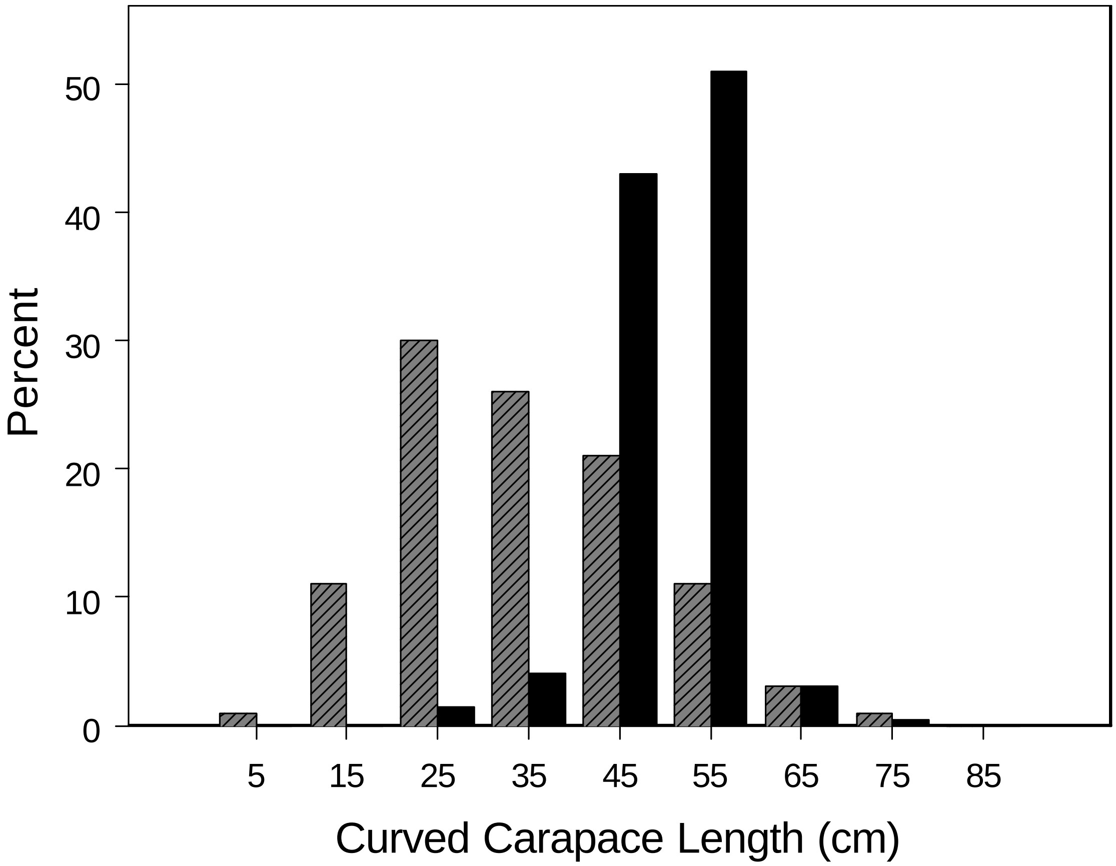


Figure 2.--Comparison of the size distributions of all loggerheads in the waters around the Azores (n = 731) and those captured by the longline fishery in the Azores (n = 38). The frequency distributions are significantly different (Kolmogorov-Smirnov two-sample test, $P < 0.001$).

Figure 3. Length frequency of loggerhead turtles from the Azores Islands. Hatched bars = dip netted turtles, N=1,692 (includes less than 100 longline captured turtles, also) (Bjorndal *et al.* 2000). Solid bars = longline experiment, July-December 2000, N=224[13]. The frequency distributions are significantly different (Kolmogorov-Smirov two-sample test, (KS=0.6522, P<0.0001).



[13] Bolten, A.B., H. Martins, E. Isidro, R. Ferreira, M. Santos, A. Giga, B. Riewald, and K. Bjorndal. Preliminary results of an experiment to evaluate effects of hook type on sea turtle bycatch in the swordfish longline fishery in the Azores. Bolten, A.B., University of Florida, E-mail to Nancy Thompson and Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Florida, January 14, 2001.

CHAPTER 4. REVIEW OF POST CAPTURE MORTALITY AND SELECTED MORTALITY RATES

Office of Protected Resources, National Marine Fisheries Service

The Office of Protected Resources (F/PR) was tasked by William Hogarth, Deputy Assistant Administrator for Fisheries to review information on marine turtle mortality in longline fisheries and to make a recommendation regarding the estimation of post-interaction mortality. In addition, F/PR was directed to convene a workshop to further address the issue of mortality estimation. Finally, the Southeast Region requested input on this issue in order to incorporate any new information into their analyses of the impact of the Atlantic longline fishery on marine turtles.

Summary Findings[14]

1. F/PR recommends the use of revised serious injury/mortality criteria for defining levels of injury to turtles interacting with longline fishing gear (see below).

2. F/PR recommends that 50% of longline interactions with all species of sea turtles be classified as lethal and 50% be classified as non-lethal. The 50% lethal classification is based on our analysis and evaluation of the range of mortality discussed is several investigations for lightly and deeply hooked turtles. Our recommendation assumes additional mortality under normal fishing conditions, where turtles are infrequently boarded, and gear can be assumed to be left on turtles at a greater rate than when an observer handles a turtle for a defined experiment.

Serious Injury/Mortality Criteria

In November, F/PR received from SEC staff a preliminary strawman of serious injury/mortality criteria (Attachment A). F/PR reviewed the document in consultation with SEC sea turtle staff, who agreed that a revision was needed for greater clarity and to focus reviewer comments. F/PR revised the strawman (Attachment B) and solicited input from 33 persons including veterinarians, scientists, and gear and industry experts. F/PR received a total of 7 responses from 4 veterinarians, 2 scientists, and 1 gear/industry expert. A copy of all responses is attached, including comments from F/ST staff, responding to the draft strawman developed by the SEC (Attachment C). Attachments referred to herein are in Appendix 4.

[14] Donald R. Knowles, National Marine Fisheries Service, PR, Silver Spring, Md. Personal Communication (Memo) to Joseph E. Powers, National Marine Fisheries Service, SERO, St. Petersburg, Fla.. Marine turtle mortality resulting from interactions with longline fisheries. 9 pp., January 4, 2001. Attachments referred to therein are in Appendix 4.

Reviewer Comments

Respondents were not able to quantitatively assess criteria for determining whether a particular interaction between a turtle and longline gear will result in mortality. This is not surprising given the multitude of factors involved, including, but not limited to, the nature of the interaction, the duration of the interaction (*i.e*., time elapsed from the interaction to removal of the animal from the gear), environmental conditions at capture, species, physiological status when captured (*e.g.*, turtle recently surfaced, turtle attempting to surface), turtle size, turtle behavior as the gear is retrieved, how the turtle is handled and the lack of baseline information on what constitutes a healthy turtle from which criteria for injury may be established. While not providing quantitative guidance, respondents did however provide important qualitative assessments of longline interactions. These assessments ranged from likely to recover (for superficial external hooking injuries) to likely long-term impact with eventual death if not treated (for ingested hooks). In general, respondents raised more questions than they answered. These questions are useful in that they will help to develop and focus the upcoming workshop to further discuss these complex issues. Despite the questions, and range of comments, there were a number of responses in common that shed light on the assessment of lethal and non-lethal interactions between sea turtles and pelagic longline gear.

Two respondents suggested variations on the injury categories described in the strawman. Their comments generally agreed with the strawman's categories, except that both suggested an additional description for 'moderate' or 'minor' injury that would include visible injuries that are determined to be superficial, and interactions where the gear has been removed and the animal is not weakened. PR assumes that injuries described in this category would not result in mortality, but might reduce the animal's fitness. Therefore, a new category of observed "minor or moderate" injury is proposed.

The remaining comments can be grouped into three general categories: hooking, hooking with trailing line, and entanglement. The respondents generally indicated that the degree of damage that may result from hooking is dependent upon where on the body the hook penetrated, the depth of penetration, and the length of time the hook is present. Infection, whether localized or systemic, was another important factor in determining whether the turtle would survive the hooking event. One respondent stated that he had seen turtles with ingested hooks that were apparently healthy while other ingested hooks can cause death. Another respondent stated that any turtle with an ingested hook could be in grave danger. Physiological stresses resulting from the hooking event (*e.g*., fighting the hook) was also pointed out as a concern. Respondents categorized trailing line (*i.e.*, line that is left on the turtle), particularly line that is trailing from an ingested hook, as a significant risk. Line trailing from an ingested hook is likely to be swallowed which may occlude the gastrointestinal tract and lead to eventual death. Trailing line may become snagged and may result in further entanglement with potential loss of appendages that may affect mobility, feeding, predator evasion, or reproduction. Several respondents felt that the level of risk is dependent on the size and robustness of the turtle in relation to the length of line that is left on the turtle. Characteristics of the monofilament line may also play a role in the risk of further entanglement.

F/PR believes that the reviewer's responses clearly indicate that interactions with longline gear pose a risk to the turtle and that many variables affect that level of risk. These variables cannot be quantitatively ascertained from the existing observer records. Assigning a mortality level to each specific type of interaction based on existing records and current knowledge would be extremely difficult. Revised criteria for determining injury are provided below.

Revised Criteria for Determining Injury for Sea Turtle-Longline Fishery Interactions

I. Non-serious injuries:

1. Entanglement in monofilament line (mainlines, gangion line, or float line) where there are no visible injuries (cuts and/or bleeding), the gear is completely removed, and the turtle swims strongly away from the vessel.

II. Minor or Moderate injury:

1. Visible injuries determined to be superficial and interactions where the gear has been removed and the animal is not weakened (this category would not include ingested hooks under III. 4, below).

III. Serious injuries may result in mortality, or reduced ability to contribute to the population when released alive after the interaction:

1. Entanglement in monofilament line (mainline, gangion line, or float line) that directly or indirectly interferes with mobility such that feeding, breeding or migrations are impaired.
2. Entanglement of monofilament line (mainline, gangion line, or float line) resulting in substantial wound(s) (cuts, constriction, bleeding) on any body part.
3. Hooking external to the mouth resulting in substantial wound(s) (cuts, constriction, bleeding) with or without associated external entanglement and/or trailing attached line.
4. Ingestion of hook in beak or mouth (visible), with or without associated external entanglement and/or trailing attached line.
5. Ingestion of hook in the mouth, throat area, esophagus or deeper, with or without associated external entanglement and/or trailing attached line.

Estimating Post-Interaction Sea Turtle Mortality

F/PR has reviewed the results of research on post-hooking mortality of sea turtles interacting with longline fisheries and has discussed results with several experts. The research to determine post-hooking mortality is based primarily on satellite tracking of hard-shell turtles after their treatment for hooking/entanglement and release. The transmitters are placed on the carapace of the turtle and data are downloaded from a satellite link at pre-determined intervals when the turtle is on the surface. Some transmitters also measure the turtle's diving behavior. The lack of any satellite transmission after 30 days may be categorized as an unsuccessful track and probable turtle mortality. Properly functioning transmitters should operate anywhere from 9-18 months. The failure rate of transmitters is minimal and attachment to the turtle shell is certain, so that the sinking of the turtle after death is assumed when transmissions are no longer received after 30 days. However it is important to note that this one-month criterion cannot be evaluated for its direct relation to mortality and the actual "cut-off" for assuming mortality may be significantly higher or may be lower.

Post-Hooking Studies: Hawaii

Studies aimed at elucidating post-longline hooking mortality using satellite telemetry devices are ongoing in the Hawaii longline fishery operating in the north central Pacific. These studies have focused on olive ridleys, loggerheads, and to a lesser extent green turtles (G. Balazs, personal communication[15]). Turtles selected as part of the study are limited to those that are lightly hooked or have deeply ingested hooks. The term "lightly hooked" refers to hooks that are imbedded externally on the turtle or imbedded in the mouth or beak, and that can be removed with relative ease and without causing additional injury. The term "deep ingested" implies a hook that is not visible when the mouth is open or only part of the hook can be seen when viewed in the open mouth, in either case the "deep ingested" hook cannot be removed in the field without causing further harm. Turtles selected to carry transmitters are boarded using dip nets. Observers remove the hook and all line before beginning the transmitter attachment on lightly hooked turtles. The treatment of turtles that have deep ingested hooks differs in that the line is removed to a point as close to the hook as possible, but the hook (and in some cases attached line) remains. The transmitter attachment procedure takes several hours from start to finish, after which the turtle is released. There were no turtles studied that were entangled only and no control turtles (*i.e.*, non-hooked, wild turtles) in the same environment have been tagged as part of this study. Ongoing studies in the Eastern Tropical Pacific (ETP) may provide a control group of turtles against which to compare those tagged in the north central Pacific. However, ETP sample sizes remain small and life history stages differ for some species (*e.g.*, mature adult olive ridleys intercepted during their breeding migrations in the ETP) thus complicating comparability (P. Dutton, personal communication[16]).

Results of the Hawaii-based study, to date, are summarized in a November 2000 report by the NMFS Southwest Fisheries Science Center (NMFS 2000*a*[17]). The data are complex and some of the tracking is ongoing. However, initial results are available. The study included 35 loggerheads, 11 olive ridleys, and 3 green turtles. Of the 49 turtles outfitted with satellite transmitters (30 deep ingested, 19 lightly hooked), 30.6% (n=15) produced no transmissions or transmissions that did not exceed one month in duration (these are not considered "successful trackings"). Of these 15 turtles, four were lightly hooked (21.1%) and 11 were deeply hooked (36.7%). Analyses to test for differences in transmission time distribution, mean transmission time and mean distance traveled in the Hawaii-based study between lightly hooked and deeply

[15] George Balazs, National Marine Fisheries Service, SWFSC, Honolulu, Hawaii. Personal Communication to Barbara Schroeder, National Marine Fisheries Service, PR, Silver Spring, Md.

[16] Peter Dutton, National Marine Fisheries Service, SWFSC, La Jolla, Calif. Personal Communication to Barbara Schroeder, National Marine Fisheries Service, PR, Silver Spring, Md., January 2001.

[17] NMFS. 2000*a*. Post-hooking survival research of marine turtles (analyzed by D. Parker and G. Balazs). Unpublished Report. National Marine Fisheries Service, SWFSC, Honolulu, Hawaii, November 2000, 20 pp.

hooked turtles revealed no significant differences. Twenty-seven percent (27%) of the lightly hooked loggerheads and 42% of the deeply hooked loggerheads were classified as non-successful tracks. Seventeen percent (17%) of the lightly hooked olive ridleys and 20% of the deeply hooked olive ridleys were classified as non-successful tracks. Sample sizes of green turtles (n=3) were too small to produce meaningful results.

Reliability of transmitters is an important consideration in studies employing satellite telemetry to elucidate the behavior and migrations of sea turtles. Four “types” of transmitters were used in the Hawaii-based study. No significant differences were found in the comparison of different duty cycles or battery types for the duration of tracking for turtles that produced successful tracks (NMFS 2000*b*[18]).

We believe the cessation of transmissions within a one-month period and the absence of transmissions post-release (collectively termed “non-successful tracks) from 30.6% of the tagged turtles can be considered a minimal indicator of post-hooking mortality in this study. We believe it is unlikely that mechanical failure of the transmitters or separation of the transmitter from the turtle would cause such a result. Satellite telemetry studies on post-nesting hawksbills in the Caribbean, utilizing similar, though not identical units, resulted in only one tagged turtle (2.5%) from which no transmissions were documented and catastrophic failure of the telemetry unit is suspected (B. Schroeder, personal communication[19]). Studies deploying over 100 similar, though not identical tags (primarily Telonics ST-14 units and a smaller number of Wildlife Computer SDR units) on post-nesting loggerhead and green turtles in Florida and studies on post-nesting green turtles in Hawaii and elsewhere in the Pacific have resulted in no total failures (Balazs, personal communication[20] and Schroeder, personal communication[21]). In these studies, cessation of transmissions within short periods of time (*e.g.*, less than one month, but not total failure) are also relatively uncommon when proven attachment techniques and transmitter designs are used.

Post-Hooking Studies: Eastern Atlantic

Similar, though not identical studies are being conducted in the eastern Atlantic in an attempt to elucidate post-longline hooking mortality of immature loggerheads. This research includes wild-captured turtles (*i.e.*, not hooked) from the same area as turtles incidentally captured in the Azores swordfish longline fishery (considered “control turtles”) and was conducted in two discrete segments - Fall 1998 and Summer 2000 using Wildlife Computers

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[18] NMFS. 2000*b*. Post-hooking survival research of marine turtles: duty cycle and battery configuration analyses. Unpublished Report. National Marine Fisheries Service, SWFSC, Honolulu, Hawaii, Oct. 2000, 8 pp

[19] Barbara Schroeder, National Marine Fisheries Service, PR, Silver Spring, Md. Personal Communication.

[20] George Balazs, National Marine Fisheries Service, SWFSC, Honolulu, Hawaii. Personal Communication to Barbara Schroeder, National Marine Fisheries Service, PR, Silver Spring, Md., January 2001.

[21] Schroeder, B., National Marine Fisheries Service, PR, Silver Spring, Md,. Personal Communication.

satellite-linked Time-Depth Recorders (Bjorndal *et al*. 1999[22]; Riewald *et al*. 2000[23]). Sample sizes are considerably smaller than the Hawaii-based study, 9 turtles have been wild-captured, 3 were lightly hooked (in mouth), and 6 turtles were deeply hooked. As in the Hawaii-based studies, turtles captured incidental to the swordfish fishery were "treated" - for lightly hooked turtles, hooks and all gear were removed and for deeply hooked turtles the monofilament line was cut at the wire leader. Turtles in the Azores study were typically released within 2-4 days of capture as opposed to several hours post-capture in the Hawaii-based study. Results from the Fall 1998 study indicated that several months after capture and release all of the turtles continued to transmit, though one of the control turtles was transmitting only sporadically and with insufficient to obtain location fixes (Bjorndal *et al*. 1999). Results from the Summer 2000 study indicate that as of the end of October 2000, two of the four transmitters on control turtles and five of the six transmitters on hooked turtles continued to function. Using criteria similar to the Hawaii-based study for "successful tracks", one of the control turtles and one of the hooked turtles ceased transmitting within one month after release. Analyses to date have focused on diving behavior and movement patterns and directions. A diurnal pattern in dive behavior was evident for most hooked and control turtles, distribution of dives for hooked turtles were skewed toward longer dives and shallower dives and hooked turtles did not show the bimodal distributions of maximum dive depths that were characteristic of control turtles (Riewald *et al*. 2000). Riewald *et al*. (2000) opines that transmitters that provide dive profiles are necessary to determine whether transmitter failure is due to mortality or mechanical causes and describes the diving activity of one of the hooked turtles (still transmitting) as indicative of a dead, floating turtle, buffeted by waves. Data analyses are ongoing by the contractor.

Post-Hooking Studies: Mediterranean

A third study approached the question of post-hooking mortality in a different way. Aguilar *et al.* (1995), working in the western Mediterranean kept in captivity sea turtles that had been incidentally captured in the Spanish longline fishery with the aim of estimating the mortality rate of individuals with hooks still in their bodies. While the exact details of the study are not clearly elucidated, the assumption is that turtles held in captivity for observation had ingested a hook. It is unclear whether line attached to these hooks was removed to the maximum extent possible, but it is reasonable to assume that this was the case. Of 38 turtles reported by Aguilar (1995) 11 died in captivity, 6 expelled the ingested hook prior to their release (range of days to expulsion 53-285), 15 turtles were released prior to expulsion of the hook (range of days to release 81-123), and 6 turtles taken in 1991 remained under observation at the time the paper was written and the fates of these turtles are unknown. Excluding the 6 turtles for whom the fates are unknown, 34.4% died, 18.8% expelled the hook and 46.9% were released without hook expulsion (see ranges of days in captivity above). As with the Hawaii-based study and the Azores-based study, turtles used in this study also underwent some level of "treatment", including removal of trailing line (reasonably assumed though not explicitly stated), maintenance

[22] Bjorndal, K.A., A.B. Bolten, and B. Riewald. 1999. Development and use of satellite telemetry to estimate post-hooking mortality of marine turtles in the pelagic longline fisheries. NMFS-SWFSC Administrative Report H-99-03C, Department of Zoology, University of Florida, Gainesville, 25 pp.

[23] Riewald, B., A.B. Bolten, and K.A. Bjorndal. 2000. Use of satellite telemetry to estimate post-hooking behavior and mortality of loggerhead sea turtles in the pelagic longline fishery in the Azores. NMFS-SWFSC Final Report Order No. 40JJNF900114. Unpublished report. Department of Zoology, University of Florida, Gainesville, 28 pp.

in a captive environment where food was regularly provided and where predator avoidance was not a factor. While it may be argued that turtles are further stressed under captive conditions, we believe that the captive environment represents a less stressful environment for an injured turtle (*i.e*., one that has ingested a hook). Additionally, the Aguilar study assumes that the 15 turtles (46.9%) released before hook expulsion survived, an assumption that cannot be quantitatively determined. One respondent to the request for comments on mortality criteria opined that without definitive necropsies, Aguilar's results can not be used to address post-hooking mortality. Based on our assessment of the study, we believe that the 34.4% observed mortality reported in the Aguilar paper is a minimal estimate of mortality for ingested hooks in the wild.

Entanglement

None of the studies discussed herein involved turtles that were only entangled, not hooked, in longline gear. The applicability of the results of the studies reviewed above to "entangled only" turtles is a valid question to explore. Comments on the draft strawman suggested that the characteristics of longline monofilament make it unlikely to remain on an "entangled only" turtle once the turtle is cut free from the gear. Data from the Hawaii longline fishery observer program from 1994-1999 indicate that the overwhelming majority of interactions involving hard shelled turtles involve hooking, not entanglement only (Table 1). Hawaii longline observer records indicated that leatherback turtles are more frequently only entangled in the gear, although nearly 75% of the time, hooking is involved (Table 1). Of the eight leatherbacks observed "entangled only", 25% (n=2) were dead, 37.5% (n=3) were recorded as "okay", and 37.5% (n=3) were recorded as "injured".

Data from the Atlantic HMS longline fishery observer program indicate similar levels of "entanglement only" for loggerheads and leatherbacks. The vast majority of loggerheads are hooked while leatherbacks interact with the gear slightly differently - a greater percentage are "entangled only" (Table 2). All of the leatherbacks observed "entangled only" were alive when the gear was retrieved.

Table 1. Breakdown of type of gear interaction, hooked (includes lightly hooked, deeply hooked) vs. entangled only (no hooking involved), 1994-1999 Hawaii longline observer program (McCracken 2000[24]).

Species	Hooked	Entangled Only	Not Recorded	TOTAL
C. caretta	143 (97.3%)	3 (2.0%)	1 (0.7%)	147
D. coriacea	29 (72.5%)	8 (20.0%)	3 (7.5%)	40
L. olivacea	32 (100%)	0	0	0
C. mydas	8 (100%)	0	0	8

[24] McCracken, Marti L. 2000. Estimation of Sea Turtle Take and Mortality in the Hawaiian longline fisheries. NMFS-SWFSC Administrative Report H-00-06. Unpublished Report. NMFS/SWFSC/Honolulu, HI, 29 pp

Table 2. Breakdown of type of gear interaction, hooked (includes lightly hooked, deeply hooked) vs. entangled only (no hooking involved), 1999 Atlantic longline observer program. (Data source: J. Hoey (unpublished report, 2000[25], summary of 1999 NMFS observer data for HMS Atlantic longline).

Species	Hooked	Entangled Only	Not Recorded	TOTAL
C. caretta	60 (93.8%)	1 (1.6%)	3 (4.7%)	64
D. coriacea	26 (57.8%)	12 (26.7%)[26]	7 (15.6%)	45
Unknown	1 (33.3%)	2 (66.7%)	0	3

Conclusions and Recommendations

The Aguilar *et al*. (1995) results and the results of the Hawaii-based study, for mortality from deeply ingested hooks, 34.4% and 42% respectively, are similar. Preliminary data from the Azores study, with very limited sample sizes, indicating a 33.3% mortality from deeply ingested hooks is also in the same range, assuming one month criteria and contractor interpretation of diving behavior. Whether these results are corroborative or purely coincidental cannot be qualitatively determined. The mortality range for lightly hooked and deeply hooked hard-shelled turtles in the Hawaii-based study is 17 - 42%, based on a one-month criteria established for successful vs. non-successful tracks.

This one-month criterion cannot be evaluated for its direct relation to mortality and the actual "cut-off" for assuming mortality may be significantly higher or may be lower. It is important to remember that the turtles used in all studies underwent a level of treatment (*e.g.*, line and/or hook removal as well, recuperative time on deck, captive maintenance) that undoubtedly improved their survival outlook. We believe that mortality rates in the wild, under actual fishing conditions are likely higher than mortality rates indicated by the studies reviewed herein. Given the available information, as well as adopting a risk-averse approach that provides the benefit of the doubt to the species where there are gaps in the information base[27], F/PR

[25] Hoey, J. 2000. Unpublished summary of 1999 observer record comments on sea turtle interactions in the Atlantic HMS fishery. National Marine Fisheries Service, ST, Silver Spring, Md., 9 pp.

[26] Four of eight turtles may have been hooked in addition to entangled, hooking location unknown.

[27] The Endangered Species Act Section 7 consultation process requires NMFS to use the best available scientific and commercial data. The Services established criteria to ensure that the information used in the Section 7 consultation process was reliable, credible, and representative of the best available data (59 FR 34271; July 1, 1994). To the extent practicable, NMFS must use primary and original sources of information including, but not limited to, anecdotal, oral, and gray literature as well as published documents. If data gaps exists that would help determine the impacts to listed species and the action agency intends to proceed with the proposed action, NMFS must proceed with the existing information and is expected to provide the benefit of the doubt to the species concerned with respect to such gaps in the information base (H.R. Conference Report No. 697, 96th Congress, 2nd Session 12 (1979).

recommends that 50% of longline interactions be classified as lethal and 50% be classified as non-lethal. The 50% lethal classification considers the range of mortality discussed above for lightly and deeply hooked turtles and assumes additional mortality under normal fishing conditions, where turtles are infrequently boarded, and gear can be assumed to be left on turtles at a greater rate than when an observer handles a turtle for a defined experiment. Observer efforts to disentangle turtles and to remove trailing line can sometimes be described as heroic and while we believe that some fisherpersons will undertake similar efforts, others will not. As discussed above, most of the respondents to the NMFS request for comments/information on post-hooking mortality characterized gear left on turtles as a serious problem, especially trailing line which would be a significant risk to the turtle, especially when ingested hooks are involved. While these studies are limited to hard-shelled turtles, in the absence of evidence to suggest that interactions with leatherbacks would result in higher survival rates, we recommend that the 50% mortality figure be applied to leatherbacks as well as hard-shelled turtles. One respondent to the request for input on mortality criteria commented that leatherbacks are not as resilient as hard-shelled turtles and that actions such as hooking, lifting from the water, and ingestion of hooks and lines may have more damaging and long lasting impacts. Our review of the available information does not suggest that a differential mortality estimate can be applied to lightly hooked vs. deeply hooked *vs*. “entangled only” turtles at this time. While we believe that lightly hooked turtles and “entangled only” turtles, especially those that have trailing line and hooks removed have a greater chance of survival than deeply hooked turtles, the data do not exist to provide for a differential apportionment. In reality, the figure may be higher than 50% for deeply hooked turtles and lower than 50% for lightly hooked and “entangled only” turtles. In the future, refinements to these estimates can be made if additional information is gathered and further evidence can be provided to quantitatively define post-hooking mortality. Data collected by observers must be standardized and of sufficient detail and description to assess and categorize the interaction. F/PR intends to convene an expert workshop in early 2001 to further discuss the question of sea turtle survival following interactions with longline gear and to refine, if possible, post-interaction survival rates.

Literature Cited

Aguilar, R., J. Mas, and X. Pastor. 1995. Impact of Spanish longline fisheries on loggerhead turtle *Caretta caretta* population in the western Mediterranean. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-361:1-6.

CHAPTER 5. SUMMARY OF TAKES BY THE PELAGIC LONGLINE FISHERY IN THE ATLANTIC OCEAN AND MEDITERRANEAN SEA

Joanne Braun-McNeill and Wayne N. Witzell

Summary of Takes

The pelagic longline fishery for tuna and swordfish incidentally captures loggerhead and leatherback sea turtles (see Table 8 of Chapter 2 and Appendices 2 and 3). Loggerhead juveniles, during their pelagic life stage, circumnavigate the North Atlantic via the Atlantic Gyre and are exposed sequentially to a series of longline fisheries that primarily target swordfish and tuna. Because leatherbacks utilize the open ocean during all life stages, they are exposed to pelagic fishing gears throughout their entire life history. Loggerhead turtles readily ingest baited hooks (Witzell 1999). While leatherbacks are more likely than loggerheads to become captured through entanglement in the main and branch lines than ingestion of the baited hooks (Witzell 1984, Tobias 1991, Witzell 1999), there have been reports of leatherbacks ingesting the squid bait used on swordfish longline gear (Skillman and Balazs 1992). According to the National Marine Fisheries Service mandatory Pelagic Logbook Program records for the U.S. fleet, loggerhead and leatherback CPUE was greater with vessels utilizing light sticks (targeting swordfish) than vessels without (targeting tuna) (Witzell 1999). It has been suggested that leatherbacks are attracted to the lightsticks used by vessels targeting swordfish, perhaps mistaking the light sticks for bioluminescent schyozoa and then becoming entangled in the line (Witzell 1999). This relationship, however, could not be demonstrated from observer data where analyses indicated that sea turtle (both loggerhead and leatherback) interactions were not positively influenced by the use of lightsticks (Hoey 1998[28]). Most fishery-reported U.S. fleet longline interactions with loggerhead and leatherback turtles occur from the Mid-Atlantic Bight to areas northward. (Witzell 1999). Observer data, however, revealed greater loggerhead interactions in the Caribbean and the Gulf of Mexico for certain years (Figs. 1 and 2). Noteworthy was that marine turtle bycatch estimated from observer data was significantly higher ($p<0.05$) than that reported in logbooks (Johnson *et al.* 1999) indicating that an assessment method dependent upon the fishery's self-reporting has limitations. According to observer records, an estimated 7,891 loggerhead and 6,363 leatherback sea turtles were captured by the U.S. Atlantic tuna and swordfish longline fisheries 1992-1999 of which 66 loggerhead and 88 leatherbacks were estimated to have been released dead (Table 8 of Chapter 2). Some of those released alive may not have survived. The National Marine Fisheries Service Office of Protected Resources recommends that 50% of longline interactions with all species of sea turtles be classified as lethal (Table 1) and 50% be classified as non-lethal (see Chapter 4).

The U.S. longline fleet accounts for a relatively small proportion (<5-8%) of total hooks fished in the Atlantic Ocean compared to the other nations conducting longline fishing in this

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[28] Hoey, J.J. 1998. NEFSC pelagic longline data review & analysis of gear, environmental, and operating practices that influence pelagic longline interactions with sea turtles. Final contract report NOAA Contract - 50EANA700063. Unpublished report from National Fisheries Institute, Inc., Arlington, Va. to National Marine Fisheries Service Northeast Regional Office, Gloucester, Mass., 32 pp.

area (see Chapter 1), but accounts for an average of 28% and 18% respectively, of the swordfish and tuna landed from the North Atlantic. These other nations include Taipei, Brazil, Trinidad, Morocco, Cyprus, Venezuela, Korea, Mexico, Cuba, U.K., Bermuda, Peoples Republic of China, Grenada, Canada, Belize, France, and Ireland (Carocci and Majkowski 1998). In the tropics, Brazil, Korea, Portugal, Cuba, Peoples Republic of China, Equatorial Guinea, Spain, Libya, Cuba, Venezuela, USSR, and Portugal prosecute swordfish and tuna longline fisheries in addition to the U.S. (Carocci and Majkowski 1998). Unfortunately, leatherback incidental capture data for these other nations is limited. From 1987-1998, observers from the International Observer Program in the Scotia-Fundy Region aboard longline vessels in the north Atlantic Ocean reported the incidental capture of 25 leatherback sea turtles; the highest incidental catch of leatherbacks was in 1995 (n=10 turtles) and 1998 (n=8 turtles) (James 2000).

Uruguayan longliners targeting tuna and swordfish in the southwest Atlantic reported loggerhead and leatherback captures for the years 1994-1996 with a CPUE of 1.8/1000 hooks; an estimated 98.1% were released alive (Achaval *et al.* 2000). Observers of the Mexican longline tuna fishery in the Gulf of Mexico reported 2 loggerhead and 43 leatherback sea turtles incidentally captured in 37 fishing trips (8.5% of the total effort) (Ramirez and Ania 2000). Of the leatherbacks, 42% were caught by becoming entangled in monofilament fishing line. Estimated incidental capture of sea turtles (both loggerheads and leatherbacks) in this fishery is 5 turtles/100 trips; mortality is estimated to be 1.6 turtles/100 trips (Ramirez and Ania 2000). In Belize, longline fishing for sharks is reportedly catching leatherbacks (Smith *et al.* 1992). Incidental capture information for the longline fisheries prosecuted in the tropics also is very limited. The longline fishery in Antigua/Barbuda is estimated to catch 100 or more loggerhead and leatherback sea turtles each year (Fuller *et al.* 1992). In St. Vincent and the Grenadines, "some" leatherbacks also are caught by longlines (Scott and Horrocks 1993). Although there are longline vessels in the coastal waters of Barbados, no bycatch data is available (Horrocks 1992). Local longliners at Anegada in the British Virgin Islands have caught "some" leatherbacks (Eckert *et al.* 1992, Cambers and Lima 1990, Tobias 1991).

The longline fisheries prosecuted in the Mediterranean Sea include the countries of Algeria, Cyprus, Greece, Morocco, Spain, Italy, Malta, Taipai, Belize, Honduras, Japan, Korea, Libya, Panama, and Portugal (Carocci and Majkowski 1998). Considerably more loggerhead than leatherback sea turtles were reported incidentally captured in these fisheries. The Italian longline fleet targeting swordfish reported the incidental capture of 275 loggerhead and only a ‘few’ leatherback sea turtles from 1978-1986 (De Metrio and Magalfonou 1988), 1,817 loggerheads but only 6 leatherbacks from 1978-1981 (De Metrio *et al.* 1983), and 650 loggerheads and no leatherbacks from 1981-1990 (Argano *et al.* 1992). Out of a total of 1,098 loggerheads reported captured by the Spanish longline fleet from 1991-1992, only 2 leatherbacks were reported (Aguilar *et al.* 1995). Loggerheads observed captured in the Spanish swordfish fishery during the years 1986-1995 ranged from 443-8389 (mean=4417); estimated number captured ranged from 1,953-19,987 (mean=11,673) (Camiñas 1997). Malta's swordfish longline fishery was estimated to catch 1,500-2,500 loggerhead but no leatherback sea turtles; an estimated 500-600 loggerheads were killed (Gramentz 1989). From 1989-1991, 116 loggerhead but no leatherback sea turtles were caught in 531 fishing trips; an estimated 70-100 loggerhead turtles are captured annually with multiple recaptures noted (Panou *et al.* 1991[29], 1992[30]).

Impacts of the Pelagic Longline Fishery on Sea Turtle Populations

It is very difficult to identify the impact of a fishery on sea turtle populations as the response of the populations is based on the cumulative impacts from all sources. The environmental baseline against which the pelagic longline fishery is being evaluated can be found in Appendix 1 and is discussed in the Impacts sections of both the loggerhead and leatherback stock assessment reports (Part I and Part II).

An important consideration in assessing fishery impacts on sea turtle populations is whether or not interactions result in mortality and subsequent loss to the population. Sea turtles that are stressed as a result of being forcibly submerged rapidly consume oxygen stores, triggering an activation of anaerobic glycolysis, and subsequently disturbing the acid-base balance, sometimes to lethal levels (Lutcavage and Lutz 1997). Forced submergence for extended periods is marked with metabolic acidosis as a result of high blood lactate levels and recovery may be as long as 20 hours (*Ibid*.). Additional factors such as size, activity, water temperature, and biological and behavioral differences between species also bear directly on metabolic rates and aerobic dive limits and will therefore also influence survivability after a gear interaction. In addition, disease factors and hormonal status may also play a role in anoxic survival during forced submergence. Although turtles released "unharmed" do not have visible injuries, they may have been stressed from being caught or entangled in gear. Recent necropsy results from the Hawaiian fishery (Work 2000[31]) indicated that there seems to be a higher incidence of observed drowning mortality in the Hawaiian fishery than the Atlantic fishery, possibly to differences in fishing strategy (lines are fished deeper in the Pacific) and/or turtle species composition (7 olive ridleys, 2 greens, 2 leatherbacks). In Atlantic observers' records for 1992-1996, only one observed leatherback turtle out of 82 was obviously moribund and only 1 loggerhead out of 51 turtles (hard-shelled) appeared dead (Lee and Brown 1998). Work also concluded that mortality rates using the "lightly hooked' vs. "deeply hooked" criteria may not be satisfactory criteria to determining probability of survival.

[29] Panou, A., S. Moschonas, L. Tselentis, and N Voutsinas. 1991. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Inst. Zool. Univ. Munich, Germany. Unpublished Report. Institute of Zoology, University of Munich, Germany, 6 pp.

[30] Panou, A., G. Antypas, Y. Giannopoulos, S. Moschonas, D. Mourelatos, G. Mourelatos, Ch. Mourelatos, P. Toumazatos, L. Tselentis, N. Voutsinas, and V. Voutsinas. 1992. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Unpublished Report. Institute of Zoology, University of Munich, Germany, 8 pp.

[31] Work, T.M. 2000. Synopsis of finding of sea turtles caught by the Hawaii-based pelagic longline fishery. Unpublished Report. U.S. Geological Survey, National Wildlife Health Center, Hawaii Field Station, Honolulu, Hawaii, 5 pp.

In areas of turtle concentrations (*e.g*., Mediterranean Sea, Grand Banks) turtles have been reported to have been hooked from two to eight times (Panou *et al*. 1991[32,]1992[33], Gramentz, 1989, Argano *et al*. 1992, Witzell 1999, Hoey and Moore 1999[34]). This not only compounds mortality estimates, but it also complicates take estimates. Current bycatch estimates do not take into consideration that an animal may be captured multiple times. Also, we do not yet have serious injury criteria upon which an animal may be assessed for likelihood of survival and therefore we are assuming that 50% of all animals interacting with the pelagic longlines subsequently die as a result of that interaction, regardless of where hooked, amount of line remaining on the animal, or the species (Table 1).

Literature Cited

Achaval, F., Y. H. Marin, and L.C. Barea. 2000. Incidental capture of turtles with pelagic longline. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-436:261.

Aguilar, R., J. Mas, and X. Pastor. 1995. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the Western Mediterranean. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-361:1-6.

Argano, R., R. Basso, M. Cocco, and G. Gerosa. 1992. Nouvi data sugli spostamenti di tartaruga marina comune (*Caretta careta*) in Mediterraneo. Bollettino Musel Istitiuti Universita Genova 56-57:137-163.

Cambers, G. and H. Lima. 1990. Leatherback turtles disappearing from the BVI. Marine Turtle Newsletter 49:4-7.

Camiñas, J.A. 1988. Incidental captures of *Caretta caretta* (L.) with surface long-lines in the western Mediterranean. Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration de la Mer Mediterranee 31(2): 285.

Camiñas, J.A. 1997. Capturas accidentales de tortuga boba (*Caretta caretta*, L. 1758) en el Mediterráneo occidental en la pesquería de palangre de superficie de pez espada (*Xiphias gladius* L.). International Commission for the Conservation of Atlantic Tunas Collective Volume of Scientific Papers 46:446-455.

[32]Panou, A., S. Moschonas, L. Tselentis, and N Voutsinas. 1991. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Inst. Zool. Univ. Munich, Germany. Unpublished Report. Institute of Zoology, University of Munich, Germany, 6 pp.

[33]Panou, A., G. Antypas, Y. Giannopoulos, S. Moschonas, D. Mourelatos, G. Mourelatos, Ch. Mourelatos, P. Toumazatos, L. Tselentis, N. Voutsinas, and V. Voutsinas. 1992. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Unpublished Report. Institute of Zoology, University of Munich, Germany, 8 pp.

[34]Hoey, J.J. and N. Moore. 1999. Captain's report: multi-species catch characteristics for the U.S. Atlantic pelagic longline fishery. MARFIN Grant – NA77FF0543 and SK Grant – NA86FD113 from National Marine Fisheries Service, Silver Spring, MD to National Fisheries Institute, Inc., Arlington, VA, 78 pp.

Carocci, F. and J. Majkowski. 1998. Atlas of tuna and billfish catches. CD-ROM version 1.0. FAO, Rome, Italy.

De Metrio, G. and P. Megalofonou. 1988. Mortality of marine turtles (*Caretta caretta* L. and *Dermochelys coriacea* L.) consequent to accidental capture in the Gulf of Taranto. Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration de la Mer Mediterranee 31(2):285.

De Metrio, G., G. Petrosino, A. Matarrese, A. Tursi, and C. Montanaro. 1983. Importance of the fishery activities with drift lines on the populations of *Caretta caretta* (L.) and *Dermochelys coriacea* (L.) (Reptilia, Testudines), in the Gulf of Taranto. Oebalia IX, N.S.: 43-53.

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 Environmental Programme, United Nations Environment Programme, Technical Report 17,116 pp. Kingston, Jamaica.

Fuller, J.E. K.L. Eckert, and J.I. Richardson. 1992. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST), sea turtle recovery action plan for Antigua and Barbuda. Caribbean Environmental Programme, United Nations Environment Programme, Technical Report 16, 88 pp. Kingston, Jamaica.

Gramantz, D. 1989. Marine turtles in the central Mediterranean Sea. Centro 1(4): 41-56.

Horrocks, J. 1992. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST), sea turtle recovery action plan for Barbados. Caribbean Environmental Programme, United Nations Environment Programme, Technical Report 12, 61 pp. Kingston, Jamaica.

James, M.C. 2000. Distribution of the leatherback turtle (*Dermochelts coriacea*) in Atlantic Canada: evidence from an observer program, aerial surveys and a volunteer network of fish harvesters. M.S. Thesis, Acadia University, 71 pp.

Johnson, D.R., C. Yeung, and C.A. Brown. 1999. Estimates of marine mammal and marine turtle bycatch by the U.S. Atlantic pelagic longline fleet in 1992-1997. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-418, 70 pp.

Lee, D.W. and C.J. Brown. 1998. SEFSC pelagic observer program data summary for 1992-1996. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-408, 21 pp.

Lutcavage, M.E. and P.L. Lutz. 1997. Diving physiology. *In* P.L. Lutz and J.A. Musick, eds. The biology of sea turtles. CRC Press, Boca Raton, Florida, 432 pp.

Ramirez, P.A.U. and L.V.G. Ania. 2000. Incidence of marine turtles in the Mexican long-line tuna fishery in the Gulf of Mexico. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SEFSC-436:110.

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 Environmental Programme, United Nations Environment Programme, Technical Report 27, 80 pp. Kingston, Jamaica.

Skillman, R.A. and G.H. Balazs. 1992. Leatherback turtle captured by ingestion of squid bait on swordfish longline. Fishery Bulletin 90:807-808.

Smith, G.W., K.L. Eckert, and J.P. Gibson. 1992. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST), sea turtle recovery action plan for Belize. Caribbean Environmental Programme, United Nations Environment Programme, Technical Report 18, 86 pp. Kingston, Jamaica.

Tobias, W. 1991. Turtles caught in Caribbean swordfish net fishery. Marine Turtle Newsletter 53:10-12.

Witzell, W.N. 1984. The incidental capture of sea turtles in the Atlantic U.S. Fishery Conservation Zone by the Japanese tuna longline fleet, 1978-81. Marine Fisheries Review 46(3):56-58.

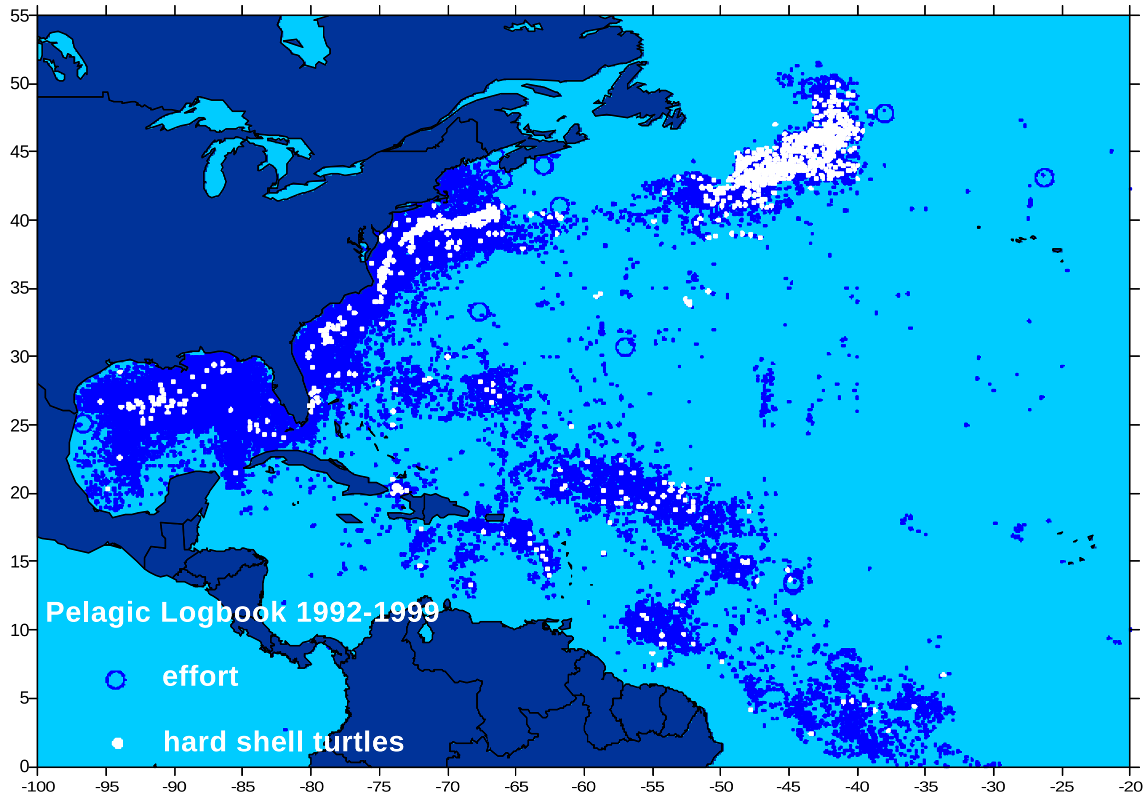
Witzell, W.N. 1999. Distribution and relative abundance of sea turtles caught incidentally by U.S. longline fleet in the western North Atlantic Ocean, 1992-1995. Fishery Bulletin 97:200-211.

Table 1. Estimated deaths of sea turtles in the U.S. Atlantic pelagic longline fishery. Mortality estimates are 50% of the total bycatch estimates (see Chapter 2, Table 8).

Species	1992	1993	1994	1995	1996	1997	1998	1999
Loggerhead	147	209	672	1220	459	192	553	496
Green	44	16	17	20	8	0	7	0
Hawksbill	10	0	0	0	0	8	9	0
Kemp's Ridley	1	0	13	0	0	11	0	0
Unidentified	13	16	17	86	1	24	1	33
All hardshell turtles*	214	240	719	1325	468	235	569	529
Leatherback	457	527	419	467	452	154	200	506

* Assuming all unidentified turtles are hardshell turtles.

Figure 1. Hardshell and leatherback turtles reported captured in the U.S. pelagic longline fleet's logbooks and effort reported therein.



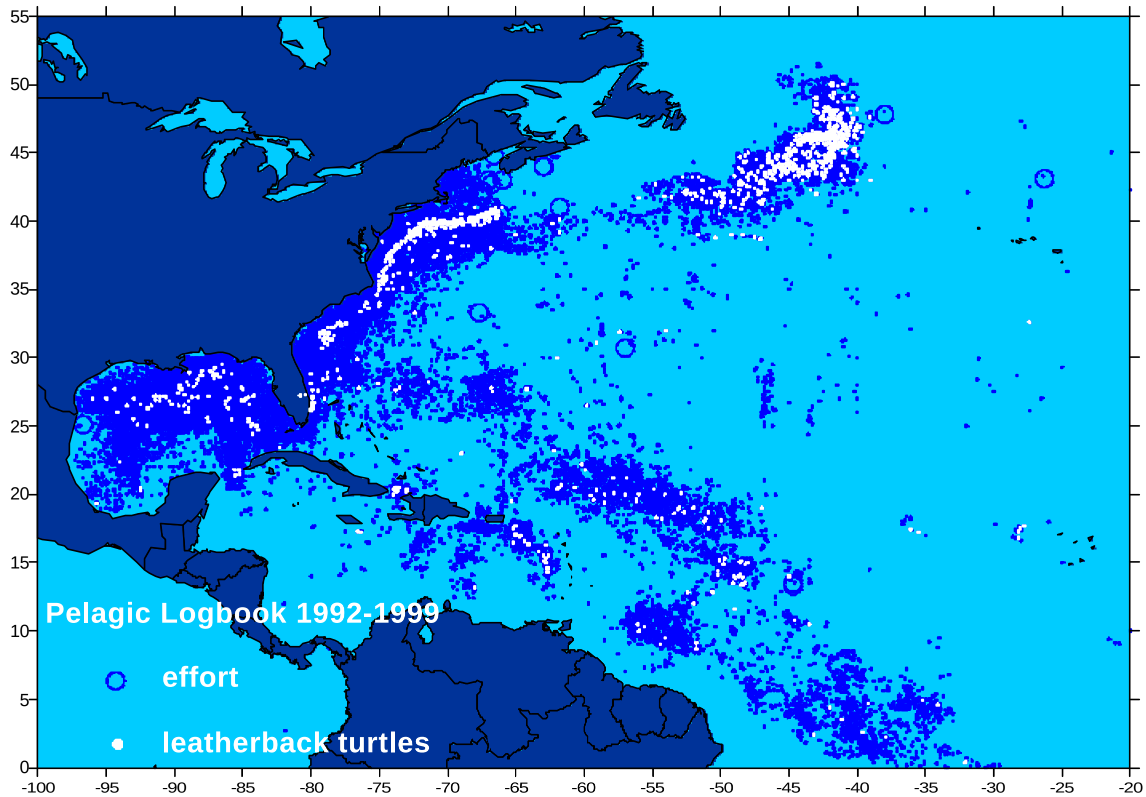
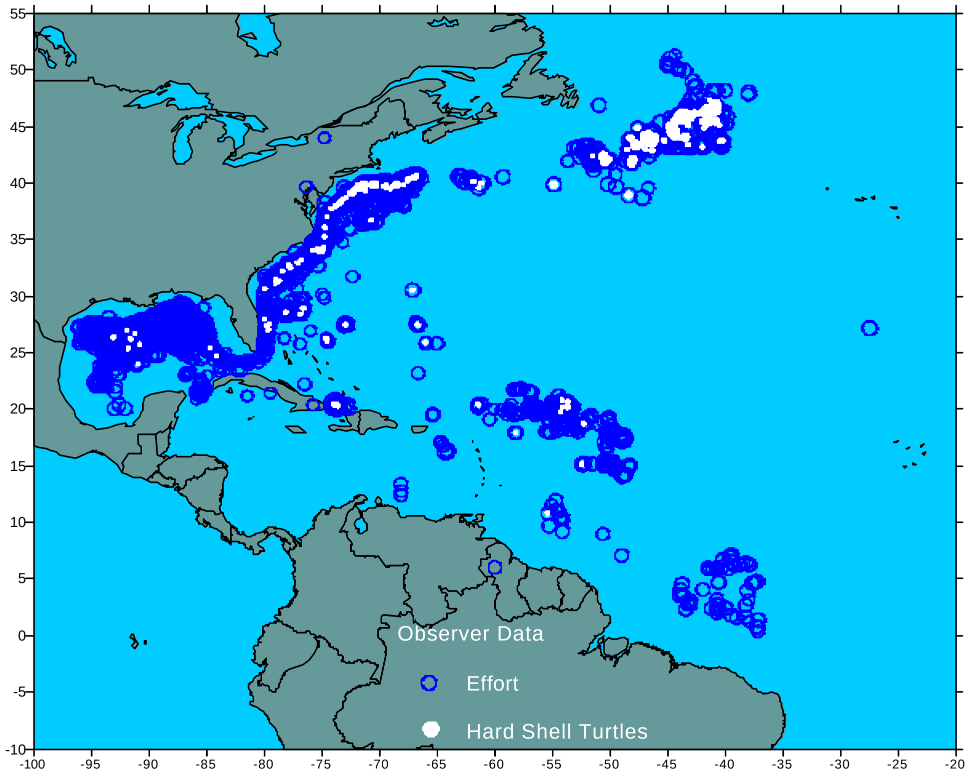
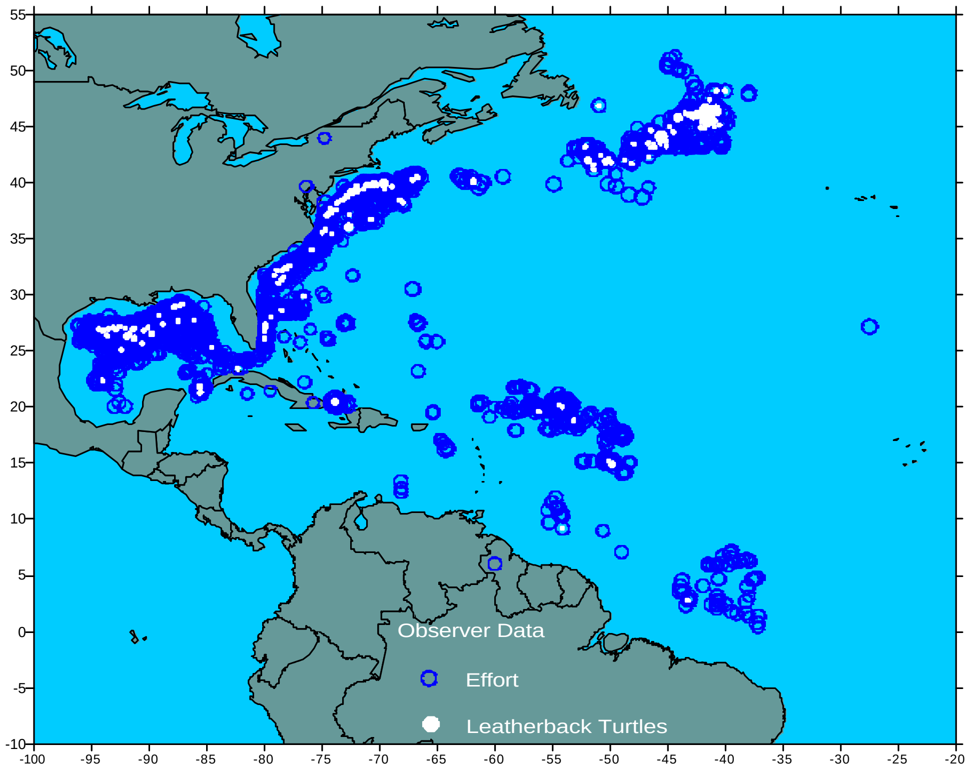


Figure 2. Hardshell and leatherback sea turtle captures reported by observers in the U.S. pelagic longline fleet and observed fishing effort.





CHAPTER 6. IMPACT OF THE PELAGIC LONGLINE FISHERY ON LOGGERHEAD SEA TURTLES

Sheryan P. Epperly, Melissa L. Snover, and Larry B. Crowder

The loggerhead sea turtle (*Caretta caretta*) occurs throughout the temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans (Dodd 1988). Its range of habitat includes open ocean waters, continental shelves, bays, lagoons, and estuaries. Loggerheads in the Western North Atlantic nest on high-energy beaches between the latitudes of 18° and 35° North. At least 5 subpopulations have been identified as management units and there may be more. Loggerheads are long-lived species which typically cannot withstand high exploitation rates, whether intentional or incidental (Heppell *et al*. 1999).

The impact of the pelagic longline fishery on loggerhead sea turtle management units must be assessed in the context of existing sources of mortality. Appendix 2 identifies known sources of anthropogenic impacts on sea turtle populations. Relative to the identified domestic (U.S.) sources, if we assume that 50% of all takes by the pelagic longline fishery result in mortality (see Chapter 5, Table 1), the impact of the pelagic longline fishery on loggerhead sea turtles, in terms of numbers of animals removed from the population, is second only to that of the shrimp fishery. However, survival of interactions in both of these fisheries might be increased through NMFS regulatory actions.

NMFS has taken steps to reduce the mortality of sea turtles in the shrimp fishery and is proposing further actions. Federal regulations have required turtle excluder devices (TEDs) in shrimp trawls at least seasonally since 1990. In early 2000 NMFS published an advance notice of proposed rulemaking (65 FR 17852-17854, April 5, 2000). The agency is proposing technical changes to the requirements for TEDs, including modifying the size of the escape opening to allow the larger benthic immature and adult turtles to escape. Epperly and Teas (1999[35]) determined that the body depth of loggerhead turtles is exceeding the minimum required TED height openings before the turtles can reach maturity. Turtles with deeper bodies than the height opening cannot escape; hence existing TEDs likely only are beneficial to the small benthic immature stage of loggerheads.

Heppell *et al.* (in press) constructed matrix projection models to assess the impacts of different TED effectiveness scenarios on population growth. They looked at 2 models, one using parameters from previous matrix models and one using parameters consistent with new information about growth rates of loggerheads. They initiated the model runs with a population declining at a rate of 5% per year. In the model runs where only small turtles benefit from the use of TEDs, the rate of decline in population growth rates slowed, however, the trend was still negative. Only when small and large benthic turtles both benefited with decreases in mortality did the population trend become positive. Including reductions in mortality for adult sized animals increased population growth rates further.

[35] Epperly, S.P. and W.G. Teas. 1999. Evaluation of TED opening dimensions relative to size of turtles stranding in the Western North Atlantic. Unpublished Report. National Marine Fisheries Service Southeast Fisheries Science Center Contribution PRD-98/99-08, 31 pp., Miami, Fla.

In Part I we revised the models of Heppell *et al.* (in press) with new vital rate information and looked at 4 models representing different possible stage durations and lengths of time to maturity. We initiated our model runs at three different population growth rates, at declines of 5% and 3% per year and a stable population at 0% change per year. We also looked at three different possible sex ratios where the proportion of female offspring were 0.35, 0.50 and 0.80. See Part I for model results.

Through the current reinitiation of consultation on the pelagic longline fishery, NMFS may be able to identify reasonable and prudent alternatives that would effect some proportional reduction in mortality of sea turtles by the pelagic longline fishery. Some measures to reduce mortality already are in place and others are under consideration (see Chapter 8). Effective early 2001 all Atlantic pelagic longline vessels issued Federal Highly Migratory Species permits must carry on board dipnets and line clippers and must comply with requirements for the use for these and for the handling of incidentally caught sea turtles (65 FR 60889-60892, October 13, 2000). This measure was designed to reduce the mortality rate of captured sea turtles by providing devices to facilitate the removal of hooks and line from the turtles.

We examined the effect of two possible regulations: (1) the expanded TED regulations and (2) unidentified regulations that would effect some proportional reduction in mortality by the pelagic longline fishery. These actions would be affecting two different life stages of loggerheads. The TED regulations would positively affect survival in the benthic immature and adult stages. A decrease in the mortality due to the pelagic longline fishery would positively affect survival of the pelagic immature stage.

These regulatory effects are evaluated relative to the first of the recovery goals set for the species (NMFS and USFWS 1991):

1. The adult female population in Florida is increasing and in North Carolina, South Carolina, and Georgia, it has returned to pre-listing levels (N.C.-800 nests/season; S.C.=10,000 nests/season; Ga.=2,000 nests/season). The above conditions must be met with data from standardized surveys which will continue for at least 5 years after delisting.
2. At least 25 percent (560 km) of all available nesting beaches (2,240 km) are in public ownership, distributed over the entire nesting range and encompassing at least 50 percent of the nesting activity within each State.
3. All priority one tasks have been successfully implemented.

We evaluate the population trajectories of the annual numbers of nesting females under different management scenarios: (1) expanded TED regulations in the absence of any regulation of the pelagic longline fishery, (2) regulation of the pelagic longline fishery alone to effect an increase in survival of pelagic animals, and (3) the combination of both regulations. The number of nesting females can be related to the number of nests identified in the recovery goal by assuming that a female, on average, lays 4.1 clutches of eggs/season (Murphy and Hopkins

1984[36]). In 1990 an estimated 7,737 nests were observed in the northern subpopulation, translating to 1,887 nesting females (TEWG 2000). Thus, all the model runs begin with an adult female population size of 2,000 animals in 1990. At the time the recovery plan was written management units had not been identified. The beaches of North Carolina, South Carolina, and Georgia roughly approximate the nesting range of the northern subpopulation but the subpopulation's nesting range also includes northern Florida. From 1990 to 1998, the contribution of northern Florida to total nest numbers for the northern subpopulation averaged 21% (TEWG 2000). Thus the recovery goal of 12,800 nests/season for North Carolina, South Carolina and Georgia translates to an estimated 15,488 nests/season for the northern subpopulation, corresponding to 3,777 nesting females per season.

In Part I, we considered 4 models, each based on different stage lengths and time to maturity. We found that for the combination of parameters in model 2, the pelagic survival rates were unreasonably high, 0.91 and 0.99, and not likely to be representative of actual annual pelagic stage survival rates for loggerheads. Hence, we consider only models 1, 3, and 4 in this impact assessment. For each of the 3 models, we looked at three possible initial population growth rates for the northern subpopulation, -5% per year (suggested for South Carolina trends in TEWG (1998) and used in models by Heppell *et al.* (in press), -3% per year (estimated for Little Cumberland Island, Georgia trends by Frazer (1983) and used in models by Crouse *et al.* (1987) and Crowder *et al.* (1994) and 0% per year (suggested by a preliminary meta-analysis of nesting trends (see Appendix 1 of this document for the revised analyses)). For this impact assessment we again consider all three possible population growth rates as there is evidence for each of them and we cannot eliminate any one of them unequivocally.

Within each of these population growth rates we considered 3 possible sex ratios. From our analysis of sex ratios of the individual subpopulations (Part I), we estimated 35% female hatchlings are produced in the northern nesting subpopulation and 80% in the south Florida subpopulation. To be consistent with the historical models we also consider a 50% production of female offspring. In summary there are 27 different model scenarios: 3 different stage durations (Models 1, 3, and 4) (see Tables 11-14 in Part I), 3 different pre-TED regulations population growth rates, and 3 different sex ratios.

Expanded TED Regulations

We first looked at the effect of expanded TED regulations on population growth rates. The models were initiated with a population at stable age distribution for annual survival rates incorporating a 30% reduction in mortality for small benthic turtles and subsequently run with annual survival rates incorporating 30% reductions in mortality for large benthic juveniles and adults. The models run at a sex ratio of 0.5 are most comparable to Heppell *et al*. (in press) (Fig. 1). Heppell *et al.* (in press) found that an initial population growth rate of –5% would achieve positive population growth rates with similar mortality reductions. We found that while positive growth rates are achieved for the model representative of historical population parameters (Model 1), positive growth rates are not achieved for the new population vital rates (Models 3

[36] Murphy, T.M. and S.R. Hopkins. 1984. Aerial and ground surveys of marine turtle nesting beaches in the southeast region, U.S. Final report to National Marine Fisheries Service Southeast Fisheries Science Center. Unpublished Report. South Carolina Marine Resources Department, Charleston, S.C., 52 pp.

and 4). Population growth rates are positive for all models at the remaining two initial population growth rates (-3% and 0%, Fig. 1)

At a sex ratio of 0.35, which results in a fecundity value that is likely more representative of the northern subpopulation, a similar trend is seen though proportionately reduced and populations only achieve stable growth (0%) when the initial population is declining at –3% per year (Fig. 2). When the production of female offspring increases to 80%, the expanded TED regulations (% change in pelagic survival equals 0) result in increasing population trends in all cases except for Model 4, which has the longest stage durations, at a population that is initially declining at a rate of –5% per year (Fig. 3). Population trajectories are plotted in Figs. 5-7, 9-11, and 13-15 as a 0% change in pelagic survival. The initial increases in nesting females in each of these plots results from increased survival of adults and increased numbers of large benthic juveniles reaching maturity. Once the pulse of large benthic juveniles has aged through to adults (length of time equal to the duration of the large benthic juvenile stage), the numbers of nesting females levels out or begins to decline depending on the population growth rate. Other shifts will occur once the offspring of the increased number of adults reach maturity, however this can only be seen in the plots for Model 1 (Fig. 5, 9, and 13) as time series were not run long enough for Models 3 and 4 (Fig. 6, 7, 10, 11, 14, and 15).

<u>Changes in Pelagic Juvenile Annual Survival Rates</u>

We next examined how a potential regulation of the pelagic longline fishery to affect an increase in survival of pelagic animals would impact population growth rates. For the same 27 model scenarios described above, we increased and decreased pelagic juvenile annual survival rates by 5 and 10%. These models were again initialized with survival rates representing a 30% reduction in mortality in the small benthic juvenile stage.

At a sex ratio of 0.35 and a population initially declining at a rate of 5% per year, reductions in pelagic mortality rates alone are not enough achieve increasing population growth rates with the exception of a 10% increase in survival in Model 1 (Figs. 16 and 17). If the initial population is stable, increases in pelagic juvenile survival rates proportionately increase annual population growth rates beyond that affected by reduced mortality in small benthic juveniles alone (represented by the 0% annual population growth rate). However, decreases in pelagic juvenile survival reduce or negate the benefits of increased small benthic juvenile survival and at a 10% reduction in pelagic juvenile survival, populations are in decline (Fig. 16). The population trajectories for the numbers of nesting females associated with each population growth rate in Fig. 16 are plotted in Figs. 17-19. As the trajectories consider adults only, no benefits or negative impacts of changes in juvenile survival rates are seen until the effected stages reach maturity, or the sum of the lengths of the small and large benthic juvenile stages. As discussed in the above section, the effects of the increased/decreased numbers of offspring from the changes in numbers of nesting females result in another pulse in the population a generation later.

Similar but proportionately more positive trends are seen when you increase fecundity with sex ratios of 0.50 and 0.80 (Figs. 20-27). When populations are exhibiting only slight increases in growth rates (less than about 0.5%), decreases in pelagic juvenile survival rates result in decreasing population growth rates. Conversely, when populations are slightly decreasing as in Fig. 20, λ=0.97, Model 3 and Fig. 24, λ=0.97, and Model 4, increases in pelagic juvenile annual survival rates achieve positive population growth rates.

Combination of Expanded TED Regulations and Changes in Pelagic Juvenile Annual Survival

To look at the combination of both regulations, we initialized the models in the same manner described above and ran them with 30% reductions in mortality for large benthic juveniles and adults with pelagic juvenile survival rates increased and decreased at 5 and 10%.

At a sex ratio of 0.35, the highest survival rate scenario (+10% for pelagic juvenile survival) decreased the –5% per year population decline to almost 0% for the models incorporating updated stage durations (3 and 4) (Figs. 4-7) and resulted in increasing trends for sex ratios of 0.50 and 0.80 (Figs. 8-15). At initial population declines of 3% per year, expanded TED regulations alone achieve 0 population growth and the additional benefit of increased pelagic juvenile survival result in positive trends (Figs. 4-7).   When the initial population is stable, increases in survival for all benthic stages maintain positive population growth rates even at decreases in pelagic juvenile survival of 10% for all sex ratios (Figs. 4-15).

Population Recovery

Because of the uncertainties involved in parameterizing these models, the population trajectory plots should not be used to quantitatively assess population size (Heppell *et al.* in press). However, in a general analysis of the plots it is apparent that some of the model combinations for the 0.35 sex ratio will not achieve the recovery goals of 3,777 nesting females per year in the time span modeled (NMFS and USFWS 1991). We believe that the stage durations of Models 3 and 4 are most representative of loggerhead growth rates for the northern subpopulation. For initial declining population growth rates of 5% and 3%, none of the regulation scenarios result in recovered populations within 25 years (Figs. 6, 7, 18 and 19) for these two models. This is due to the long benthic juveniles stages of these two models (24 and 33 years respectively), and the fact that there is a time lag before the benefits of increased juvenile survival results in increasing number of nesting females on the beach. The scenarios with increased survival for all in-water life-stages result in much more rapid recoveries (Figs. 6 and 7 compared to Figs. 18 and 19). If the populations were stable prior to the 1990 TED regulations, then the populations represented by Models 3 and 4 at a 0.35 sex ratios appear to be recovering, again at a much faster rate if all in-water stages have increased survivorship. (Fig. 6, 7, 18, 19). Decreased pelagic juvenile survival neutralizes or negates the recovery.

Literature Cited

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.

Dodd, C.K., Jr. 1988. Synopsis of the biological data on the loggerhead sea turtle Caretta caretta (Linnaeus 1758). U.S. Department of the Interior, Fish and Wildlife Service Biological Report 88(14), 110 pp.

Frazer, N.B. 1983. Demography and life history of the Atlantic loggerhead sea turtle (*Caretta caretta*). Ph.D. Dissertation. University of Georgia.

Hempell,S.S., L.B. Crowder, D.T. Crouse, S.P.Epperly, and N.B. Frazer. in press. Population models for Atlantic loggerheads; past, present and future. In A. Bolton and B. Witherington, editors, Synopsis of the Biology and Conservation of Loggerhead Sea Turtles, Smithsonian Institution Press.

Heppell, S.S., L.B. Crowder, and T.R. Menzel. 1999. Life table analysis of long-lived marine species with implications for conservation and management. American Fisheries Society Symposium 23:137-148.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1991. Recovery plan for U.S. population of loggerhead turtles. National Marine Fisheries Service, Silver Spring, Md., 64 pp.

Richardson, J.I. and T.H. Richardson. 1982. An experimental population model for the loggerhead sea turtle (*Caretta caretta*), pp. 165-174. In K.A. Bjorndal, ed. Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.

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, 96pp.

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.

Figures 1-3. Annual population growth rates for expanded TED regulations that reduce mortality in all benthic stages by 30%. Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 050 for Figure 1, 0.35 for Figure 2 and 0.80 for Figure3.

Figure 1

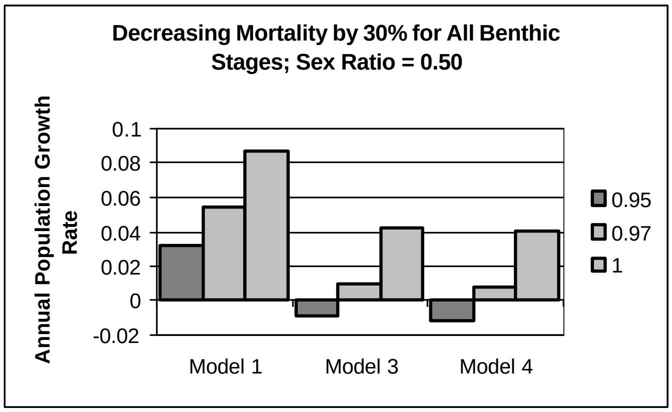


Figure 2

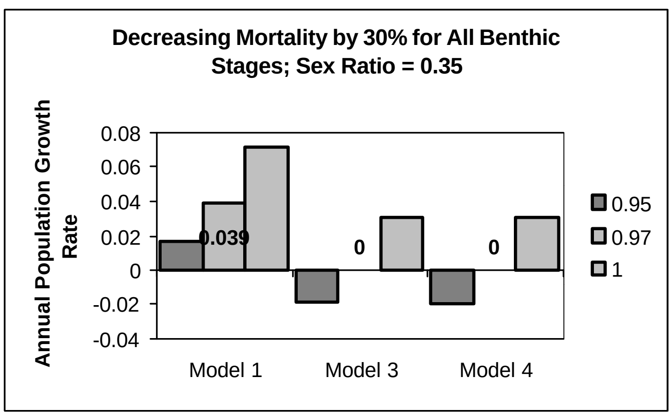


Figure 3

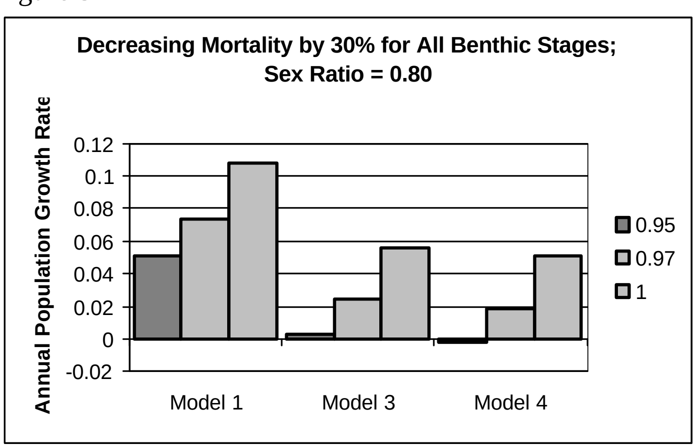


Figure 4. Annual population growth rates for expanded TED regulations that reduce mortality in all benthic stages by 30%. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.

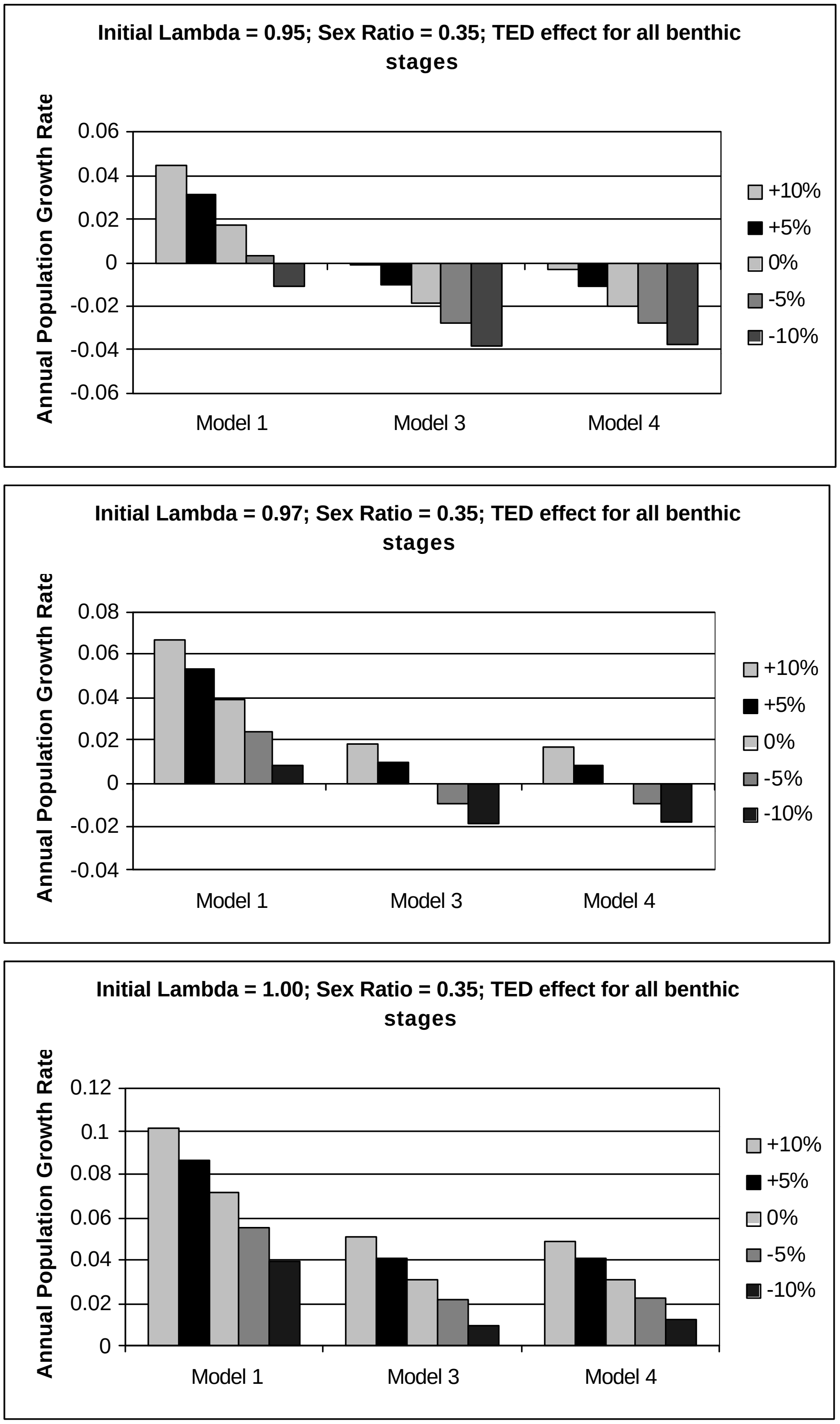
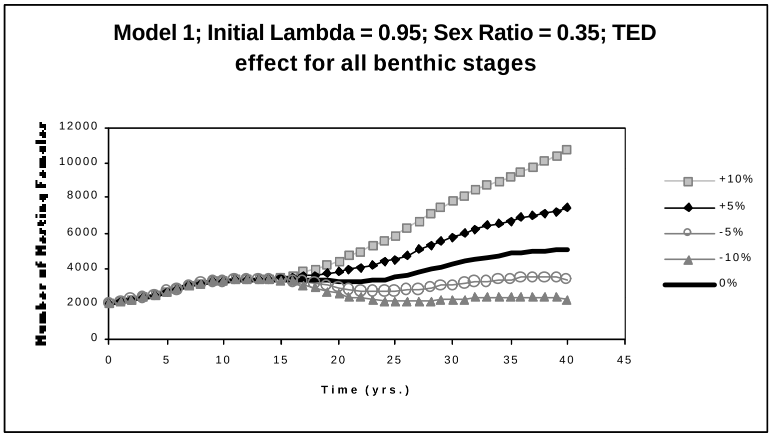
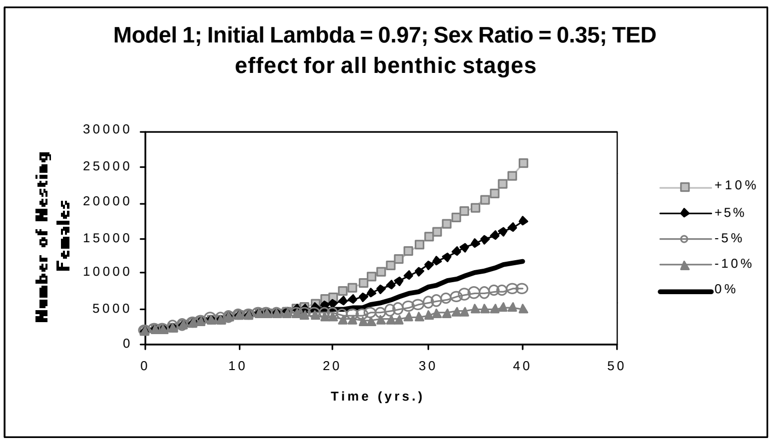


Figure 5. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 1 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.





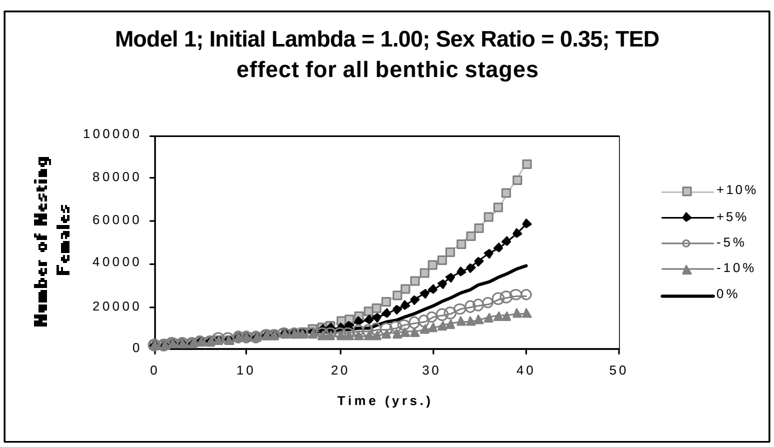


Figure 6. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 3 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.

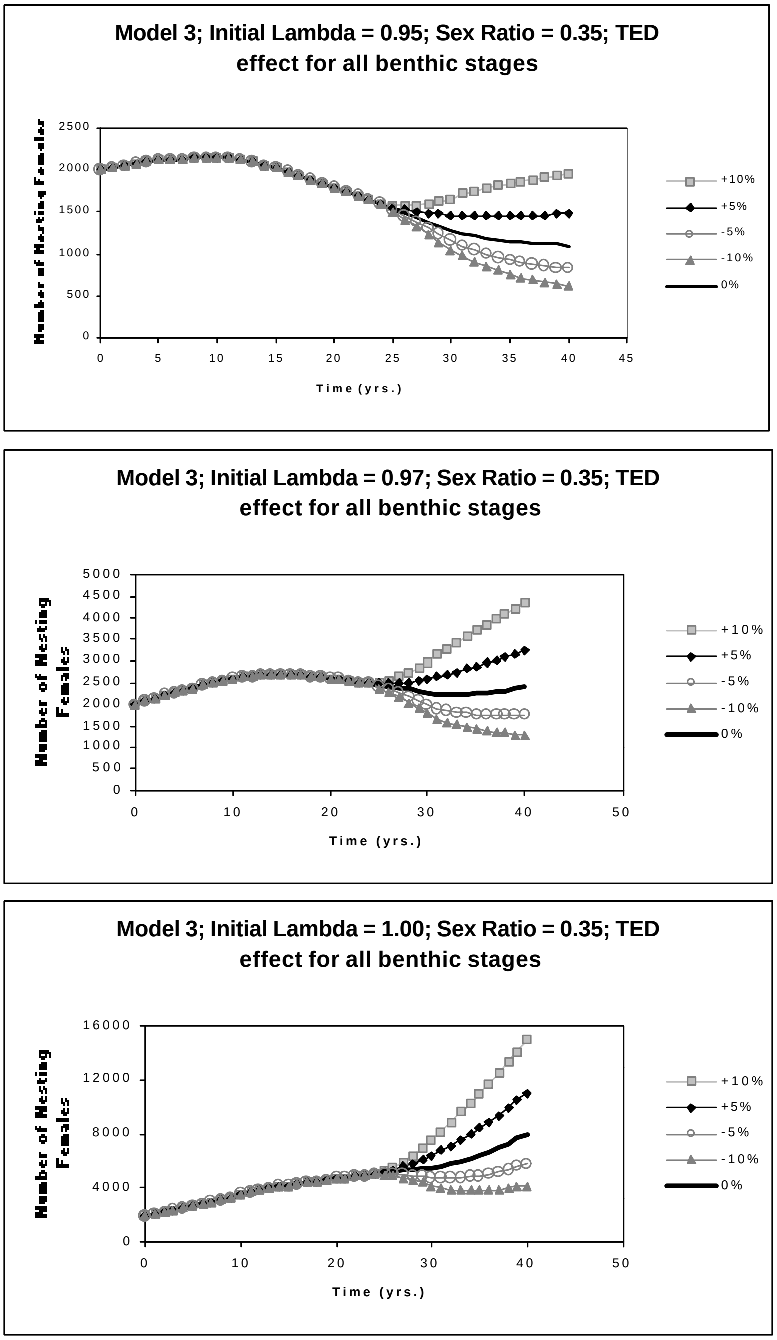
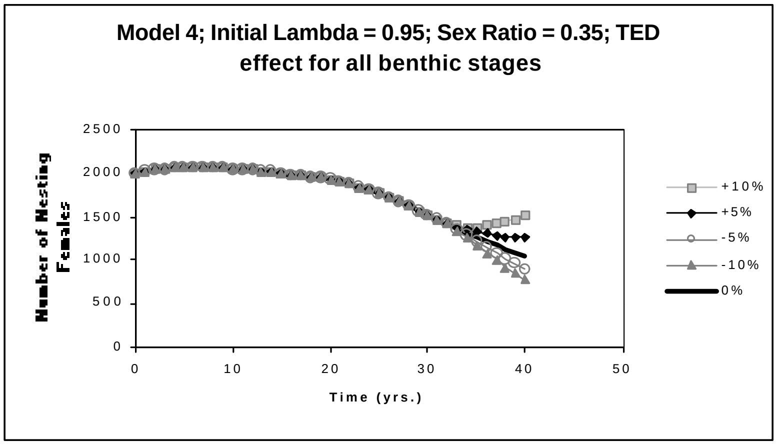
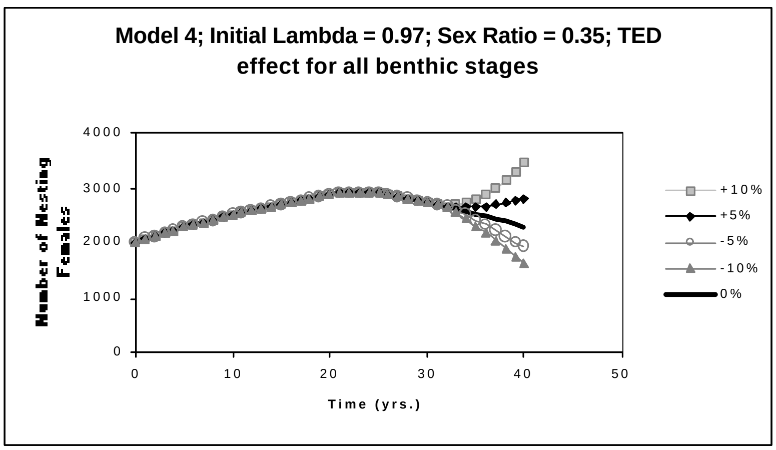


Figure 7. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 4 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.





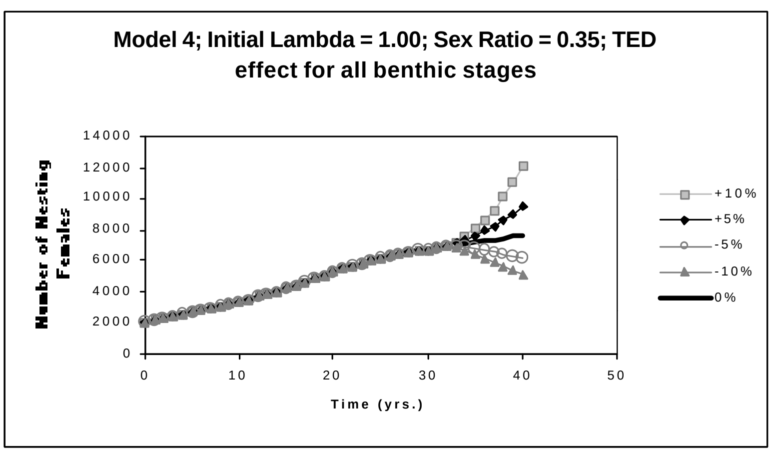


Figure 8. Annual population growth rates for expanded TED regulations that reduce mortality in all benthic stages by 30%. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.

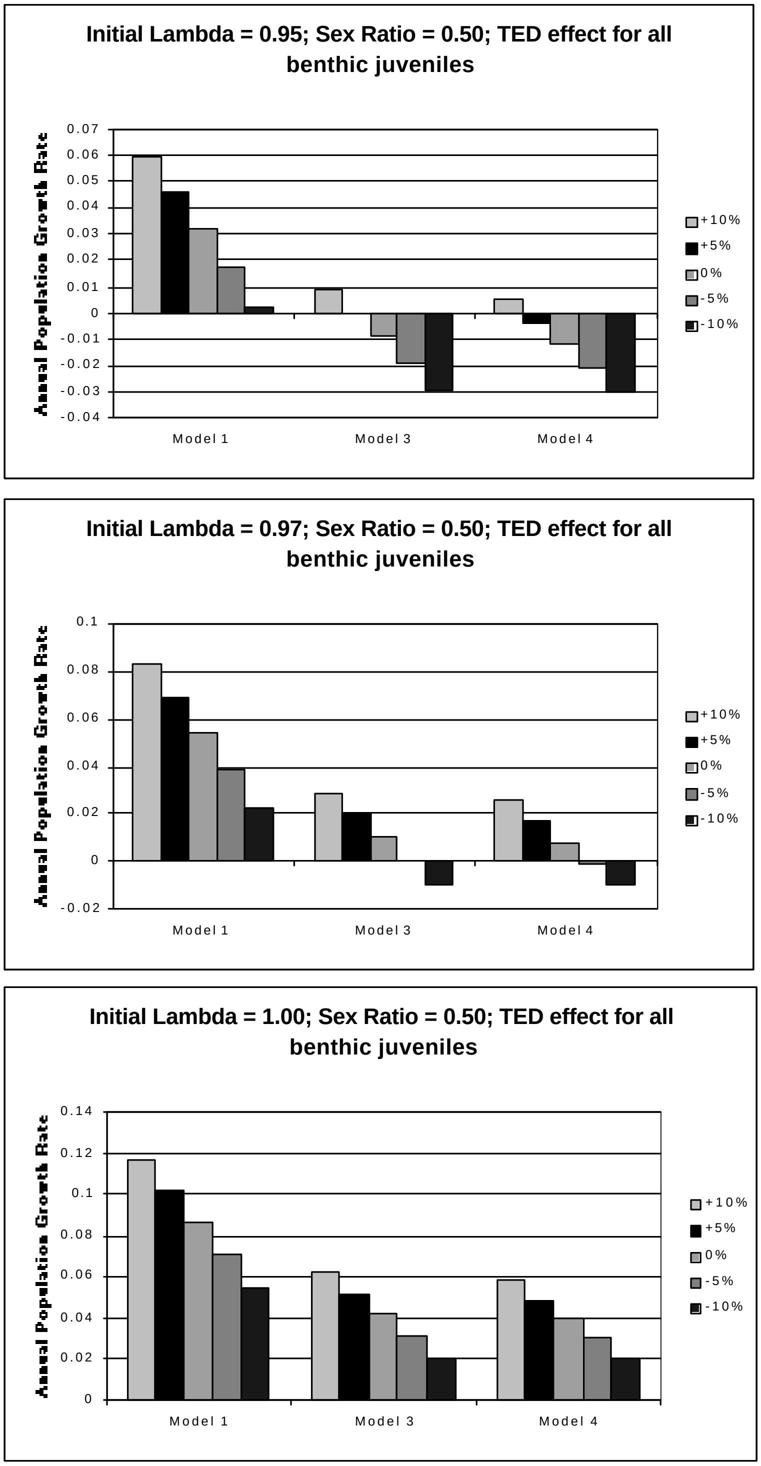
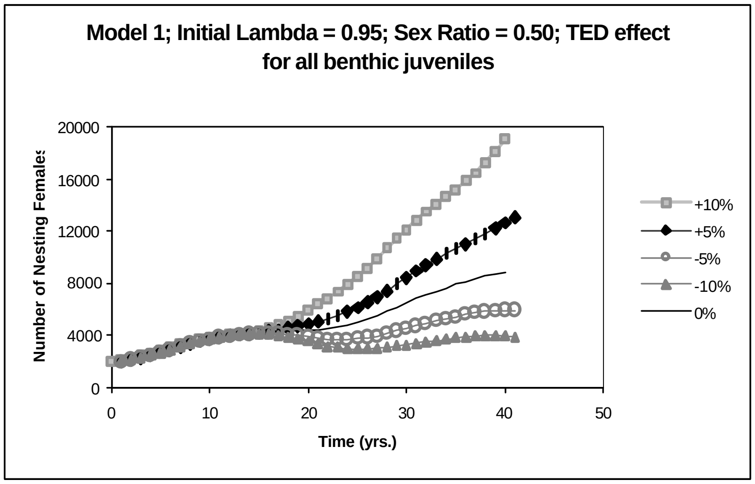
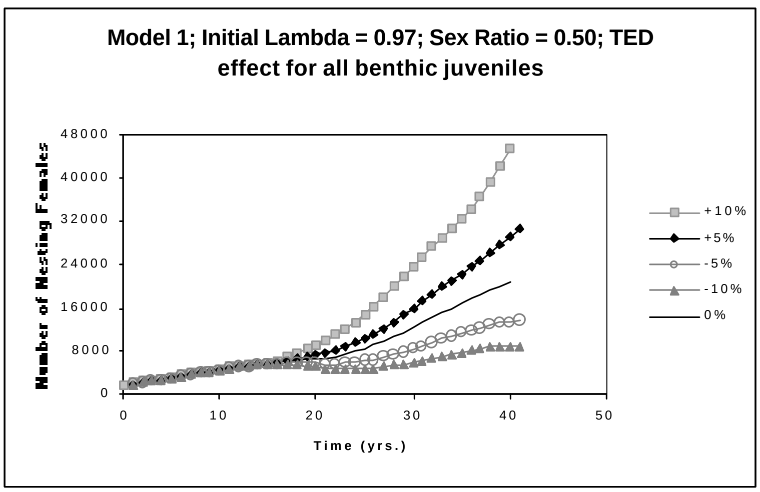


Figure 9. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 1 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.





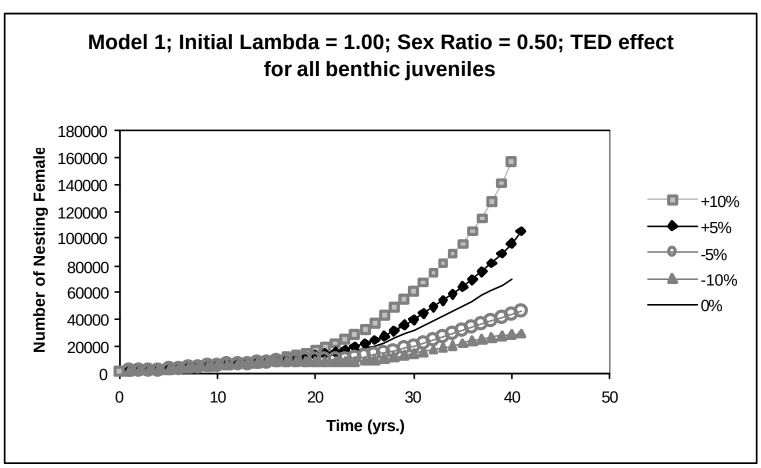
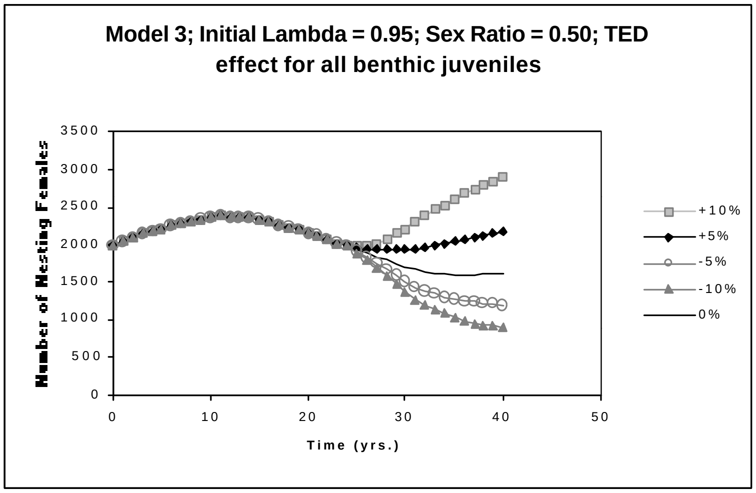
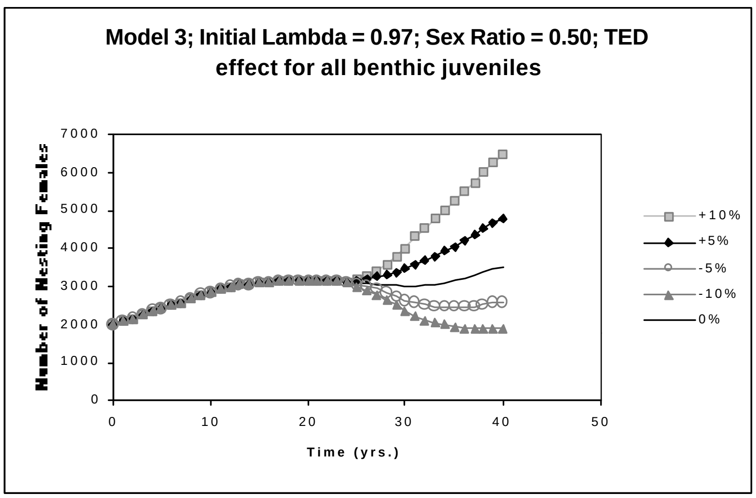


Figure 10. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 3 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.





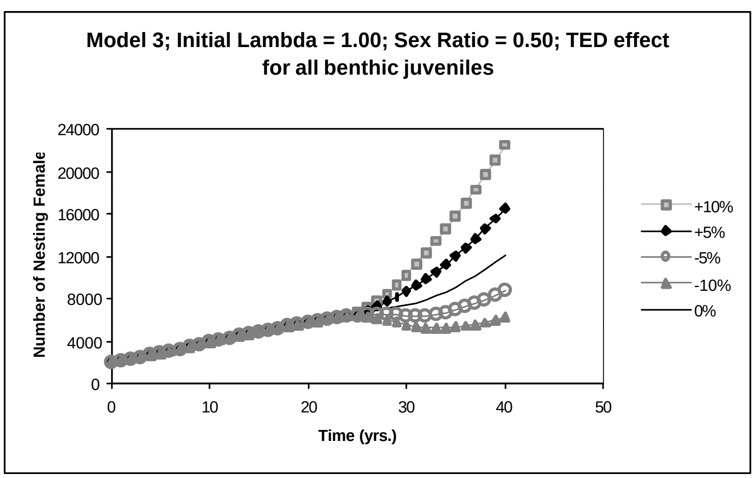
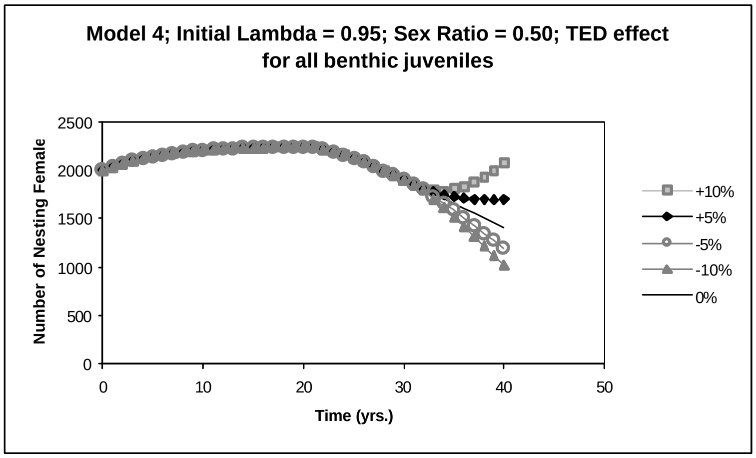
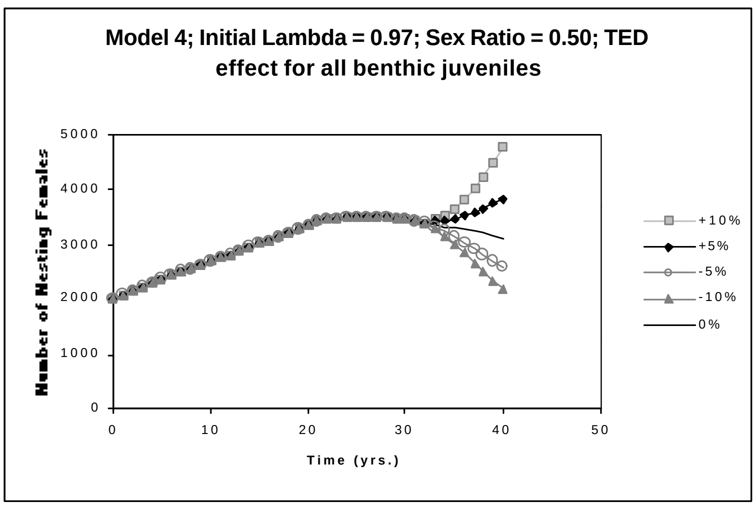


Figure 11. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 4 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.





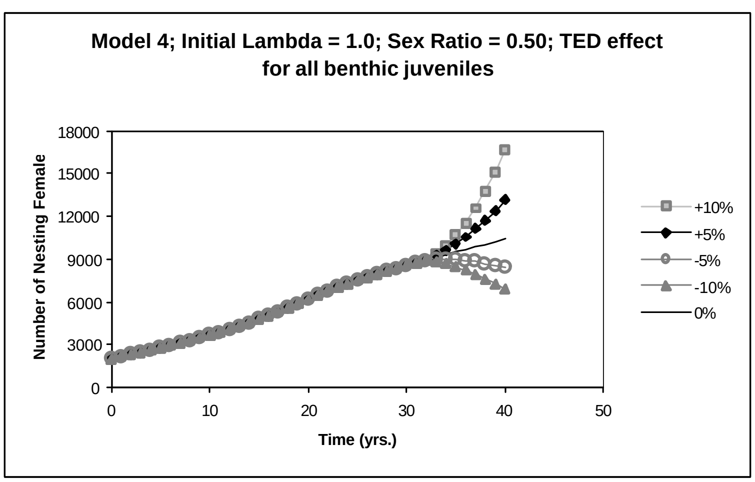
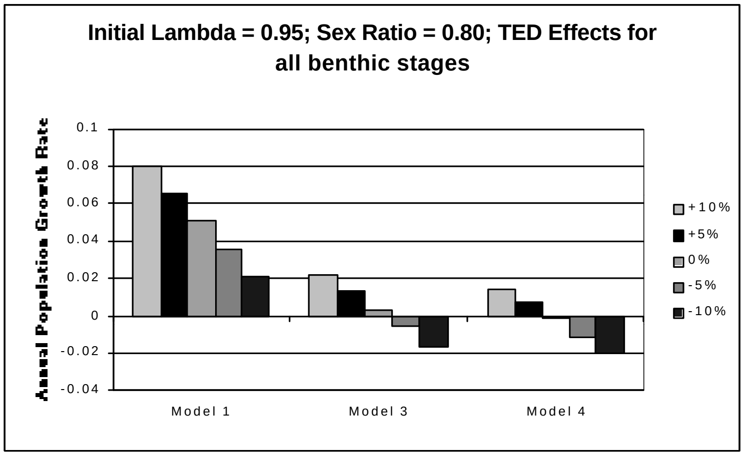
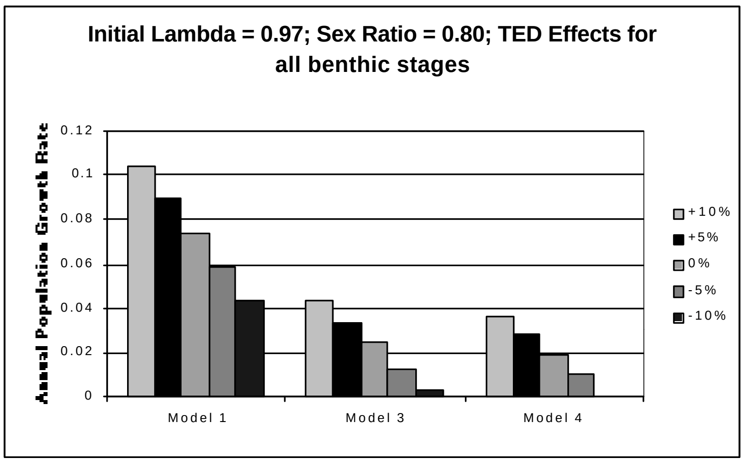


Figure 12. Annual population growth rates for expanded TED regulations that reduce mortality in all benthic stages by 30%. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.





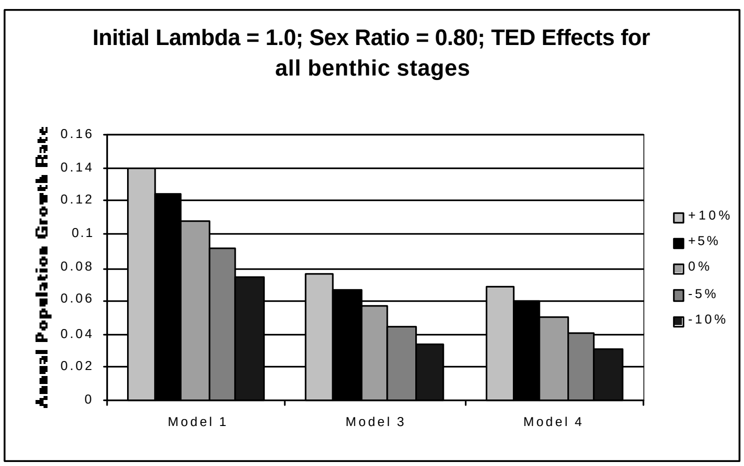
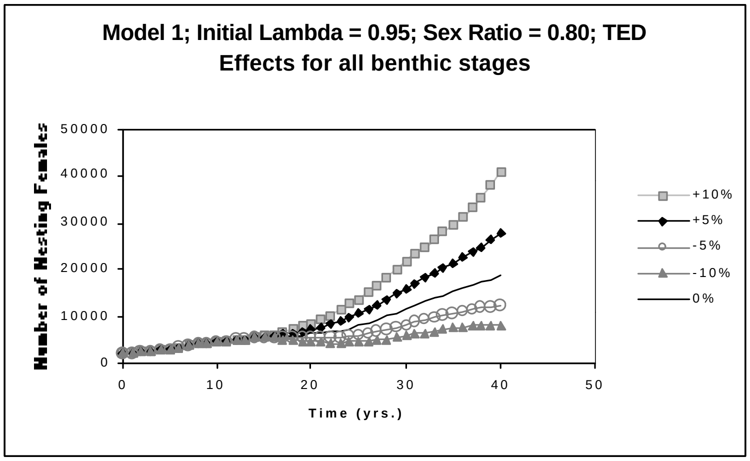
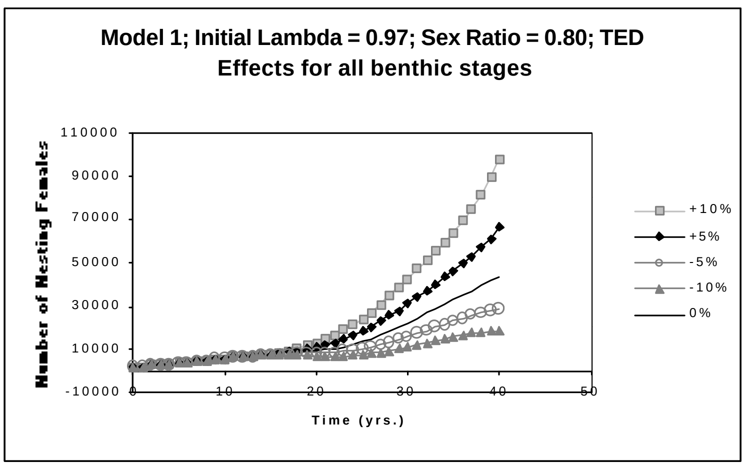


Figure 13. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 1 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.





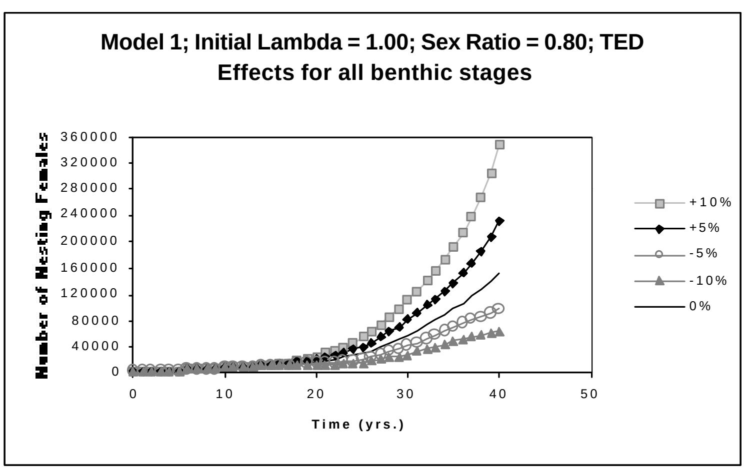
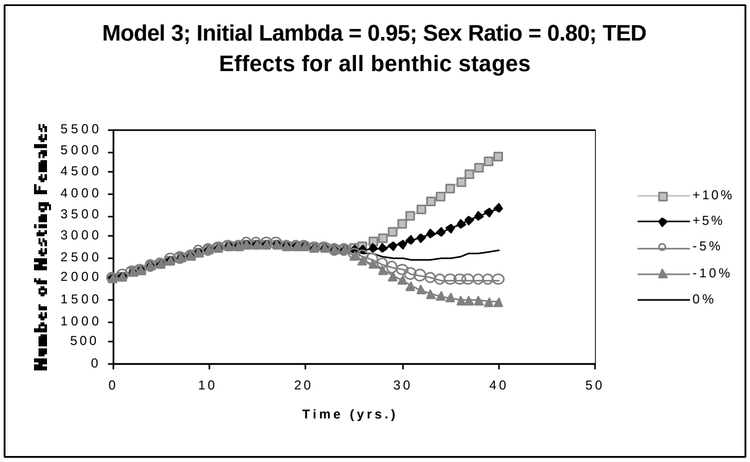
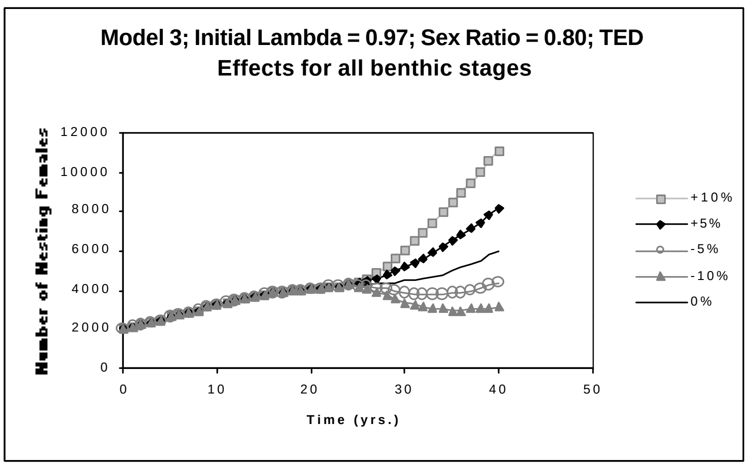


Figure 14. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 3 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.





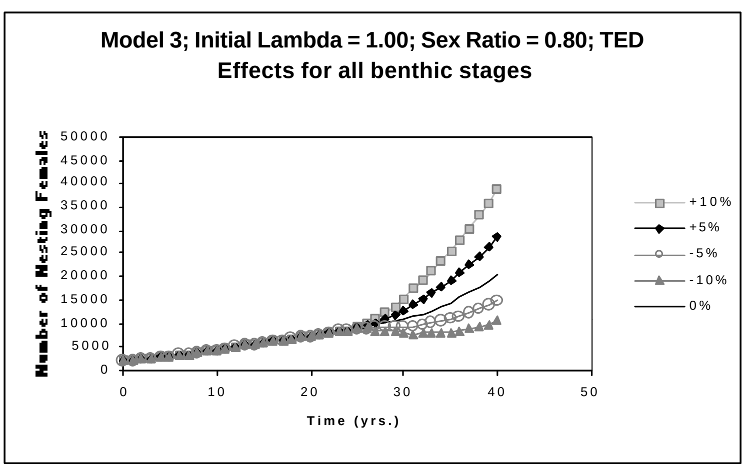
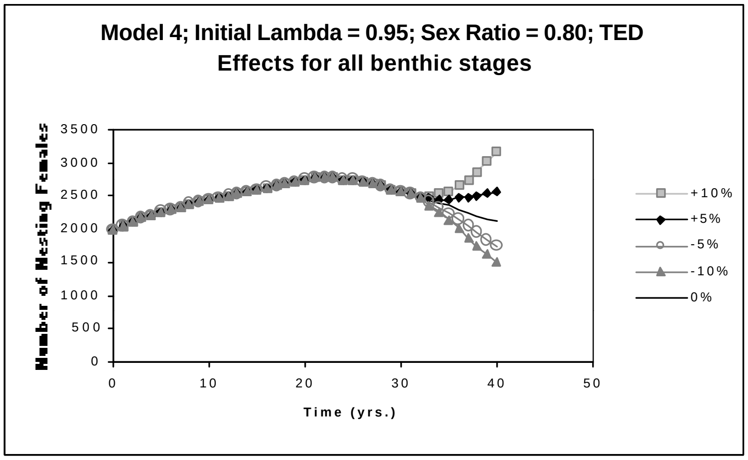
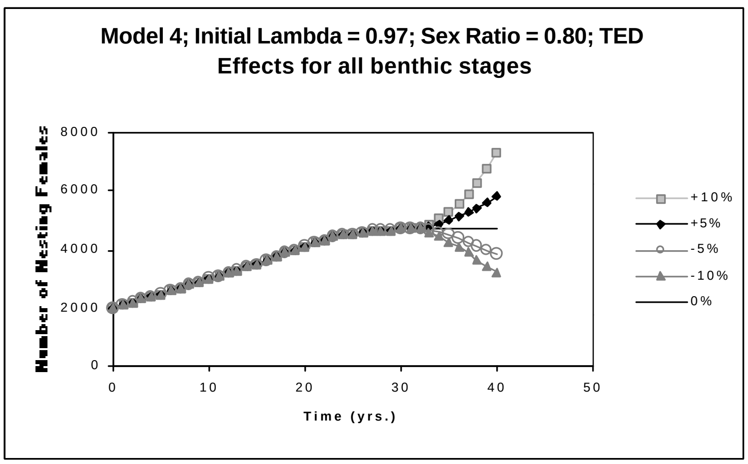


Figure 15. The population trajectories for expanded TED regulations that reduce mortality in all benthic stages by 30% under the Model 4 scenario. The 0% value represents the baseline pelagic juvenile survival rate calculated in Part I. The other values represent percent increases or decreases in pelagic juvenile survival rates from baseline (combination of pelagic longline fishery regulations and expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.





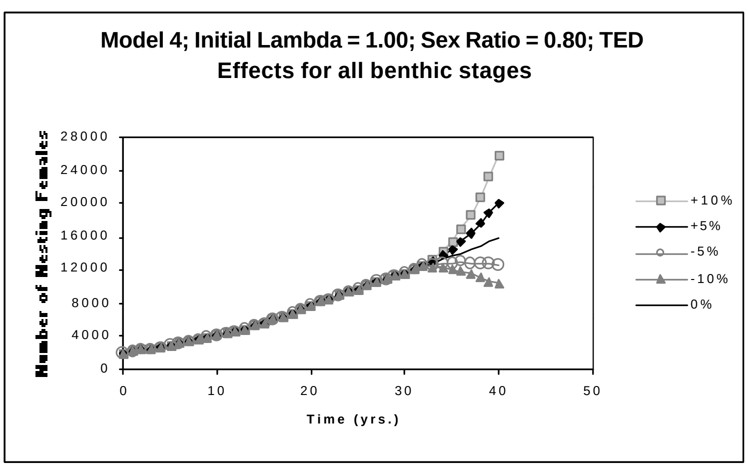


Figure 16. Annual population growth rates increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.

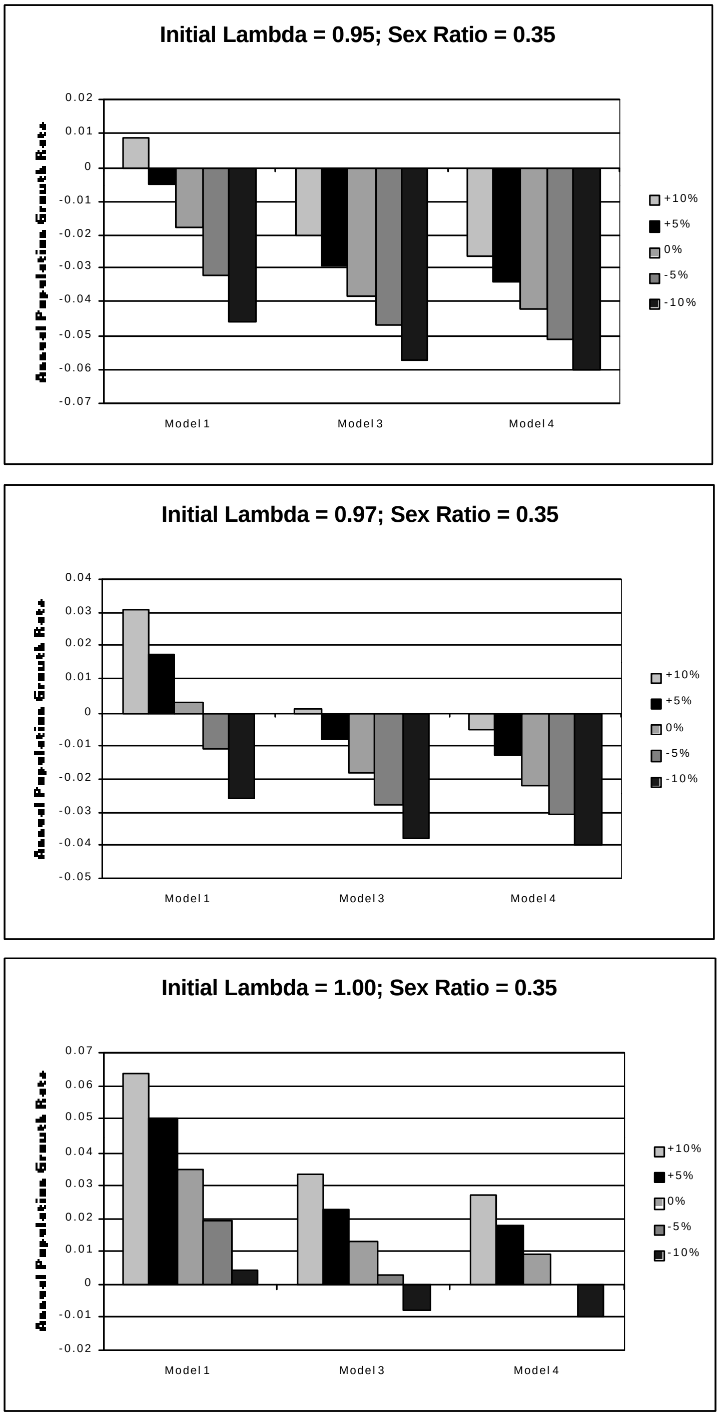
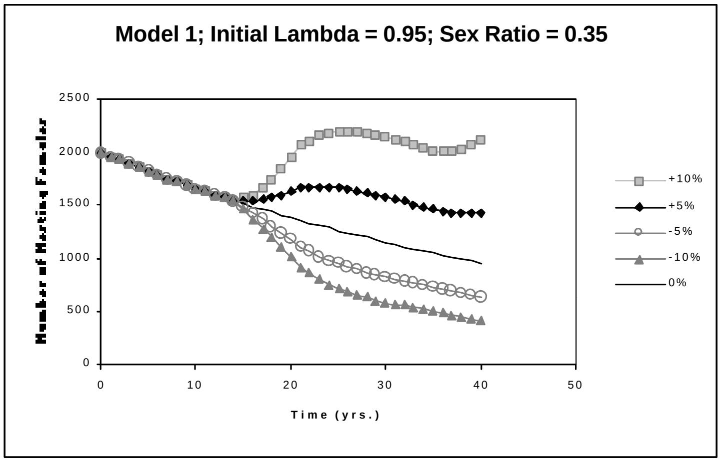
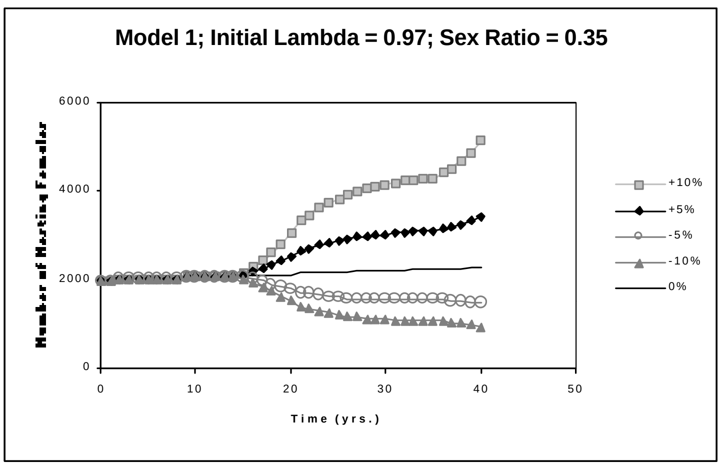


Figure 17. The population trajectories for the Model 1 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.





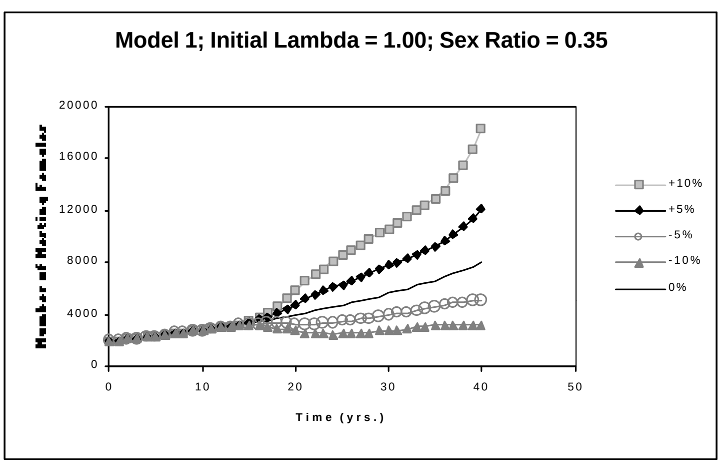
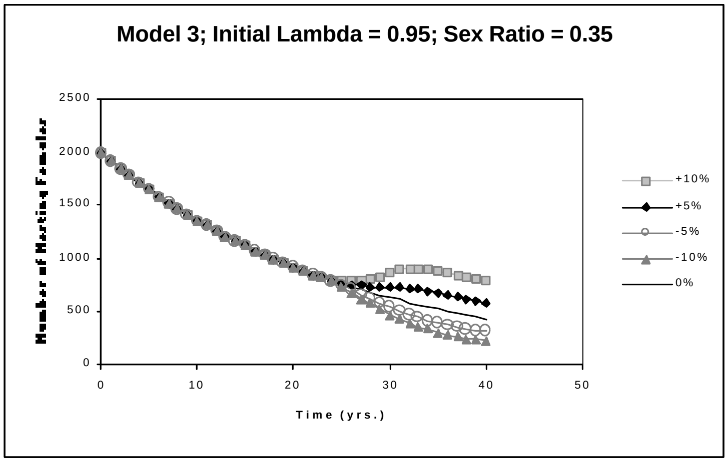
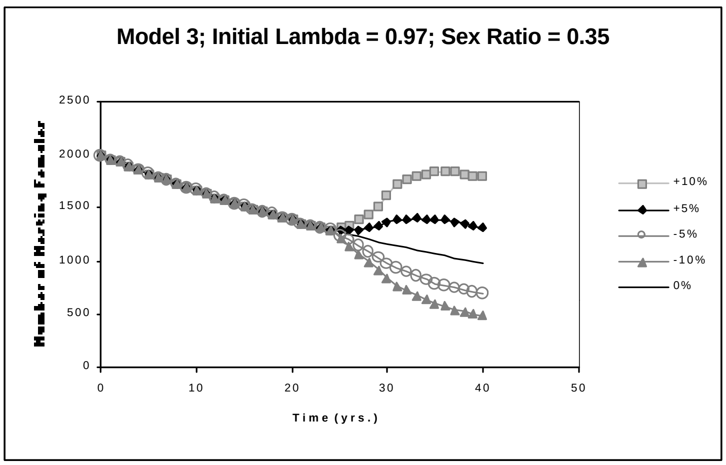


Figure 18. The population trajectories for the Model 3 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.





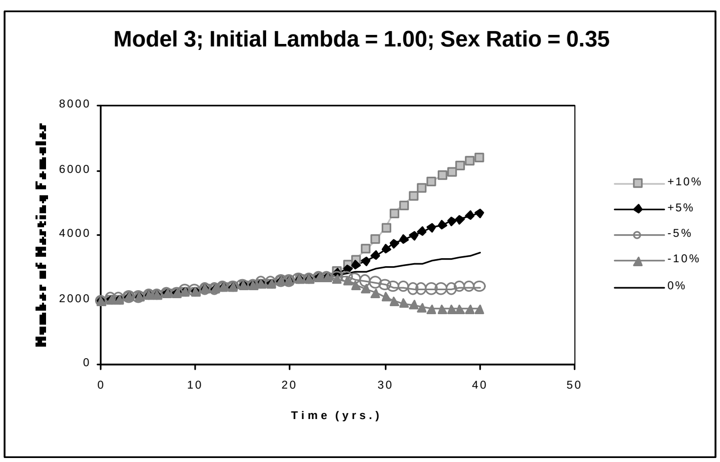
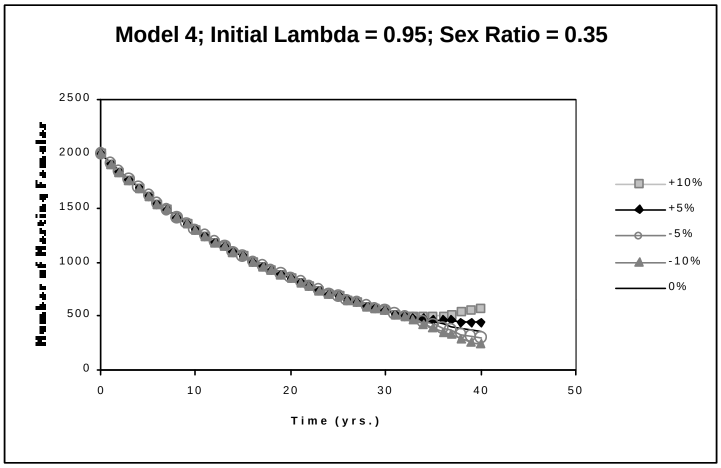
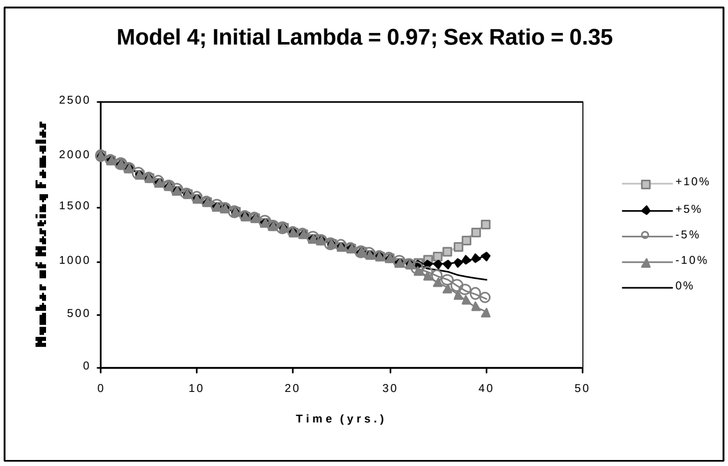


Figure 19. The population trajectories for the Model 4 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.35.





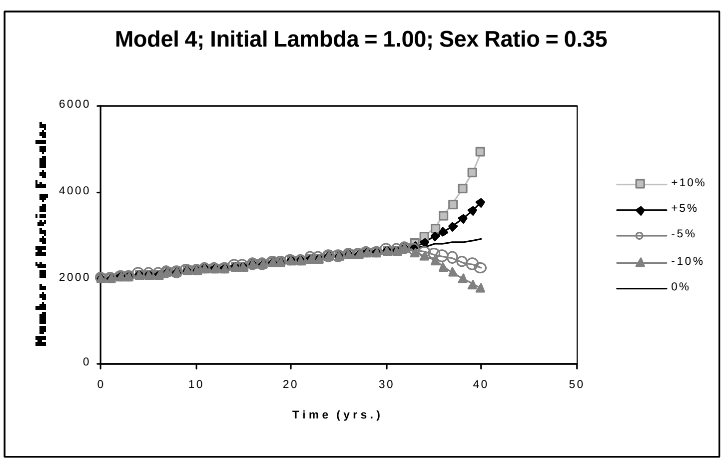
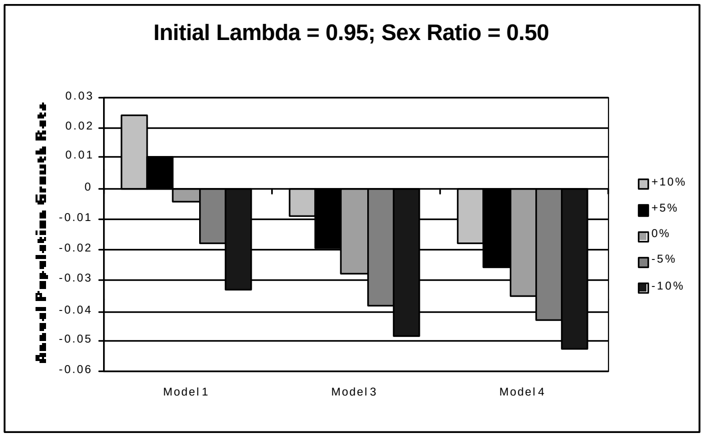
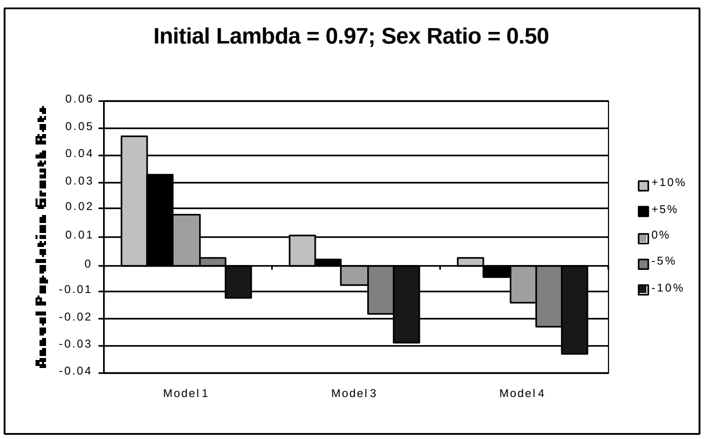


Figure 20. Annual population growth rates increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.





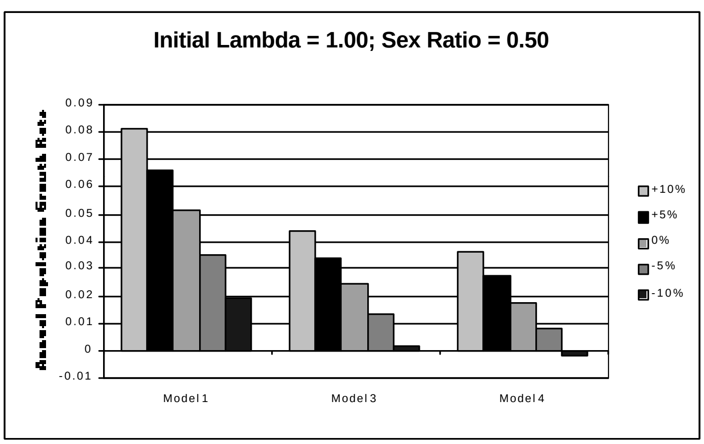


Figure 21. The population trajectories for the Model 1 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.

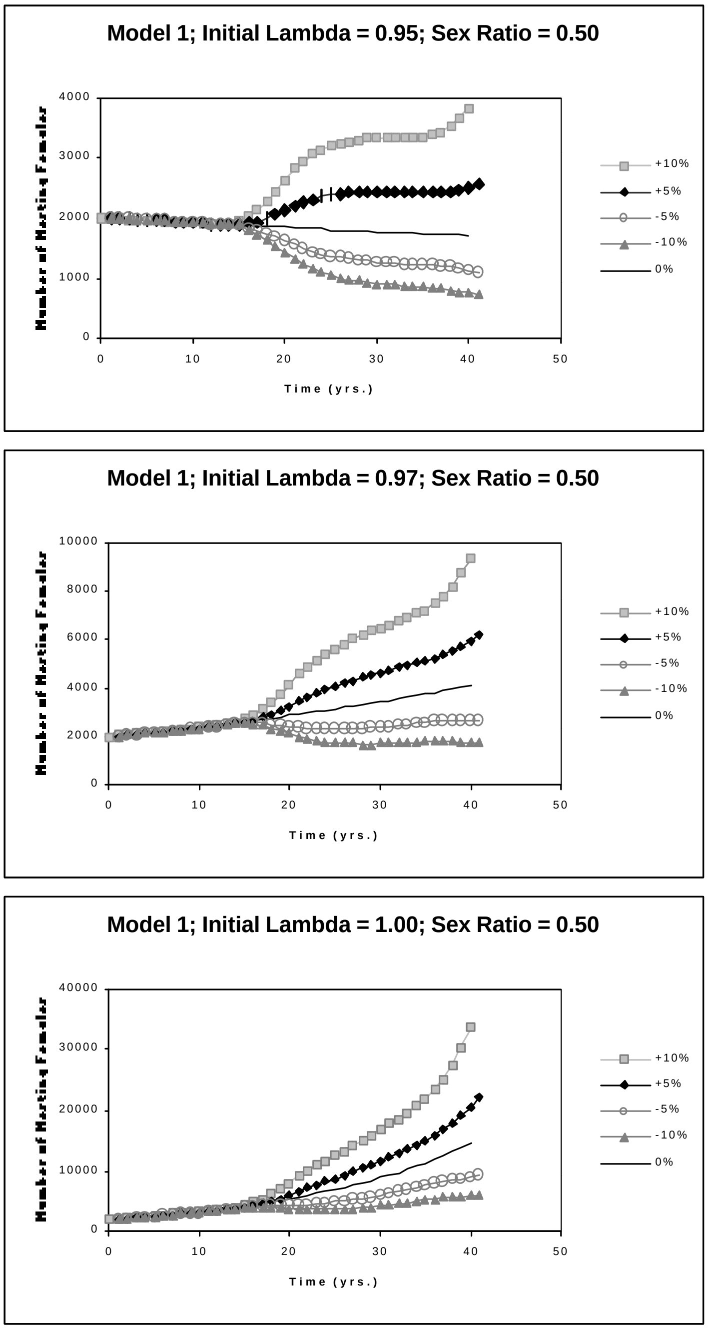
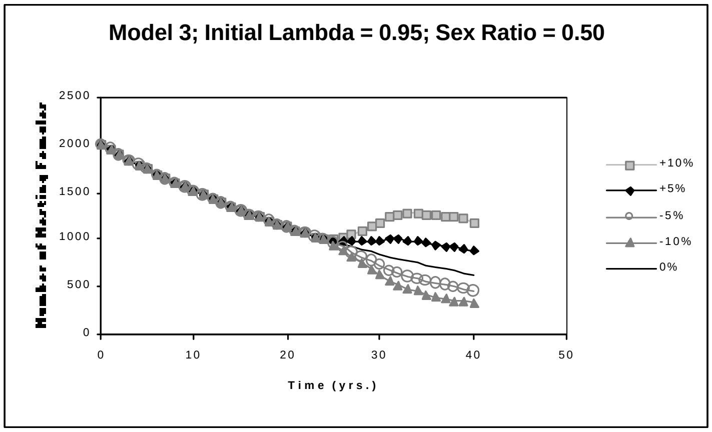
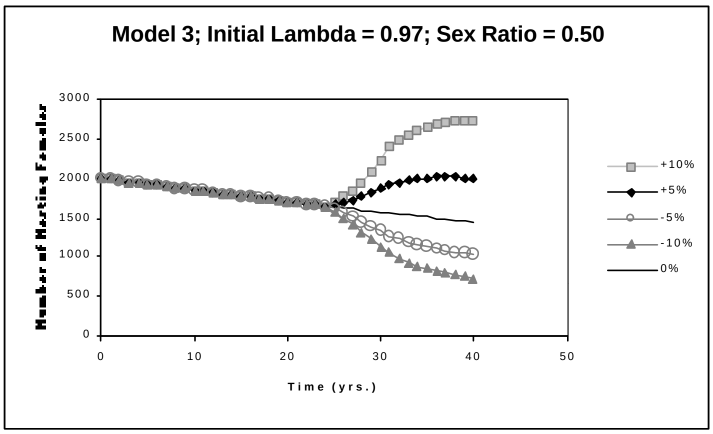


Figure 22. The population trajectories for the Model 3 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.





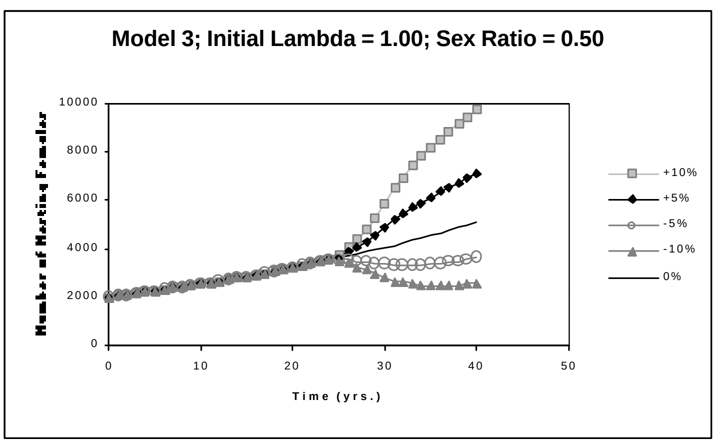


Figure 23. The population trajectories for the Model 4 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.50.

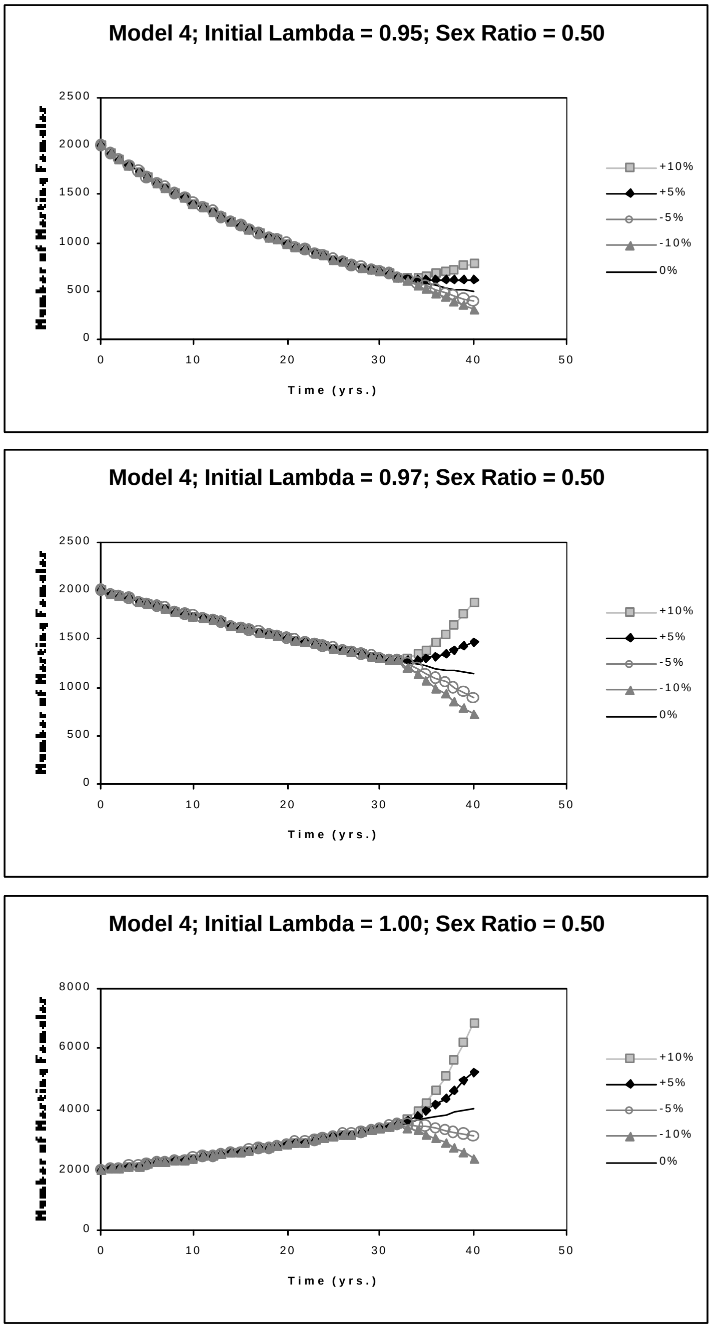


Figure 24. Annual population growth rates increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.

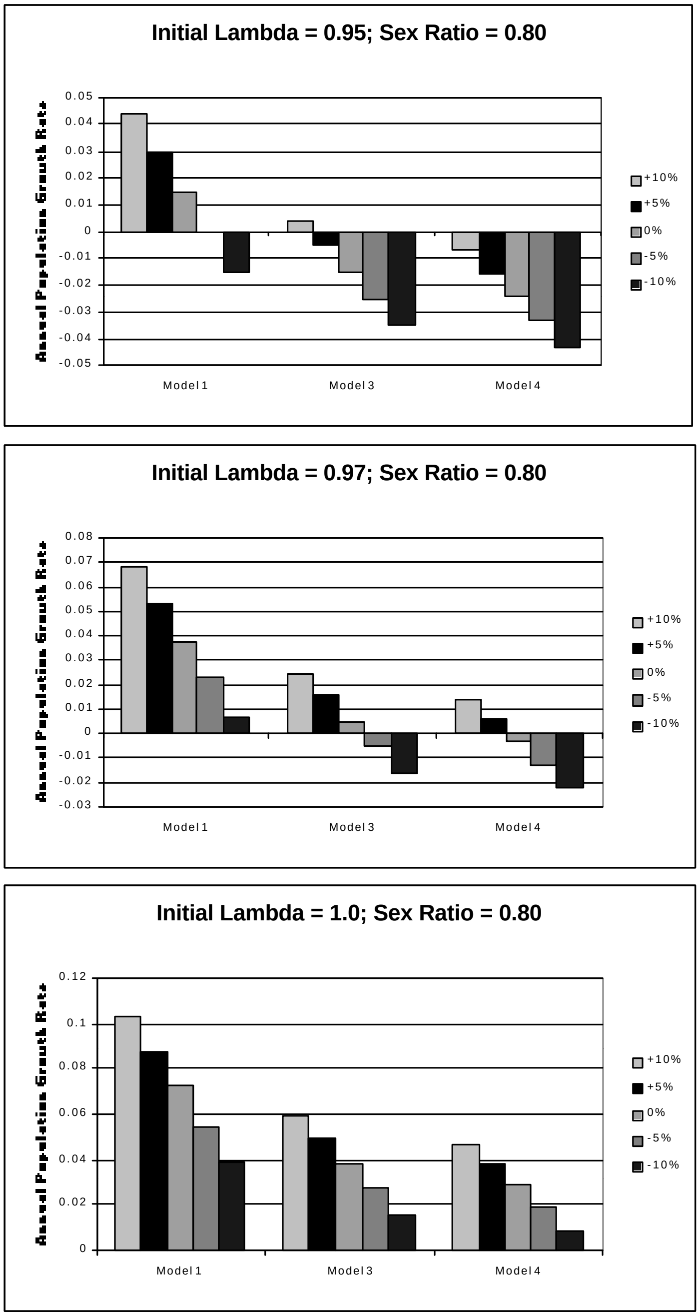
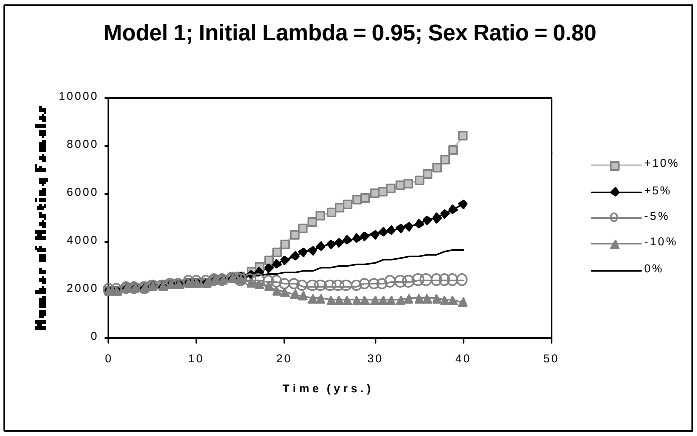
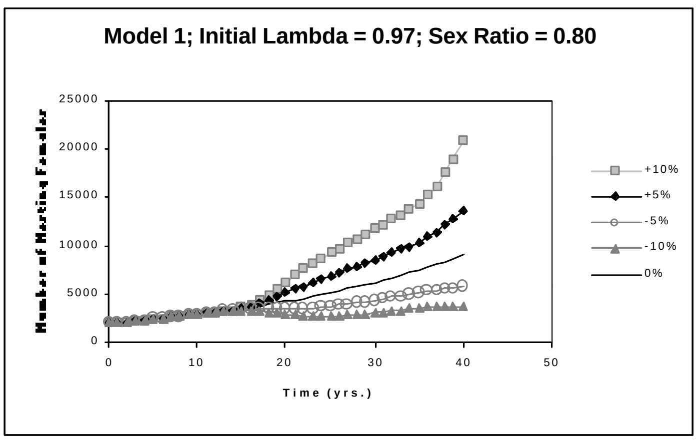


Figure 25. The population trajectories for the Model 4 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.





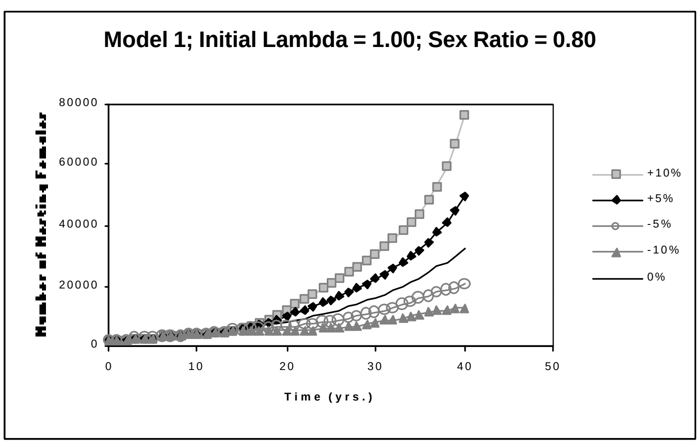


Figure 26. The population trajectories for the Model 3 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.

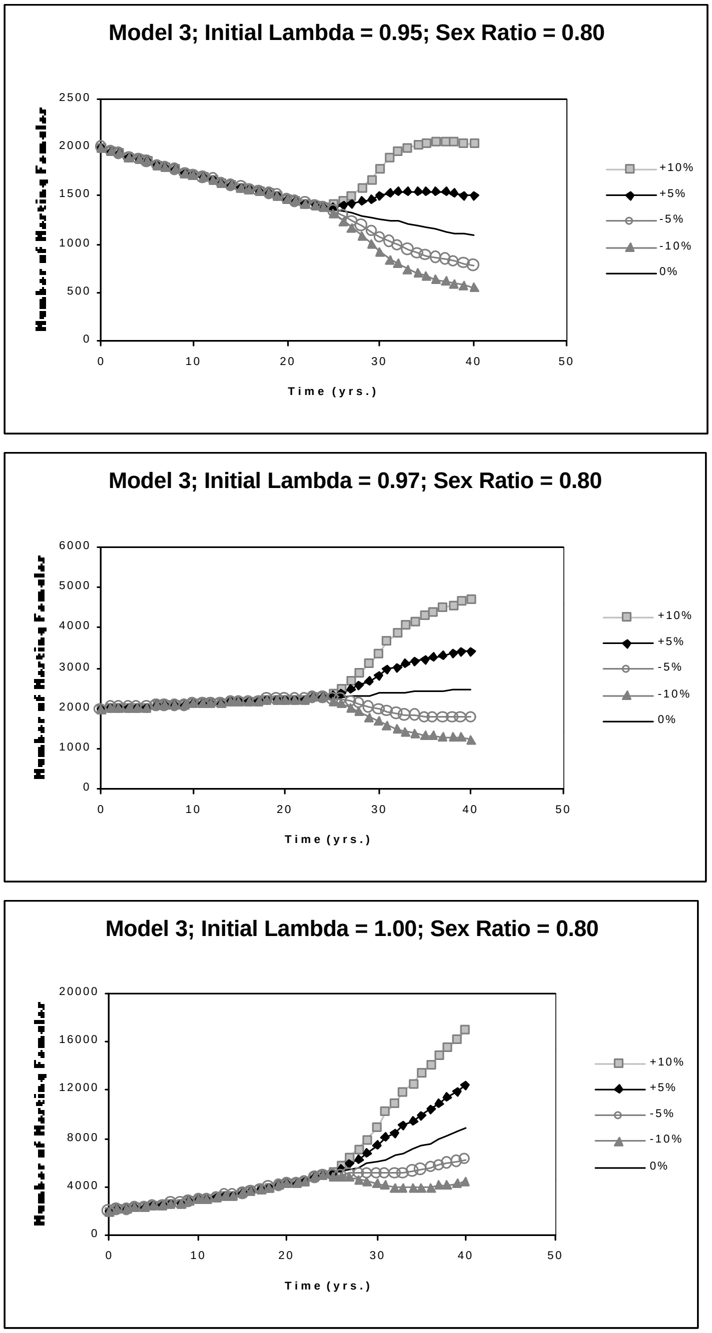
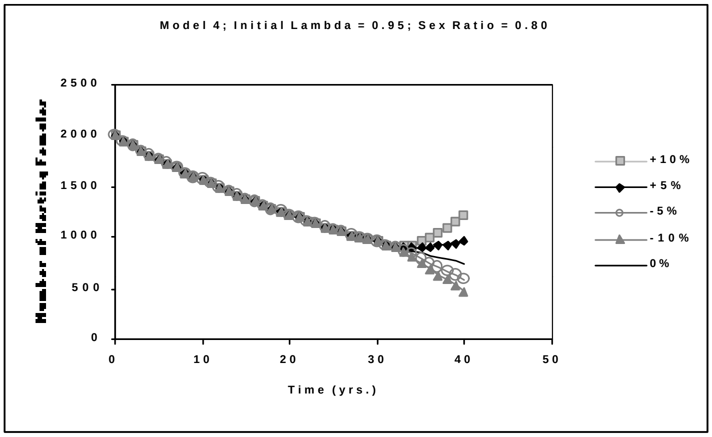
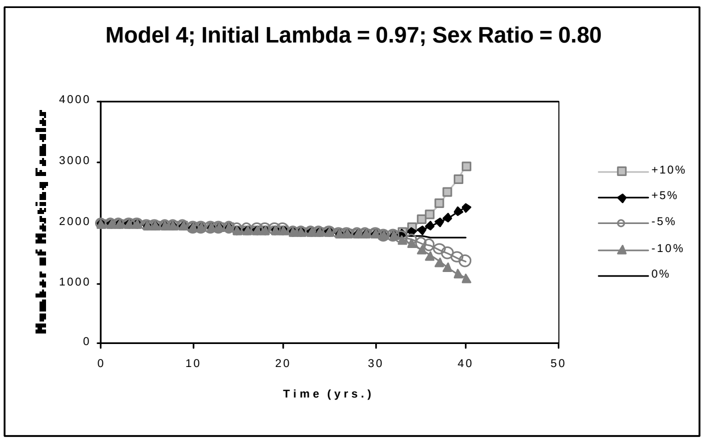
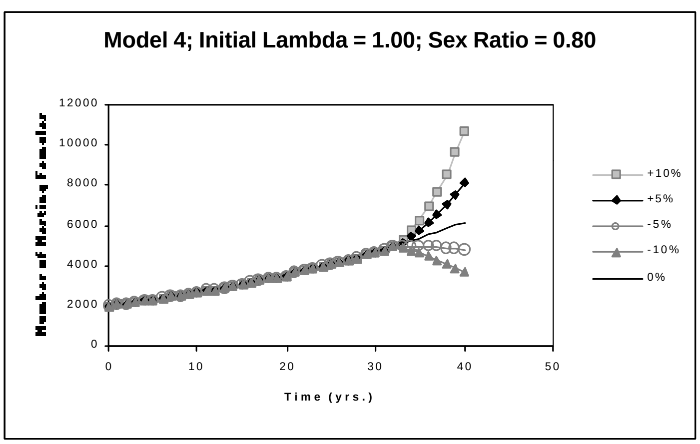


Figure 27. The population trajectories for the Model 4 scenario resulting from increases and decreases in the annual pelagic juvenile survival rate (-10%, -5%, 0%, +5% and +10%) and a 30% decrease in mortality for small benthic juveniles only (no expanded TED regulations). Models were based on pre-1990 population growth rates of –5%, -3% and 0% (equivalent to λ values of 0.95, 0.97 and 1.0). Proportion of female offspring is 0.80.







CHAPTER 7. IMPACT OF THE PELAGIC LONGLINE FISHERY ON LEATHERBACK SEA TURTLES

Nancy B. Thompson

Leatherback turtles are the largest of the sea turtle species and display a large range within the Atlantic Ocean and in the western North Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico (Pritchard and Trebbau 1984). They inhabit all the oceans of the world and are found in both coastal and pelagic waters and unlike the other turtle species, all life history stages beyond the egg are found in the pelagic zone (Pritchard and Trebbau 1984). They may grow rapidly achieving sexual maturity in as little as 3-6 years or may not reach maturity until as late as 19 years (Rhodin 1995, Zug and Parham 1996). They nest frequently (up to 7 nests per year) during a nesting season and nest about every 2-3 years. During each nesting, they produce about 100 eggs or more in each clutch and thus, can produce 700 eggs or more per nesting season (Shultz 1975). Hatchlings through subadults may remain in warm tropical/subtropical waters and when reaching lengths greater than 100 cm carapace length, demonstrate seasonal movements in the western North Atlantic and range as far north as Canadian waters in the summer. Turtles that arrive in northern waters can be derived from any Atlantic nesting beach and based on ocean currents such as the south to north direction of the Gulf Stream, are from the South American and U.S. beaches. Turtles in northeastern waters are generally > than 100 cm curved length which is consistent with fishers in northeastern U.S. and the Grand Banks encounter.

Dutton *et al*. (1999) describes stock structure and concludes that there may be distinct nesting subpopulations along the western North Atlantic coast. They conclude at this time that turtles nesting in St. Croix/Puerto Rico and Trinidad are different from each other and different from all other nesting areas in the Western North Atlantic based on their genetic analyses. Turtles nesting in Florida could not be distinguished from those nesting in the nor from those from the Indian Ocean. They offer several hypotheses about why there is little difference between these nesting "populations" and caution that these results alone should not be used to describe stock structure. However, this does mean that the ability to assign turtles to nesting beaches when away from nesting beaches would be limited to mainland v. St. Croix/Puerto Rico v. Trinidad using their methods.

Regardless of hypothesized stock structure, the decline measured on beaches of northern South America, which support the largest nesting aggregation in the western North Atlantic Ocean, is of immediate concern and the causes need to be identified. The trend in nesting females in the U.S. has been increasing for the past 20 years (Appendix 1). Measurable trends in the major nesting area, beaches along the northern coast of South America, were increasing from the 1970's to the early 1990's and have been decreasing since 1992 (*Ibid.*). Looking at the nesting numbers for the South American beaches suggests nesting may be cyclic or in fact is on a real decline since 1992 which contrasts with nesting in the U.S. which has increased nearly 5-fold from the early 1980's to the present. The question that remains to be explored is why is nesting declining along the northern South American coast whereas it has been increasing in the Caribbean and Florida during the same time period. An answer to this question is explored with a series of hypotheses and within the context of an impact of the U.S. longline fishery in the western North Atlantic.

Estimated annual leatherback turtle bycatch from the U.S. longline fishery from 1992 to 1999 ranges from 308-1054. Turtles are caught in all waters from the Gulf of Mexico to the Grand Banks with the largest estimated bycatch in the spring and summer in northeast U.S., southeast Canadian, and international waters. Applying the 50% mortality criterion results in estimated mortalities as presented in Table 1 of Chapter 5, and these range then from 154 to 527 turtles killed annually by the U.S. longline fishery. Estimates of total bycatch suggest that the estimated annual mortality from each of these areas (NED, NEC) in spring and summer (in the hundreds) is on the average about an order of magnitude higher (in the tens) than in other areas. It is reasonable to assume that there are takes and kills by the foreign vessels in this area and the magnitude of these takes could be considerable given the effort from these fleets as compared to that from the U.S. fleet

When examining all takes in all human activities for which we have data or estimates, (Appendix 1), it is clear that for U.S. activities only, the pelagic longline fishery and the estimated take from the commercial shrimp trawl fishery (estimated at 650 per year) in combination are the largest known sources of anthropogenic mortality. Under a regime of constant mortality, as more turtles enter the water, more will likely be caught.

While turtles killed by the longline fishery in the sampling areas off the northeast U.S. coast are likely > 100 cm carapace length, those killed off the southeast U.S. coast, the Gulf of Mexico, and the Caribbean can be of any length unless there is some size selectivity of the gear as there is in loggerheads (Bolten and Bjorndal 1994). The lengths of animals stranding throughout the Gulf of Mexico and along the southeast U.S. coast while ranging from < 30 cm curved carapace length, are primarily greater than 130 cm curved carapace length (See Part II). These animals represent only those dying in waters close enough to the coast to have stranded and may not be representative at all of the size distributions of turtles in offshore waters where deaths are unlikely to result in strandings. However, at least in the southeast U.S., these turtles may be representative of what is taken by the shrimp fishery and other coastal fishing. Sizes of turtles at sexual maturity have been observed as minimally about 120 cm carapace length with an average minimum of about 140 cm carapace length (Marquez 1990). Thus, turtles taken by fishing in coastal waters and longline fishing in northeastern waters are large juvenile to adult sizes.

Recovery criteria for the leatherback turtle in U.S. western North Atlantic waters (NMFS and FWS 1992) are used to consider de-listing and are: (1) the adult female population increases over the next 25 years, as evidenced by a statistically significant trend in the number of nests at Culebra, Puerto Rico, and St. Croix, U.S.V.I. and along the east coast of Florida, and (2) nesting habitat encompassing at least 75 percent of nesting activity in the U.S.V.I., Puerto Rico and Florida is in public ownership and, (3) all priority one tasks have been successfully implemented. The first criterion requires an increasing trend in nesting females in 3 index beaches under control by the United States. Based on trend analyses (Appendix 1), the number of leatherback nests on Florida and U.S.V.I. beaches is increasing at 10.3% and 7.5% per year, respectively, since 1979. However, the largest leatherback rookeries in the western North

Atlantic remain along the northern coast of South America in French Guiana and Suriname. While Spotila *et al.* (1996) indicated that turtles may have been shifting their nesting from French Guiana to Suriname due to beach erosion, analyses show that the overall area trend in number of nests has been negative since 1987 at a rate of 15.0% per year (Appendix 1). Chevalier *et al*. (1999) suggest that this decline could be from both reduced hatching success (as low as 22% -35% per year) and takes of nesting females by coastal fishing. Previously, Chevalier and Girondot (2000) suggested that Suriname beaches up to 1992 had shown increases in nesting and hypothesized that this increase, which correlated with the decline along French Guiana beaches, was a result of shifts in nesting activity. However, recent trend analyses show a decline overall in these beaches since 1987. The decline in the major nesting areas for leatherbacks has been clearly described and the cause of this decline needs to be identified.

To determine the cause of the decline in nesting in the beaches of the Guianas, a series of hypotheses are offered: (1) the trends represent a natural cycle in nesting of leatherback turtles in this region; (2) natal homing in leatherbacks is imprecise and the turtles are nesting elsewhere and not reported or observed nor recognized as migrated from another rookery; (3) the mortality rate for female turtles has increased over the past 10 years relative to the previous 25 or so for turtles nesting in the Guianas but not increased to the same extent on females nesting on U.S. beaches; (4) the mortality rates for any or all life history stages for turtles derived from Guianas beaches is higher than that for turtles derived from U.S. beaches. The following is a discussion of each hypothesis:

1. There is a natural, decadal cycle in female nesting. Biological cycling of this sort is typically seen as a density dependent response to organisms that can increase in numbers very rapidly and as a biological phenomenon for this species does not seem logical. However, Schulz (1975) describes the Suriname beaches along the coast of South America as dynamic and undergoing regular cycles of erosion and accretion which means beach availability cycles. Schulz (1975) also indicates that over the past few centuries the availability of nesting beach to sea turtles in general has been rare along the Suriname coast as beaches have appeared only relatively. Schulz (1975) indicates that these cycles are in about 10 year periods. Chevalier *et al*. (1999) suggest that there are shifts in nesting along this coastal region and that turtles have been shifting nesting activity from French Guiana to Suriname as a result of beach availability and quality.

2. Turtles have shifted to other nesting beaches and may be unreported. Genetic studies indicate that turtles nesting on Florida beaches and beaches of the Guianas beaches are not distinguishable and the increases seen in Florida beaches as well as those throughout the Caribbean, could be from South American nesting females. From 1992 to 1997, the numbers of nests in French Guiana decreased from about 50,000 nests to less than 15,000 nests, a 75% decrease in total nests reported. This same relative amount of decrease in nests was reported for Suriname beaches. While the rate of increase in nesting on U.S. beaches is similar to the decrease seen in South America, the total numbers of nests is much less than expected if all females have shifted to U.S. beaches. This type of emigration could explains the lack of distinction seen in mainland nesting Atlantic leatherbacks, but would not explain the differences maintained between the insular populations and the mainland population. In the eastern North Atlantic Ocean, nesting in

Gabon is estimated at almost 5,000 females and has been described as stable (Spotila *et al.* 1996). What other nesting is occurring along the West African North Atlantic coast is not known. The level of decrease in the South American beaches reflects the increase in nesting seen from U.S. beaches for the same period of time. However, the overall annual total number of nests is still significantly less for U.S. than South American beaches.

3. The mortality rate for adult females has increased over the past ten years causing a decrease in the number of nesting females. For decreases in nesting to be observed on South American beaches but not U.S. beaches suggests that this may be true for turtles nesting in South America only. Spotila *et al*. (1996) indicated that the number of turtles killed in the South American offshore fishery had increased "dramatically". It is not known what the magnitude of this increase is and cannot be identified as the cause of the decline, but neither can it be discounted as a direct cause of the decrease. Coastal gillnet fisheries and shrimp trawling do occur in the Guianas and could be contributory to mortality (Chevalier *et al*. 1999, Chevalier and Girondot 2000). Shrimp trawlers in these waters are not required to use TED's (Chevalier and Girondot 2000). The decreases seen at these beaches and increases in nesting in U.S. beaches, suggests that some source of mortality may be effecting the South American nesting females and not effecting the U.S. and Caribbean nesting females. Of course, the signal may yet to be measured on U.S. beaches but this would suggest differential growth rates as well, with turtles nesting along South America growing faster resulting in a measurable decrease in females before observed in other nesting beaches. Given the range and movements of these turtles, it would be expected these turtles exhibit the same growth rates.

4. The mortality rates for any or all life history stages have increased. This increase in mortality rate could be impacting turtles from U.S. beaches and throughout the Atlantic as well and we have yet to measure this as decreases on the nesting beach but are seeing the effect on South American beaches. The same argument about differential growth rates would have to be applied here as for hypothesis 3. The proportion of turtles by nesting beach origin is likely variable in any given year due to turtles essentially utilizing the entire Atlantic Ocean basin and exhibiting even transoceanic movements. Assuming that the longline fishery and other human activities away from the nesting beach do not discriminate based on beach of origin, then it would be expected that this mortality would be observed as decreases in all nesting areas. Either the signal has not been measured in U.S. beaches or this mortality is selective for turtles from South American beaches only.

Any mortality from U.S. longline fishing would be expected to produce the same effect for all western North Atlantic leatherback turtles regardless of beach of origin or "population" if they were mixing on the high seas. For longline effort measured in total hooks fished, the U.S. effort is less than 10% of the total effort or hooks in the North Atlantic as prosecuted by nations party to ICCAT (see Chapter 1), but the U.S. accounts for 25-33% (mean=28%) of the swordfish yield, 1990-1997 and 11-26% (mean=18%) of the tunas yield from the North Atlantic. Thus, efficiency of the U.S. fleet as compared with foreign fleets and based on CPUE is 4-8 times greater for swordfish and 2-3 times greater for tunas. How this efficiency relates to the capture of sea turtles is not known. The bycatch rate of sea turtles is most significantly correlated with swordfish catch, and secondly to shark, but negatively correlated with tuna (all species) (Chapter 2). Results also indicate that effort in terms of number of hooks set is not significant compared to the time-area factors. However, whether based on effort or yield when determining the relative impact of the domestic fishery relative to the foreign fleet, it is clear that the foreign fleet, when overlapping with the U.S. fleet, catches and kills turtles. Again, this mortality would not be expected to be selective and target turtles by beach of origin.

Turtles are taken and killed by the U.S. pelagic longline fishery. The total effort as measured in total hooks is larger for the foreign fleet than the U.S. fleet, although the magnitude of this take and mortality is not known and may be larger than that by the U.S. fleet alone. The greatest overlap in effort and numbers of leatherback turtles occurs in the entire western North Atlantic (Figure 7, Chapter 8). Thus, it would be expected that this mortality would be evidenced on nesting beaches throughout the western North Atlantic Ocean. It is possible, but unlikely that this signal has not been observed in U.S. beaches. Takes and mortality from the U.S. longline fishery are relatively large and while could be contributory especially for populations undergoing other significant stresses, it is difficult to argue that this alone explains the decreases observed in the largest nesting area of the western North Atlantic. This fishery, in combination with the foreign longline fleets and coastal fishery could produce sufficient mortality to result in the decreases evident on South American nesting beaches.

On the other hand, large removals of eggs alone could produce the same result and, if turtles do grow to maturity within 5 years, would be evidenced on the nesting beach quickly. There is compelling evidence to suggest that whatever is causing the decline in nesting females along the South American coast is not effecting the numbers of females nesting on U.S. and Caribbean beaches at this time or is measurable on U.S. beaches at this time. It remains to be seen if turtles are emigrating from South American beaches to U.S. and others, there is still a possibility given the cyclic nature of the South American beaches and the inability to distinguish subpopulations at this time. Chevalier *et al*. (1999) suggest that observers need to be placed on vessels fishing working off the coastal Guianas and that tag recapture experiments need to be conducted to determine the effects of fishing on these nesting females and to determine emigration rates, respectively. To determine the impact of the longline fleets (both U.S. and foreign) on these “populations”, first there must be some apportionment of turtles by nesting beach origin, then stage or age specific mortality rates must be quantified. These parameters could be determined by research and monitoring including: continuing to pursue genetic studies to describe stock structure; continuing to place observers on vessels coupled with studies such as use of archival tags to determine mortality rates; pursuing methods to age leatherback turtles and subsequently develop growth models; and exploring methods for estimating stage or age specific mortality rates. While there are takes and kills by the pelagic longline fishery and these takes may be contributory to declines observed, it appears that the U.S. nesting numbers are increasing. It is clear that the immediate concern is that French Guiana and Suriname must work towards identifying the causes of decline along their beaches. Without this effort, even with the elimination of takes by the longline fishery, it appears unlikely that these declines would be reversed. If immediate measures to reduce identified mortalities are implemented by French Guiana and Suriname, these alone may be sufficient to reverse the declines.

Literature Cited

Bolten, A.B. and K.A. Bjorndal. 1994. Life history model for the loggerhead sea turtle (*Caretta caretta*) population in the Atlantic: Potenial impacts of a longline fishery. U.S. Department of Commerce NOAA Technical Memorandum NMFS-SWFSC-201:48-55.

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.

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.

Marquez, M.R. 1990. FAO species catalogue. Vol.11: Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. FAO Fisheries Synopsis. No. 125, Vol.11. Rome, FAO. 81pp.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1992. Recovery Plan for Leatherback Turtles in the U.S. Caribbean, Atlantic and Gulf of Mexico, National Marine Fisheries Service, Washington, D.C., 65 pp.

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.

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

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

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.

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.

CHAPTER 8. EVALUATION OF POSSIBLE REASONABLE AND PRUDENT ALTERNATIVES BEING CONSIDERED

Wayne N. Witzell, Ransom A. Myers, and Sheryan P. Epperly

There are a number of possible reasonable and prudent alternatives being discussed to allow the continuation of the pelagic longline fishery. Several workshops have been held with scientists and industry to discuss possible means to reduce both the number of interactions and the mortality resulting from those interactions. A few are reviewed below with what little information is available.

Hook Styles

A variety of fishhook styles are used in the pelagic longline fisheries 2000 (D. Lee, personal communication[37]). Boats may fish several styles of hooks at any one time depending on target species and hook availability. The traditional "J" style hooks are commonly used for swordfish and the circle hooks are commonly used for tunas. It has been proposed that a change in style of hooks used during pelagic longline fishing may effect the survival of sea turtles captured incidental to their fishing operations[38,39]. That optimism arose from promising results on other taxa.

Recent studies of circle and "J" hooks in the U.S. recreational fisheries for billfish and bluefin tunas have provided interesting results. Significantly more sailfish were jaw hooked, including corner of mouth, using circle hooks (98%) than with "J" hooks (44%). Only 2% of the sailfish were deeply hooked using circle hooks but 46% of the "J" hooked sailfish were deeply hooked (Prince *et al*. in press). Additionally, deep hooking by circle hooks with severely offset points was comparable (44%) with the deep hooking percentage for "J" hooks (Prince *et al.* in press).

There was a significant association between hook type and hook location ($p<0.05$) found in the U.S. catch and release recreational fishery for Atlantic bluefin tuna, *Thunnus thynnus* (Skomal *et al*. in press). In that study, 94% of the bluefin tuna caught with circle hooks were jaw and 3.9% were hooked in the pharynx or esophagus while 52% caught with straight "J" hooks were jaw hooked and 34% were hooked in the pharynx or esophagus. Based on these results, Skomal *et al.* (in press) estimated that 4% of the circle hooked captures and 28% of the straight

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[37] Dennis Lee, National Marine Fisheries Service, SEFSC, Miami, Fla.. Personal communication to Wayne Witzell, National Marine Fisheries Service, Miami, Fla., January 13, 2001.

[38] Kleiber, P. and C. Boggs. 2000. Workshop on reducing sea turtle takes in longline fisheries. Miami, August 31-September 1, 1999. Unpublished Report. National Marine Fisheries Service, SWFSC, Honolulu, Hawaii, 16 pp.

[39] Working Group on Reducing Turtle Bycatch in the Hawaii Longline Fishery, Report of First Meeting September 12-13, 2000 Los Angeles. Unpublished Report. National Marine Fisheries Service, SWFSC, Honolulu, Hawaii, 11 pp.

hook captures would have resulted in mortality, and recommended that circle hooks be promoted for use in catch and release recreational fisheries for juvenile bluefin tuna.

An experiment was designed to study gear effects on sea turtle bycatch by the pelagic longline fishery.[40] Preliminary data concerning the use of "J" and circle hooks experimentally fished on commercial Spanish longline vessels in the Azores Islands July-December 2000 is now available (A. Bolten, personal communiation[41,42,43]) The experiment consisted of 93 longline sets, each set consisting of 1,500 hooks baited with squid. The target species were swordfish and blue sharks. Three hook types were tested: straight "J"(Mustad #76800 D 9/0), reversed/offset "J" (30-32^{o}) (Mustad #76801 D 9/0), and circle (Mustad #39960 ST 16/0). The hooks were alternated along the set and because there were 8 hooks between buoys, the relationship between hook type and hook position on the gear varied. The order of gear set was thus: large buoy with radar reflector, 4 small buoys, large buoy, four small buoys, large buoy with reflector, etc.(Alan Bolten, personal communication[44]). The branchline (gangion) length, including leader, was 14 m and they were spaced 45 m apart along the mainline. Buoy lines were 5.4-14.4 m long: line length on large buoy with radar reflector was 14.4 m, large buoy line length was 10.8 m, and the line length on the small buoys was 5.4 or 10.8 m, depending on fishing conditions and was determined by the captain. A single 25.4 m vessel was used throughout the experiment.

A total of 232 loggerhead, 4 leatherback, and 1 green turtle were caught. Catch per unit effort (CPUE) for all species combined was estimated at 1.7 turtles/1,000 hooks. There was no significant difference in the total numbers of turtles caught by each hook type (Chi-square test, p=0.136). However, there was a significant difference among the 3 hook types in the location of hooking in the turtles (Chi-square test, p<0.001):

	Percent Hooked in theThroat
Standard "J" Hook	57%
Offset "J" Hook	46%
Circle Hook	11%

[40] Bolten, A.B., H.R. Martins, and K.A. Bjorndal, eds. 1998. Workshop to design an experiment to determine the effects of longline gear modification on sea turtle bycatch rates. Unpublished report. University of Florida and Departamento de Oceanografia e Pescas, Gainesville, FL and Horta, Portugal, 54 pp.

[41] Alan Bolten, University of Florida, Gainesville. Personal communication (E-Mail) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., November 16, 2000.

[42] Bolten, A.B., University of Florida, Gainesville. Personal communication (Phone) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., January 15, 2001.

[43] Bolten, A., H. Martins, E. Isidro, R. Ferreira, M. Santos, A. Giga, B. Riewald, and K. Bjorndal. Preliminary results of an experiment to evaluate effects of hook type on sea turtle bycatch in the swordfish longline fishery in the Azores. Unpublished report, 2 pp.. A.B. Bolten , University of Florida, Gainesville. Personal communication (E-Mail) to Nancy Thompson and Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla, January 13, 2001.

[44] Bolten, A.B., University of Florida, Gainesville. Personal communication (E-Mail) to Sheryan Epperly, National Marine Fisheries Service, SEFSC, Miami, Fla., January 24, 2001.

Additionally, there was a tendency for more turtles to be caught on hooks closest to buoys, but there was no significant effect of hook position along the mainline on turtle bycatch (Chi-square test, $p = 0.515$).

The use of circle hooks to reduce sea turtle serious injury shows encouraging results. The presumption is that animals that ingest the hooks are less likely to survive an interaction than animals that are hooked in the mouth. Use of circle hooks would reduce the number of animals ingesting the hook, but not the total number being hooked. However, changing from "J" to circle hooks may adversely affect the catching success for target species, particularly for the swordfish fleet. In the Azores experiment, there was a significant difference among the hook types in the numbers of swordfish caught (Chi-square test, $p < 0.001$). The circle hook caught 262 swordfish and the "J" hook caught 381 swordfish, a 31.1% reduction.

Literature Cited

Prince, E.D., M. Ortiz, and A. Venizelos. In press. A comparison of circle and "J" hook performance in recreational catch and release fisheries for billfish. In American Fisheries Society Special Publication. National Symposium on Catch and Release in Marine Recreational Fisheries, December 5-8, 1999.

Skomal, G.B., B.C. Chase and E.D. Prince. In press. A comparison of circle and straight hooks relative to hooking location, damage, and success while catch and release fishing for Atlantic bluefin tuna. In American Fisheries Society Special Publication. National Symposium on Catch and Release in Marine Recreational Fisheries, December 5-8, 1999.

Time-Area Closure

Supplemental Bycatch Analysis to Determine Times and Areas of High Interactions

Bycatch data from 1992-1999 was obtained from the U.S. Pelagic Observer Program for both loggerhead and leatherback turtles. Generalized additive models were used to analyze the data. Seasonal bycatch of loggerhead and leatherback turtles appear similar within geographical regions. Number of turtles caught is higher in more northern locations, particularly in the Northeast Atlantic Ocean. For both turtle species, catches in the more southern regions are limited to the winter months. Patterns of catch in the coastal regions may follow migratory patterns: the southern bycatch decreases with day of the year in the Gulf of Mexico, while along the coast of New England it increases. Peak bycatch numbers for the loggerhead (Fig. 1) and leatherback (Fig. 2) occur in the Northeast Distant Atlantic region during mid-August.

The most recent Biological Opinion for the Highly Migratory Species Fishery[45] included a reasonable and prudent alternative (RPA) which would effectively close the fishery in the Northeast Distant Area (NED) from July-December. The NED has been identified as an area of high turtle interactions. The NMFS SEFSC was asked to evaluate whether a time/area closure smaller than the entire geographic extent and temporal duration given in the RPA could achieve the same degree of reduction in turtle takes with less impact on target catch. The SEFSC provided the following analysis.[46] The conclusion was that the interactions occur throughout the entire NED and not just in some small portion of it. An "L" shaped portion of the NED was closed under an emergency regulation for the period October 10, 2000-April 9, 2001 (65 FR 60899-60892, October 13, 2000).

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[45] Endangered Species Act - Section 7 Consultation Biological Opinion. Reinitiation of Consultation on the Atlantic Pelagic Fisheries for Swordfish, Tuna, Shark and Billfish in the U.S. Exclusive Economic Zone (EEZ): Proposed Rule to Implement a Regulatory Amendment to the Highly Migratory Species Fishery Management Plan; Reduction of Bycatch and Incidental Catch in the Atlantic Pelagic Longline Fishery, 118 pp. Consultation conducted by National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Md., June 30, 2000.

[46] Turtles involved with longline gear in the Gand [sic] Banks. Unpublished report. National Marine Fisheries Service Southeast Fisheries Science Center, Miami, FL. Attachment to E-Mail from Joseph Powers, National Marine Fisheries Service, SERO, St. Petersburg, Fla. to Karyl Brewster-Geisz, National Marine Fisheries Service, SF, Silver Spring, Md., August 25, 2000.

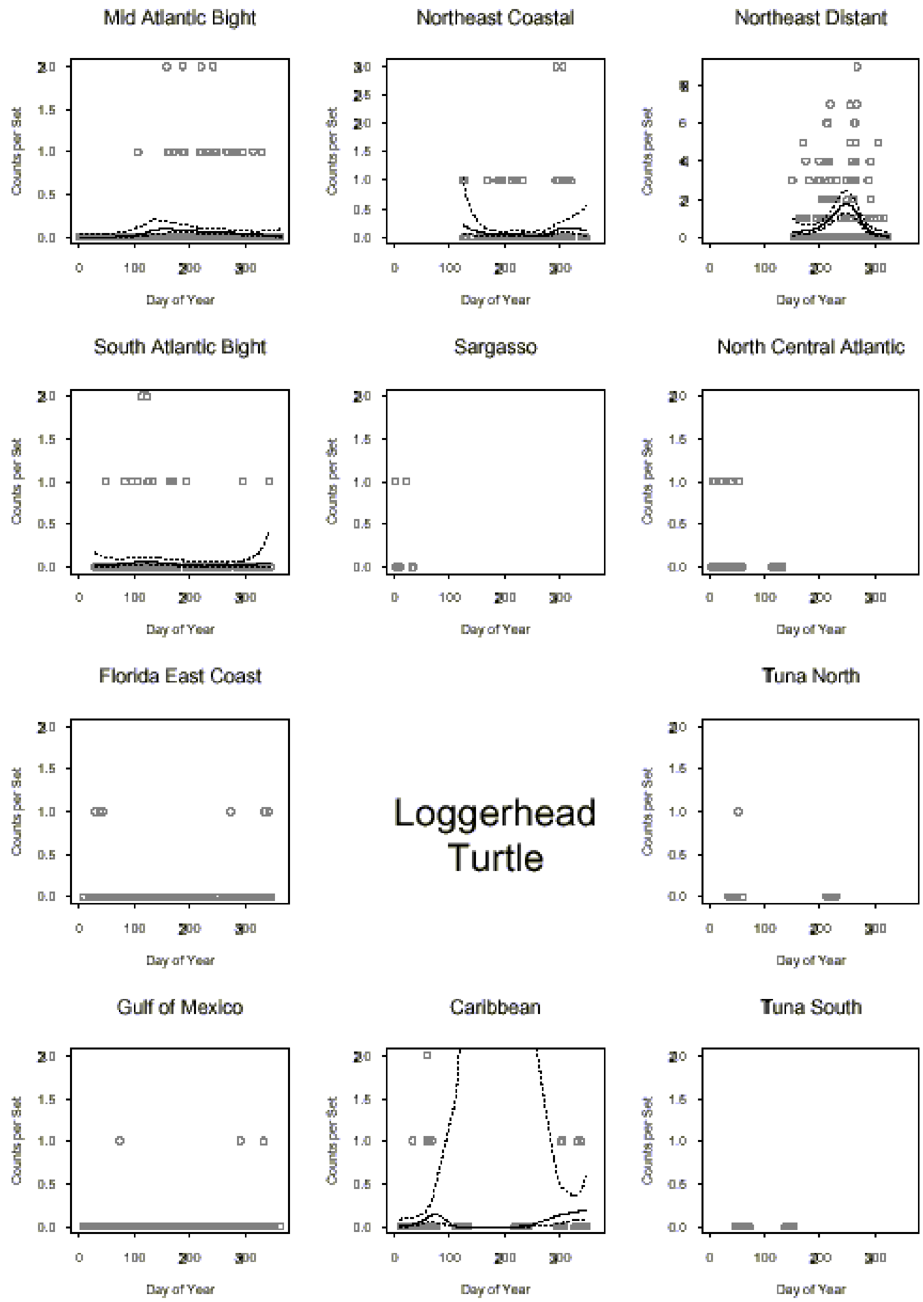

Figure 1. Seasonal counts of loggerhead turtles caught during each longline set from 1992 to 1999 (open circles). Fitted values from the model are given by a solid line and their point wise upper and lower confidence intervals are given by dotted lines. Individual plots represent 11 areas and are displayed in a pattern that roughly follows their relative north/south and east/west geographical location.

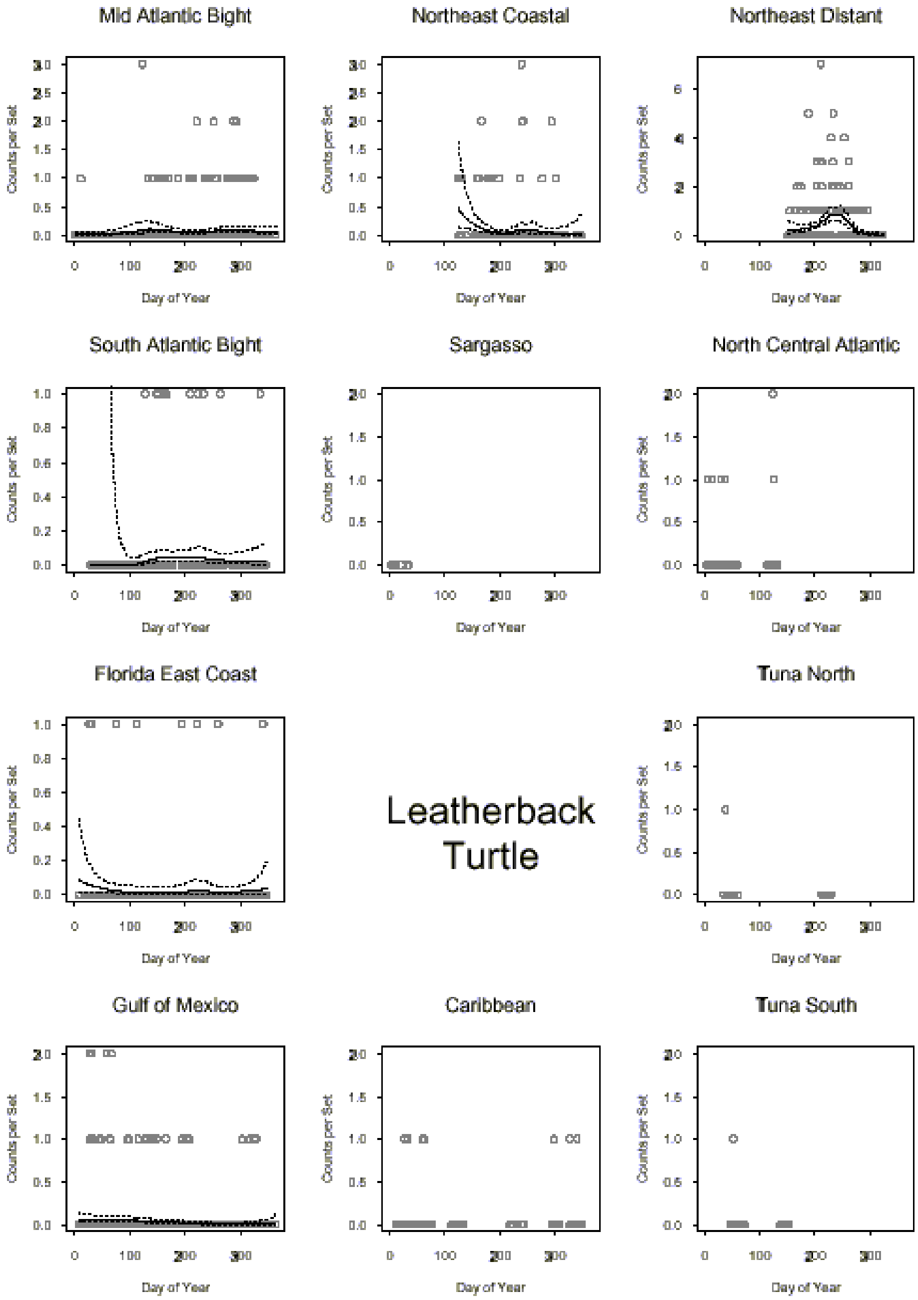

Figure 2. Seasonal counts of leatherback turtles caught during each longline set from 1992 to 1999 (open circles). Fitted values from the model are given by a solid line and their point wise upper and lower confidence intervals are given by dotted lines. Individual plots represent 11 areas and are displayed in a pattern that roughly follows their relative north/south and east/west geographical location.

Turtles Involved with Longline Gear in the Grand Banks

Data from the large pelagic logbook and the NMFS observer file were used to identify times and locations of turtle involvement with longline gear in the Grand Banks during the months July through December.

Description of data sources

Large pelagic logbook (LPL):

U.S. Atlantic, Caribbean and Gulf of Mexico fishing vessels which land swordfish have been required to provide daily records of effort and catch since October 1986. Numbers of turtles involved, injured, and killed have been reported to this file since 1992. Although a variety of gear types are represented, the predominant gear type (90% of vessels reporting) is longline gear. Fishing effort in this area is seasonal. Very little effort was reported in December.

Table 1. Numbers of turtles reported involved, injured, or killed by pelagic longline vessels in the Grand Banks between July and December 1992-1999.

	Green	Hawksbill	Kemp's Ridley	Leather-back	Logger-head	unknown
involved	74	129	16	793	2020	10
injured	1	0	0	6	35	0
killed	0	0	0	8	3	0

NMFS Observer (NMFSO):

National Marine Fisheries Service observers have observed a random sample of longline vessels targeting swordfish and tuna since 1992. Numbers of fish and turtles landed, discarded dead and discarded alive are recorded in this file as well as gear and location information.

Table 2. Numbers of turtles observed released alive or killed by pelagic longline vessels in the Grand Banks between July and December 1992-1999.

	Green	Leatherback	Loggerhead	unknown
released alive	8	106	225	1
released dead	1	0	0	0

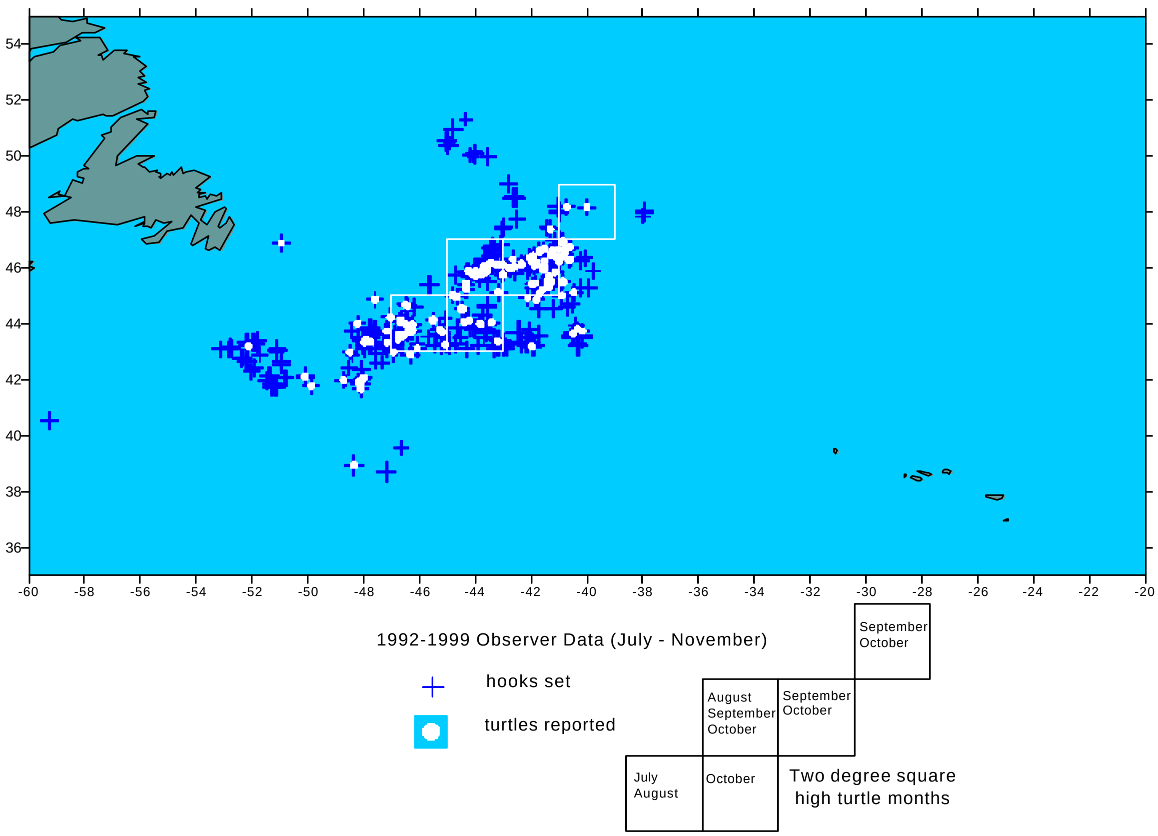

Figure 3. Locations of observed effort (hooks set) and turtle involvement (turtles reported) from NMFSO form July through November are shown on this map. Squares indicate areas of highest turtle involvement. The relevant months of high involvement for each square are indicated by listing the months in the square diagram above this caption.

Observer data were grouped within each year by month and two degree square. A GLM model was run: all turtles reported vs year and month-square. The number of hooks reported in the month-square was used as a weighting variable. Month-squares were ranked based on the LSMEAN value from the GLM. The ten month-squares with the highest estimated turtle involvement (based on the LSMEAN values) are shown in Figure 3. The month written inside the square indicates that the square was high for that month.

Table 3 gives the percentage decreases in turtles involved (relative to total involvement in the Grand Banks July-Dec), effort in hooks, and catch of other species resulting from closure of the U.S. fishery in the Grand Banks, using NMFS Observer data. Table 5 gives the same information based upon Large Pelagic Logbook data. Decreases resulting from closures of high month-squares (based on NMFSO) are shown in Table 4.

Table 3. The percent decrease with total closure for month based on observer records.

	All Turtles	Swordfish Landed	Tuna	Mako Sharks	Swordfish Dead Disc	Blue Sharks	HOOKS
total	341	6240	1904	892	1703	11263	265744
July	28%	39%	22%	60%	50%	30%	35%
August	25%	16%	4%	20%	18%	18%	14%
September	36%	19%	23%	9%	15%	13%	16%
October	9%	24%	29%	8%	13%	29%	26%
November	2%	3%	23%	3%	4%	10%	9%

Table 4. The percent decrease with closure of high two degree squares for month based on observer records.

	All Turtles	Swordfish Landed	Tuna	Mako Sharks	Swordfish Dead Disc	Blue Sharks	HOOKS
July %	6%	8%	3%	14%	10%	10%	6%
Aug %	9%	4%	0%	4%	3%	3%	4%
Sept %	24%	13%	15%	6%	9%	7%	10%
Oct %	1%	9%	7%	3%	3%	7%	8%

Table 5. The percent decrease with total closure for month based on logbook records.

Month	All Turtles	Swordfish Landed	Tuna	Mako Sharks	Swordfish Dead Disc	Blue Sharks	HOOKS
	3095	119237	23659	6846	11936	273307	4749322
July	36%	22%	14%	39%	30%	20%	22%
August	24%	27%	19%	28%	22%	29%	25%
September	24%	29%	31%	17%	23%	23%	26%
October	15%	19%	23%	13%	19%	21%	20%
November	1%	3%	12%	3%	5%	7%	7%
December	0%	0%	1%	0%	0%	0%	0%

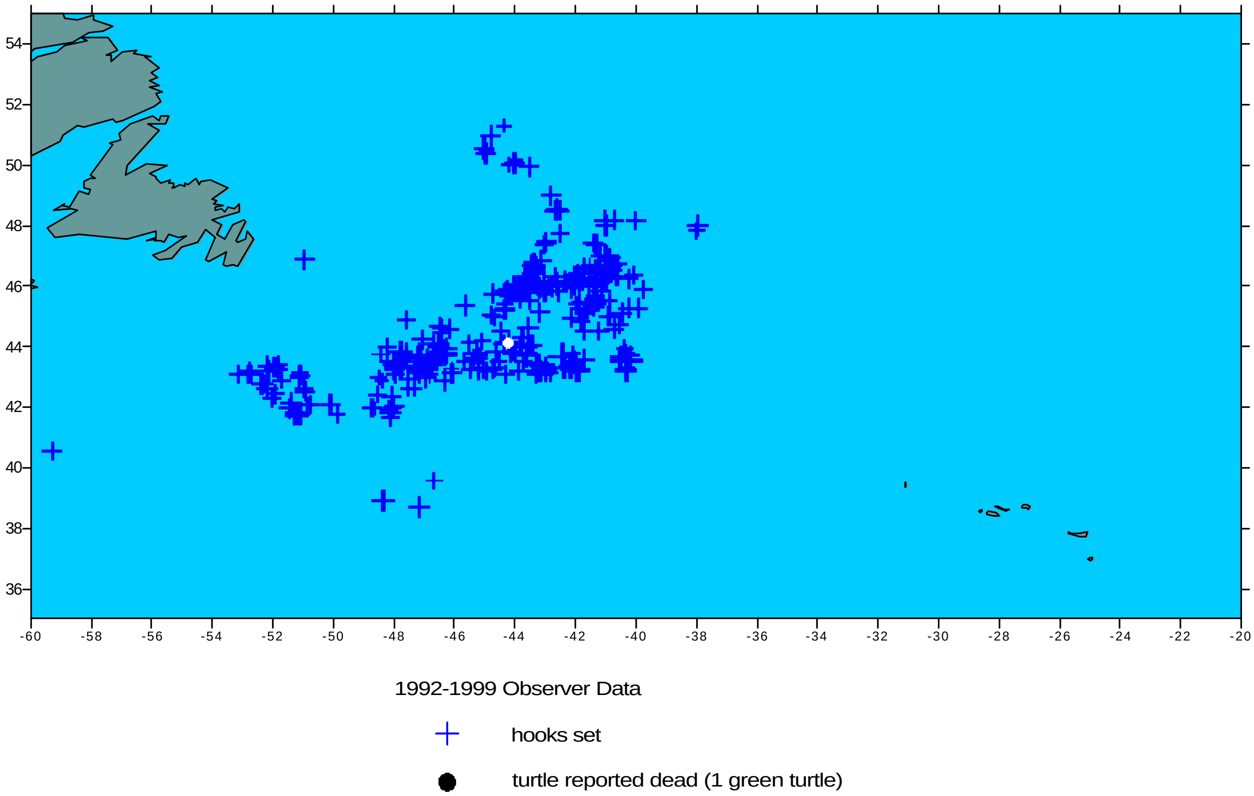

Figure 4. Location of turtles reported dead. (NMFSO)

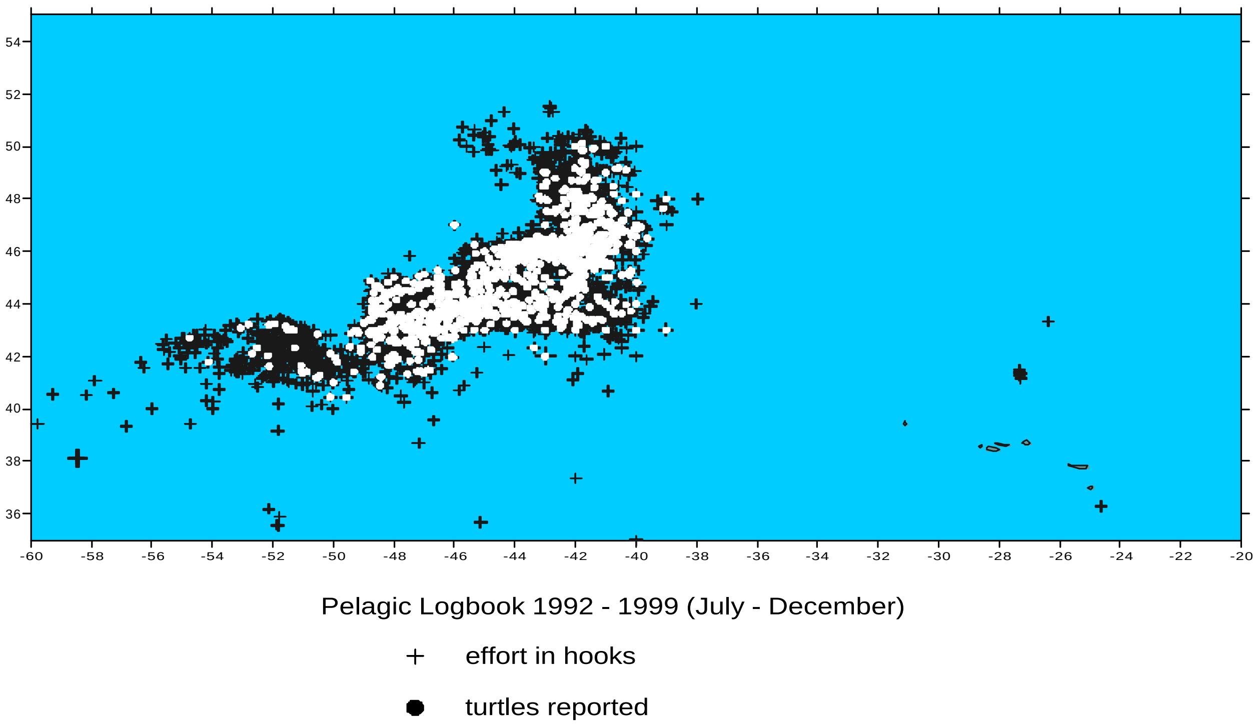

Figure 5. Locations of reported effort (hook set) and turtle involvement (turtles reported) from LPL form July through December are shown on this map

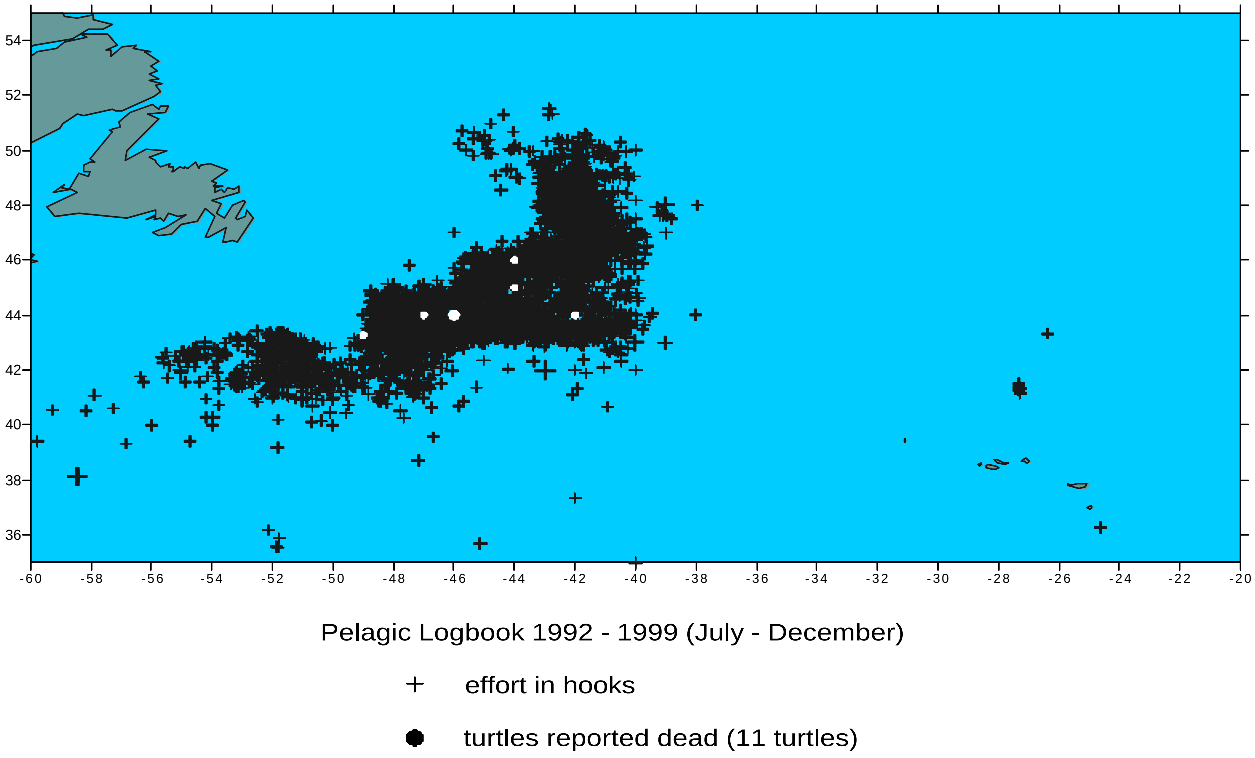

Figure 6. Locations or turtles reported killed (LPL)

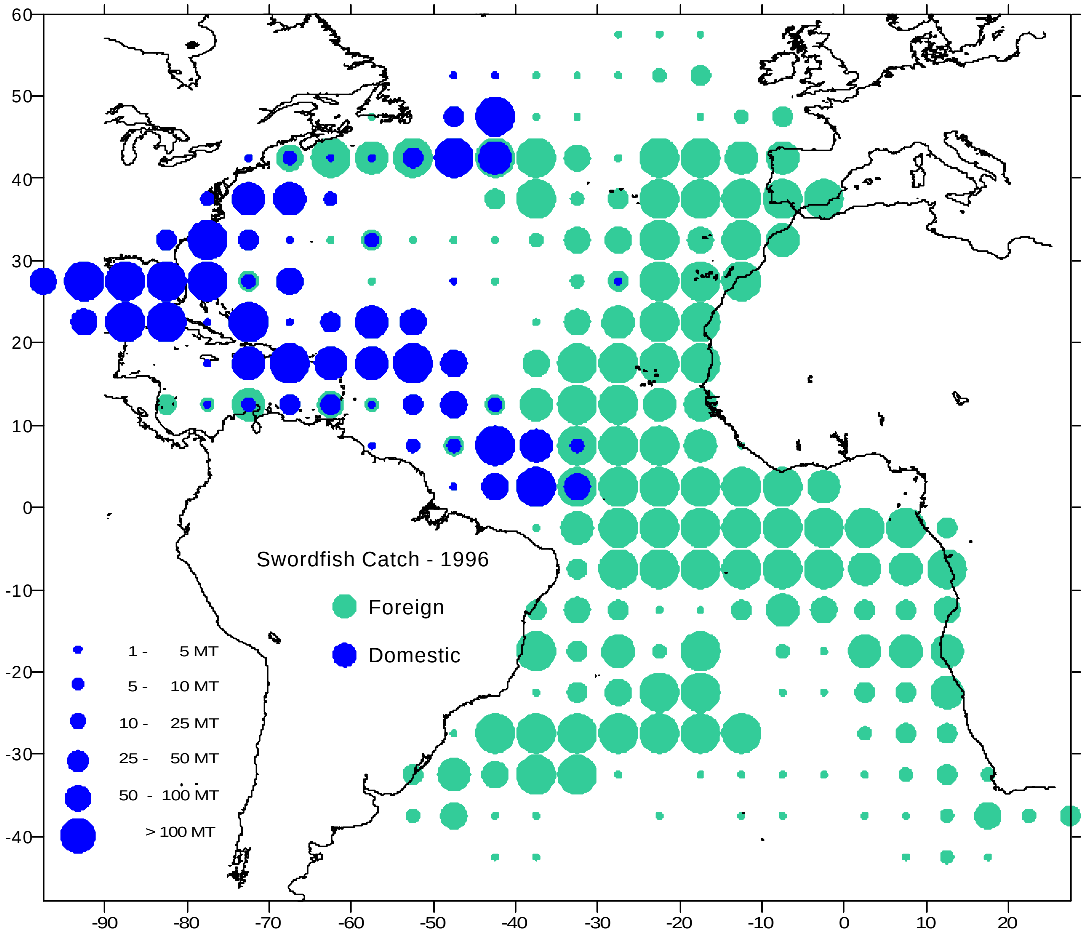

Figure 7. Domestic (U.S.) and foreign swordfish catch in 1996. Foreign catch data are incomplete and includes only North American, Asian, and Spanish reported landings. Notably not included are catches from Caribbean, Central and South America, and other European countries.

In response to a request from the NMFS Office of Sustainable Fisheries, the SEFSC provided the results of a GLM model run on the logbook data for 2 degree latitude/longitude squares (J. Cramer personal communication[47]) (Table 5) and output from these analyses were provided (J. Cramer personal communication[47]) (Appendix 5). The conclusions were the same as from analyses based on the observer data.

Table 5. The number of reported interactions (LPL) with sea turtles by the pelagic longline fleet. The first square is between 43° to 45° N latitude and 45° to 47° W longitude. The number is in the center of the two degree square. These are the highest 10 month/squares with 1 being the highest LSMEAN from the GLM.

logbook				
square	July	August	September	October
4446	8			
4642	1	4	3	
4644	2		6	
4640		9		
4442	7			
4248				5
5044			10	

[47] Jean Cramer, National Marine Fisheries Service, SEFSC, Miami, Fla. Personal Communication (E-Mail) to Karyl Brewster-Geisz, National Marine Fisheries Service, SF, Silver Spring, Md., August 28, 2000.

Evaluation of the Effect of Sea SurfaceTemperature and Time of Set on Sea Turtle Bycatch off the Northeast U.S.

One of the alternative reasonable and prudent alternatives identified in the most recent Biological Opinion was to manage all pelagic longline vessels fishing north of 35 N latitude so that they fish only in waters with sea surface temperatures cooler than 64 C. It furthermore stipulated that gear shall be not be set prior to 10 p.m.[48]

Sea Surface Temperature

Previous analyses have described factors that appear to influence rates of sea turtle interactions with the Atlantic pelagic longline fishery and suggested that sea surface temperature or time of set may influence the probability of interacting with a sea turtle (Hoey 1998[49], Hoey and Moore 1999[50]). The datasets used for those analyses were updated through 1999 and graphed (Fig. 8 and 9) to assess the effect of sea surface temperature on turtle bycatch in the Northeast U.S. (MAB and NEC areas) and Northeast Distant (NED) fishing areas (Hoey 2000[51]) (see Chapter 2 for definition of these areas).

These data are difficult to interpret because they do not represent a random sample of water temperatures in the 2 areas and the patterns observed may be an artifact of the distribution of fishing effort (Fig. 10). While it appears that the distribution of turtles may be affected by water temperature (a reasonable conclusion since sea turtles generally are poikilothermic), there is no clear pattern for swordfish, the primary target species in the area. The pattern observed for the target species is completely opposite in the two areas, with swordfish tending to be caught at a higher rate at higher temperatures on the Grand Banks and caught a higher rate at lower temperatures in the Northeast Coastal Area. Thus, an attempt to restrict the fishery to cooler waters where turtles are less likely to occur cannot be done without some potential impact on the catch of the target species.

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[48] Endangered Species Act - Section 7 Consultation Biological Opinion. Reinitiation of Consultation on the Atlantic Pelagic Fisheries for Swordfish, Tuna, Shark and Billfish in the U.S. Exclusive Economic Zone (EEZ): Proposed Rule to Implement a Regulatory Amendment to the Highly Migratory Species Fishery Management Plan; Reduction of Bycatch and Incidental Catch in the Atlantic Pelagic Longline Fishery, 118 pp. Consultation conducted by National Marine Fisheries Service, Office of Protected Resources, Silver Spring, Md., June 30, 2000.

[49] Hoey, J. 1998. NEFSC pelagic longline data review & analysis of gear, environmental, and operating practices that influence pelagic longline interactions with sea turtles. Unpublished Report. National Fisheries Institute, Inc., Arlington, VA Final Contract Report NOAA-Contract – 50EANA700063 to National Marine Fisheries Service Northeast Regional Office, Gloucester, MA, 32 pp.

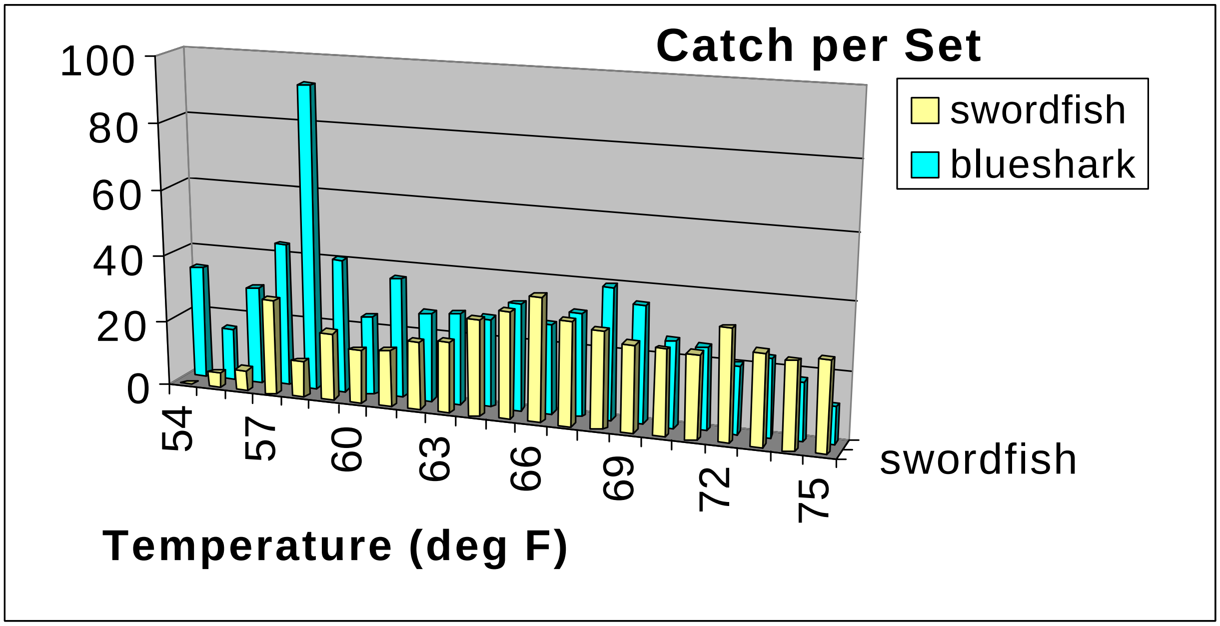
[50] Hoey, J. and N. Moore. 1999. Captain's report. Multi-species catch characteristics for the U.S. Atlantic pelagic longline fishery. Unpublished Report. National Fisheries Institute, Arlington, VA report for National Marine Fisheries Service Southeast Regional Office, St. Petersburg, FL (MARFIN Grant – NA77FF0543) and Northeast Regional Office, Gloucester, MA (Saltonstall-Kennedy Grant – NA86FD0113), 78 pp.

[51] John Hoey , National Marine Fisheries Service, ST, Silver Spring, Md. Personal Communication (E-Mail) to K. Wang, National Marine Fisheries Service, SERO, St. Petersburg, Fla., June 2, 2000. Unpublished Report. Requested re-examination of gear, environmental, and opening practices associated with sea turtle longline interactions, 26 pp

Surface water temperature is shown in regression tree analysis to be an important factor in the rate of bycatch of leatherbacks and loggerheads in the NED area in certain years (see Chapter 2). For leatherbacks, the temperature effect is nested within the month effect, and for loggerheads, the month effect is nested within the temperature factor. For all species combined, lower temperature is associated with lower bycatch rate. While this association is true also for loggerheads only, for leatherbacks, lower temperature actually accounts for a slightly higher bycatch rate, so if indeed temperature is a significant factor in bycatch rate the interaction may be species-specific. Both temperature and month effects may however simply be a reflection on the seasonal distribution of fishing effort, since effort tends to be concentrated in the 3rd quarter in NED, which is likely to have a higher average temperature than in other quarters combined.

Figure 8. Catch rates of swordfish, blueshark, hardshell (Cheloniidae) and leatherback sea turtles in the Northeast Distant Area. (A) finfish catch per set and (B) sea turtle catch per set.

(A)



(B)

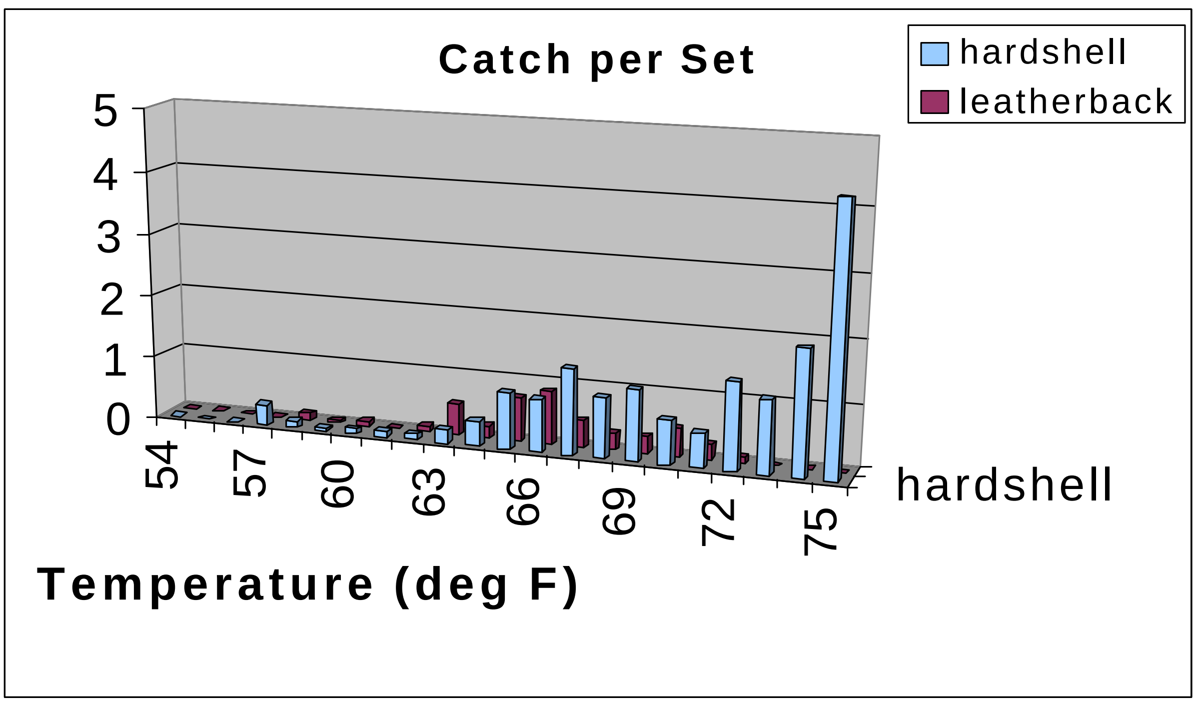
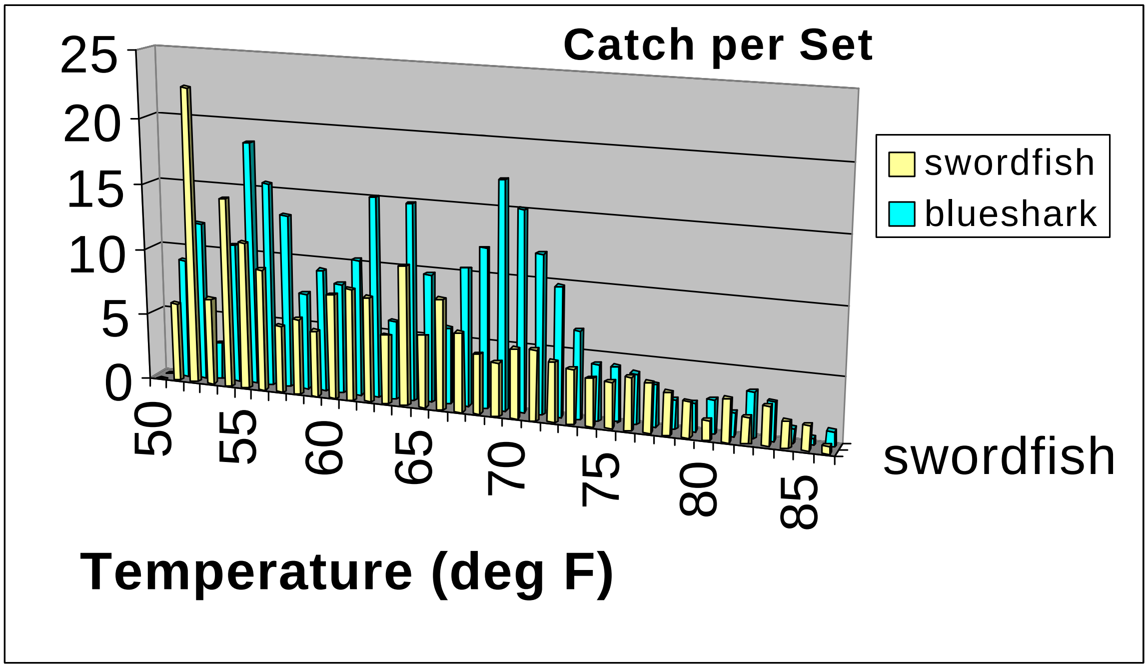


Figure 9. Catch rates of swordfish, blueshark, hardshell (Cheloniidae) and leatherback sea turtles in the Northeast Coastal Area. (A) finfish catch per hook and (B) sea turtle catch per hook.

(A)



(B)

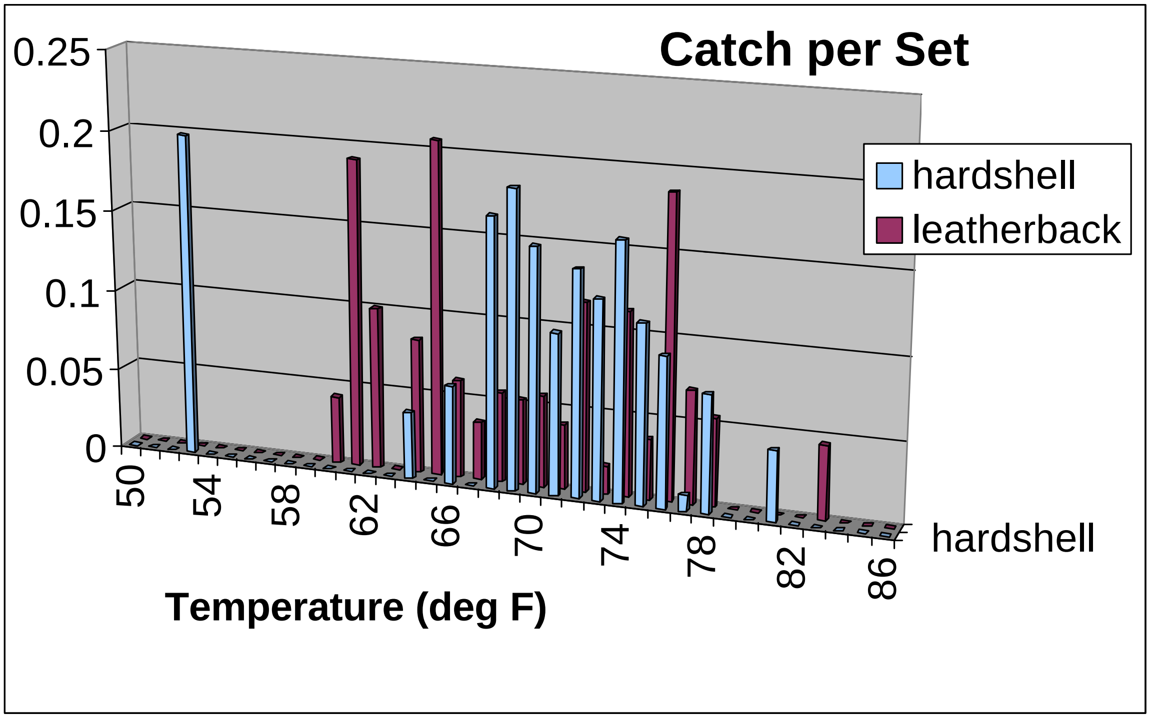
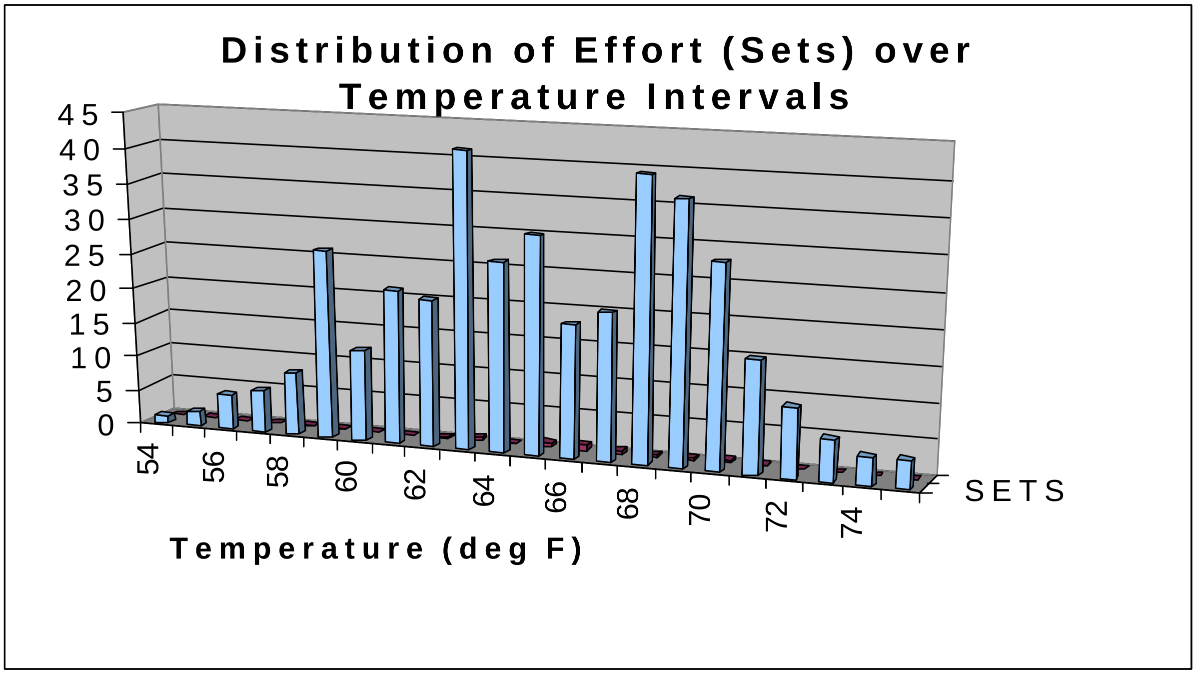
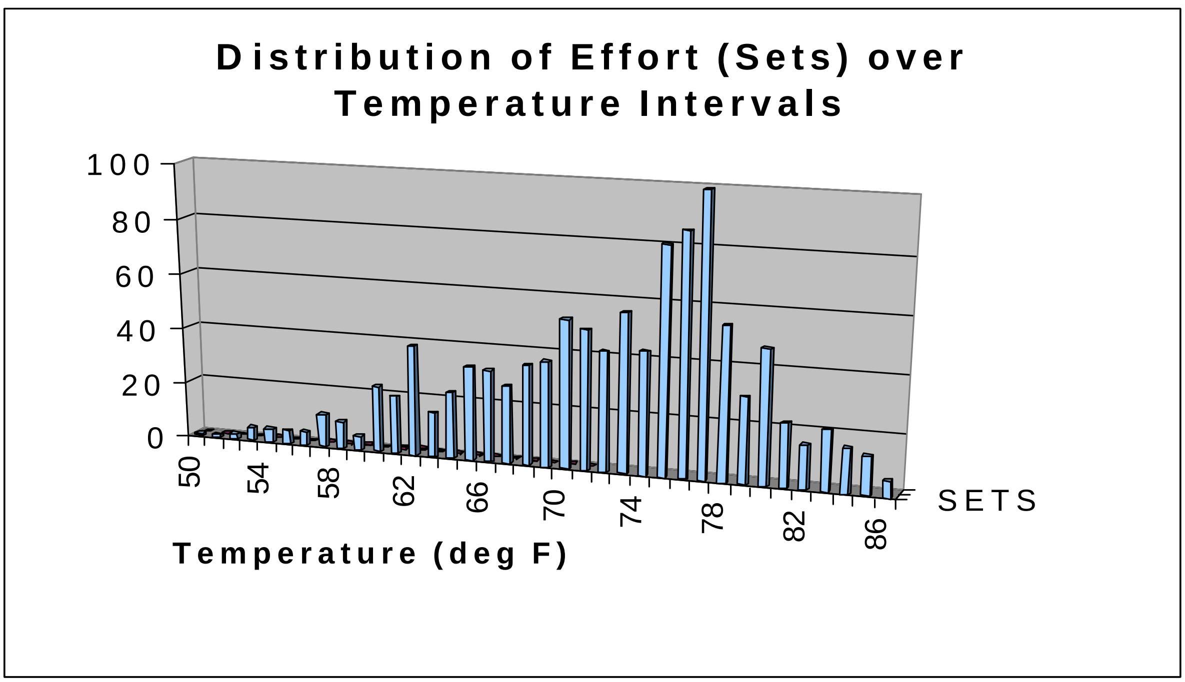


Figure 10. Distribution of effort (sets) across temperature intervals. (A) the Northeast Distant Area and (B) the Northeast Coastal Area.

(A)



(B)



Time of Set

Likewise time of day when sets were made also did not represent a random sample of times throughout a day (Fig. 11). Turtles appeared to be captured whenever sets were made (Fig. 12).

Figure 11. Distribution of effort (sets) across time intervals.

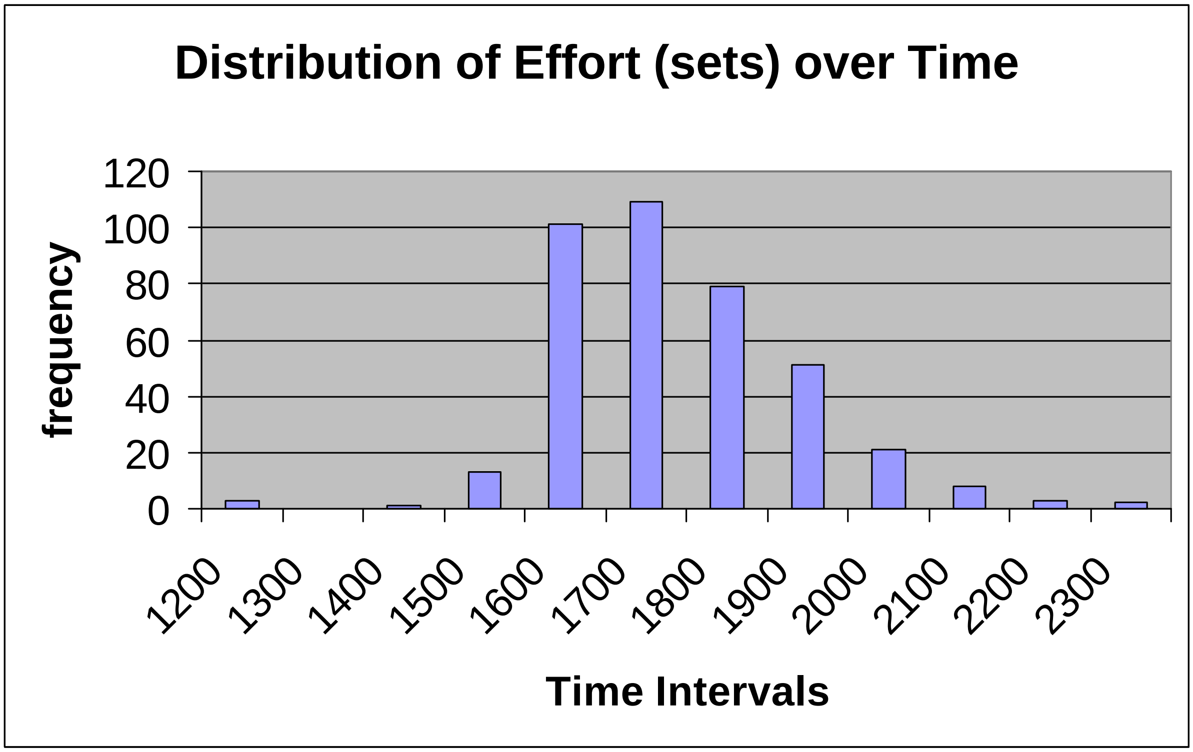
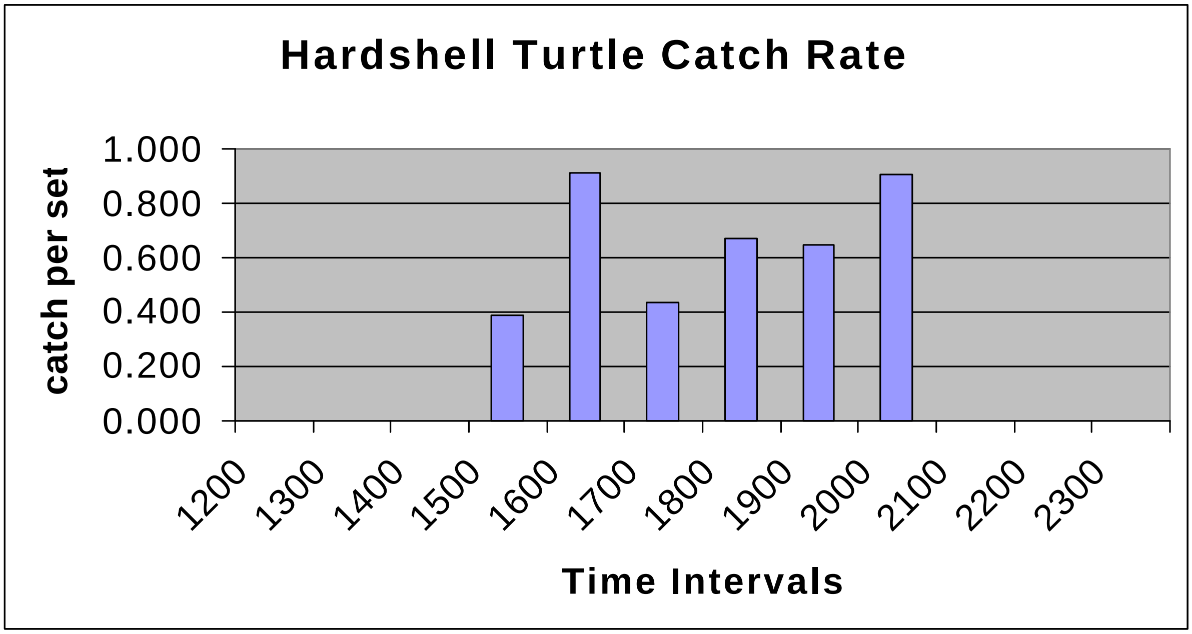
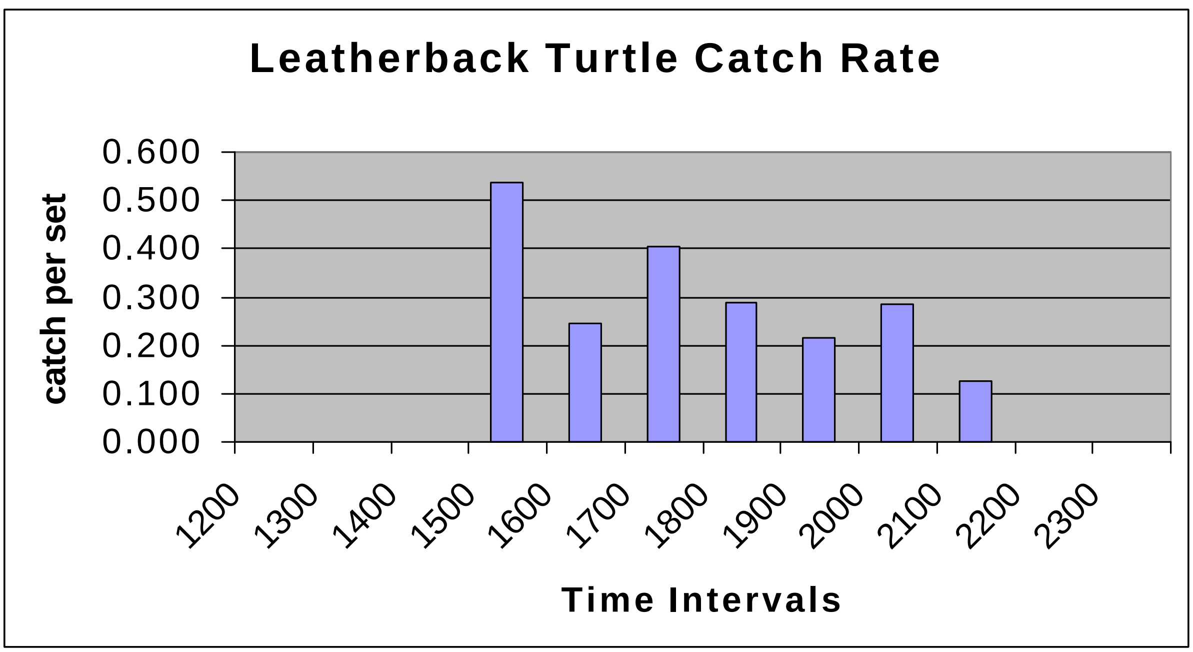


Figure 12. Catch rates of hardshell (Cheloniidae) and leatherback sea turtles in the Northeast Coastal and Northeast Distant Area. (A) hardshell turtles and (B) leatherback turtles.

(A)



(B)



APPENDIX 1:

META-ANALYSIS OF POPULATION TRENDS OF LOGGERHEAD AND LEATHERBACK TURTLES

Ransom A. Myers
Keith G. Bowen
Leah Gerber

1 Introduction

Critical conservation decisions often have to be made from widely scattered local data that may show what appears to be contradictory trends. Traditionally, each trend was examined independently to determine if they show statistically significant results. This approach–determining the proportion of studies individually exhibiting statistical significance in the prescribed direction–is known as "vote counting" in the meta-analysis literature, and is inherently flawed (Hedges and Olkin 1985). Hedges and Olkin (1980) showed that as the number of studies becomes large, the proportion of studies yielding significant results is approximately the average power of the test.

Here we suggest an improved approach. Our goal is to obtain the most powerful estimates, and still model the variation among sites.

2 A Mixed Model Approach

We begin with the simplest of models. Let X_{it} be the estimate of abundance of nesting females at each site i in year t. We will examine the simplest possible dynamic model for each site, given that each site began with an initial number of nesting females in the first year of the study, i.e. at $t = 0$ each site had x_{i0} nesting females. If each population is changing at a constant rate over the period of time of the censuses, we have

$$X_{it} = X_{i0}e^{r_i t+\varepsilon_{it}}$$

where r_i is the instantaneous rate of population change, X_{i0} is the initial population size of the ith population, and ε_{it} is the error in the estimate of abundance and deviations from the assumed model (sometimes called "process error").

It is unlikely that all the nest sites will have exactly the same rate of change, so we will investigate a simple mixed effect model where we assume that $r_i \sim N(\mu_r, \sigma_r^2)$, where μ_r is the mean instantaneous rate of change in population size for the nesting sites and σ_r^2 is the variance among populations.

We will investigate two approaches to the above model: (1) we log transform the data and use a linear mixed model and (2) we will use the raw counts and use a generalized linear mixed model. the second approach is more flexible, and can handle years in which no turtles were observed, but the first is easier to implement and understand.

3 A Linear Mixed Model

First, we can log transform the above model. Let $x_{it} = \log X_{it}$, then we have

$$x_{it} = x_{i0} + r_i t + \varepsilon_{it}.$$

Now r_i can be interpreted as a slope, and x_{i0} can be interpreted as an intercept. The initial population number is also observed with error so that it is clearer if we define the true initial log abundance to be a parameter, $\theta_i =$ true x_{i0}, which we will estimate. The above equation becomes

$$x_{it} = \theta_i + r_i t + \varepsilon_{it}.$$

The nesting sites vary in size and suitability for nesting, and these properties can be thought of as intrinsic to each site, and unrelated to any other site. Since the intercept for each nesting site determines the initial density, we treat the intercepts as site-specific fixed effects. The rate of change of the population at each nesting site, however, may reflect larger-scale phenomena such as climate or management policies. Therefore we model the slope for each nesting site as a random effect.

We used restricted maximum likelihood (REML) to fit the linear mixed models. REML can be thought of as an adjustment to the degrees of freedom accounting for the fixed effects, giving unbiased variance estimates (Searle et al. 1992). The likelihood ratio test (lrt) was used to compare the fit of different models.

We estimated the parameters of this model under two different assumptions for ε_{it}. First, we assumed that the variance of ε_{it} is the same for all sites. That is, we assume that $\varepsilon_{it} \sim N(0, \sigma^2)$, where σ^2 is estimated from the data. An alternative approach is to assume that the variances are primarily due to factors unrelated to sample size, and estimate a separate variance, σ_i for each site.

For loggerheads, we were interested in if the population growth rate has changed after the introduction of TEDs in 1989. We thus fit the piecewise linear mixed model:

$$X_{it} = X_{i0} e^{r_i t + r_i^* t^* + \varepsilon_{it}}$$

where $t^* < 0$ if $t < 1990$ and $t^* = t - 1989$ otherwise, and r_i^* is the difference in the instantaneous rate of population change before and after TEDs were introduced.

4 A Generalized Linear Mixed Model

In order to test the robustness of our approach we investigated alternative model formulations. Alternatively, we assumed that the residual variation in the above model was described by a gamma, as opposed to a lognormal, distribution. For this model, we used a generalized linear mixed model with a log link and a gamma error distribution. The variation of r among sites was still considered Gaussian. These parameters were estimated using the generalized linear mixed model methods developed by Wolfinger and O'Connell (1993).

5 Obtaining an overall estimate of population changes

The above model does not provide an estimate of the total population change over time. One approach can be used if trend data is available for all sites, though at some sites very limited data might be available. In this case we can include all reliable data and obtain predictions (BLUP) from a mixed model for each site and year.

6 Data

6.1 Loggerheads

We used data from beach surveys of nesting. We have limited our analysis to beaches where we believe the effort has been relatively constant over time by including only the years where consistent length of beach was surveyed and survey start dates were similar (within a two week time period). However, for Georgia this information was not available and the assumption of consistent effort may not always be true, particularly for the early years. We view this as the greatest uncertainty in the analysis. The loggerhead nesting data has been divided into two groups, the northern subpopulation and the southern subpopulation. The northern subpopulation includes the beaches in North Carolina, South Carolina, Georgia, and northern Florida. We combined results for two different time periods: 1979-1999 and 1989-1999. We believe that the data from the more recent period are more consistent. The following table shows the beaches that are included in the analysis.

Subpopulation	State	Beach	Distance surveyed	Date of first survey
northern	North Carolina	Cape Lookout National Seashore	?	?
northern	North Carolina	Bald Head Island Conservancy	15 miles	5/15
northern	North Carolina	Hammocks Beach State Park	3 miles	5/15
northern	North Carolina	Camp Lejeune Marine Base	6.8 miles	5/24
northern	South Carolina	Cape Island	?	?
northern	Georgia	Blackbeard Island	?	?
northern	Georgia	Cumberland Island	?	?
northern	Georgia	Jekyll Island	?	?
northern	Georgia	Little Cumberland Island	?	?
northern	Georgia	Little St. Simons Island	?	?
northern	Georgia	Tybee Island	?	?
northern	Georgia	Ossabaw Island	?	?
northern	Georgia	Pine Island	?	?
northern	Georgia	Sapelo Island	?	?
northern	Georgia	St. Catherine's Island	?	?
northern	Georgia	Sea Island	?	?
northern	Georgia	St. Simons Island	?	?
northern	Georgia	Wassaw Island	?	?
northern	Florida	Flagler Co.	24.1 km	4/25-5/1
northern	Florida	Washington Oaks	1.1-1.2 km	5/1
northern	Florida	Anastasia SRA	7.2 km	5/1
northern	Florida	Fort Mantanzas NM	11.2-11.3 km	5/14-5/27
northern	Florida	Ponte Vedra S	23.6 km	4/28-5/10
northern	Florida	Guana River SP	6.7-6.8 km	5/1-5/15
northern	Florida	Amelia Island	14.4-14.5 km	5/1
northern	Florida	Ft Clinch SP	3.7 km	5/1
southern	Florida	Hutchinson Island	36.5 km	4/10-4/24
southern	Florida	Broward Co. Beaches	34.7 km	3/1
southern	Florida	J.U. Lloyd SRA	3.9 km	4/20-4/30
southern	Florida	Boca Raton Beaches	8.0 km	3/1
southern	Florida	MacArthur SP	2.9 km	3/1-3/10
southern	Florida	Casey Key	11.8 km	5/1
southern	Florida	Siesta Key	9.0 km	5/1

A negative correlation was found between abundance and date of first nest for Cape Hatteras National Seashore, North Carolina and Pea Island National Wildlife Refuge, North Carolina. These beaches were left out of the analysis. Cape Lookout National Seashore, North Carolina is believed to be standardized after 1990 so this beach was included even though there is no distance surveyed or first date of survey. For one of the Georgia beaches, Little Cumberland Island, there has been a large amount of beach erosion. We decided to keep this beach in the analysis because this represents natural variation among beaches, and the turtles from that beach probably nested elsewhere in the region. A second analysis was performed for the northern subpopulation leaving out the

Georgia beaches because the reliability of that information is not known at this time.

6.2 Leatherbacks

Distance of beach covered and survey start date were known for some of the beaches observed for leatherback nesting. Again, we tried to use only the years with consistent coverage. The data were separated into three areas for analysis because the overall trends differed for these three areas. These areas are: South America, St. Croix (US Virgin Islands), and Florida. For Florida we have limited our analysis to beaches where we believe the effort has been relatively constant over time by including only the years where consistent length of beach was surveyed and survey start dates were similar (within a two week time period). However, for South America and the US Virgin Islands this information was not available and the assumption of consistent effort may not always be true, particularly for the early years. The following table shows the beaches that are included.

Area	Beach	Distance surveyed	Date of first survey
Florida	Hutchinson Island	36.5 km	4/8-4/18
Florida	Jupiter/Juno Beach	9.6 km	2/15-3/1
Florida	Jupiter Island	13.7 km	3/1-3/3
Florida	MacArthur SP	2.9 km	3/1
Florida	Highland Beach	4.8 km	4/1-4/15
Florida	Broward Co. Beaches	34.7 km	3/1
Florida	S Brevard Beaches	40.5 km	4/26-5/8
S. America	Yalimapo, French Guiana	?	?
S. America	Galibi, Suriname	?	?
S. America	Matapica, Suriname	?	?
US Virgin Islands	St. Croix	?	?

7 Results

We fit a variety of models to each data set: with lognormal, gamma, or extra-Poisson variability in the observation error, with separate error variances for each beach, and with and without outliers. We found that there was relatively little difference among these models fits, but that the separate error variance was usually needed. For simplicity we will report the lognormal error with separate error variances as our primary estimates.

7.1 Loggerheads

7.1.1 Georgia

As an example, we first consider the beaches in Georgia individually from 1979-1999. The estimates of the slope if each nesting site is fit individually by OLS regression are:

```
Nesting    Parameter      Standard    T for H0:
Site       Estimate          Error   Parameter=0    Prob > |T|
BKB         0.005577    0.01366527         0.408        0.6878
CUM         0.007004    0.01254062         0.559        0.5860
JEK         0.015879    0.01160858         1.368        0.1903
LCI        -0.092834    0.00900179       -10.313        0.0001
LSI         0.041901    0.03072965         1.364        0.2026
OSS         0.017643    0.01747988         1.009        0.3270
PIN        -0.011962    0.03620422        -0.330        0.7473
SAP         0.057755    0.02783523         2.075        0.0622
SCI        -0.011230    0.01948592        -0.576        0.5760
SEA         0.073510    0.04804723         1.530        0.1604
SSI        -0.192613    0.06439019        -2.991        0.0152
TYB        -0.001411    0.08965388        -0.016        0.9878
WAS         0.024396    0.01453494         1.678        0.1096
```

Note that there are two nominally significant declines (LCI and SSI), but 8 of the 13 slopes are positive.

We now consider the mixed model results. The estimate for the mean instantaneous rate of change, μ, was -0.003 (s.e. = 0.015). The standard deviation of r among sites, σ_r, was estimated to be 0.04, and the standard deviation of the error, σ, was estimated to be 0.43.

If we allowed separate error variances for each site, μ is estimated to be slightly positive ($\hat{\mu} = 0.002$, s.e. = 0.01), and with less variation among sites ($\hat{\sigma}_r = 0.03$).

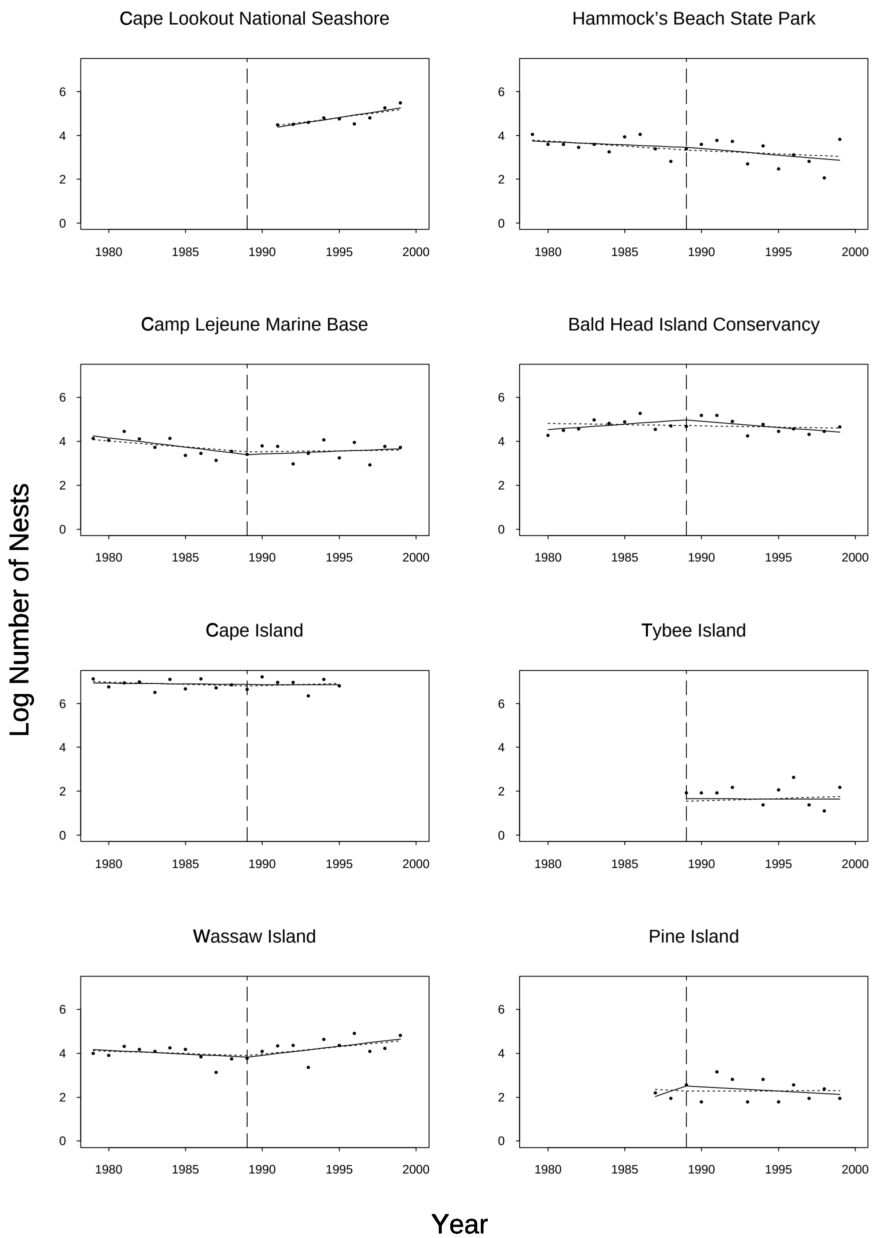
Similar results were obtained for the time period from 1989 to 1999 when the nesting data is believed to be more reliable, i.e. there was no evidence of an overall change in the populations in Georgia.

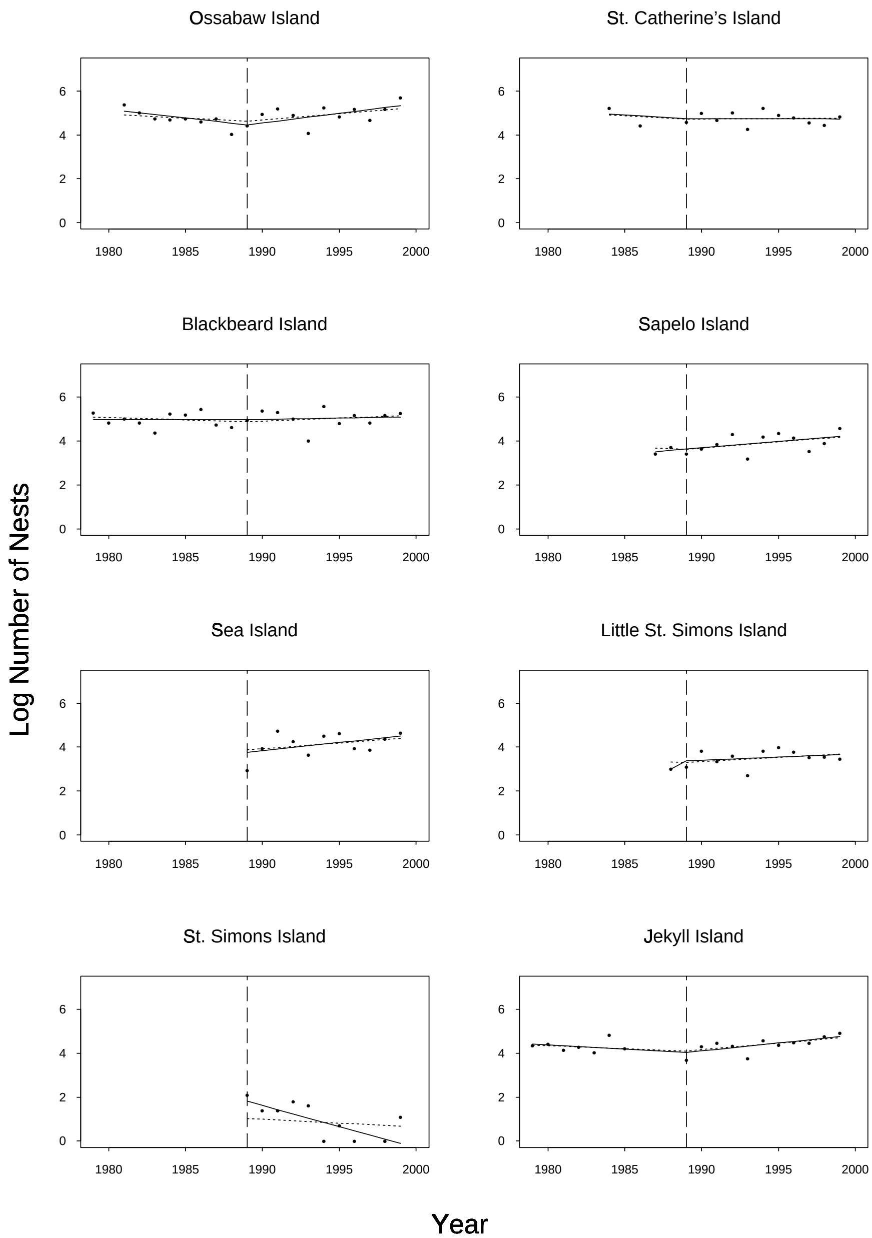
7.1.2 Northern US population

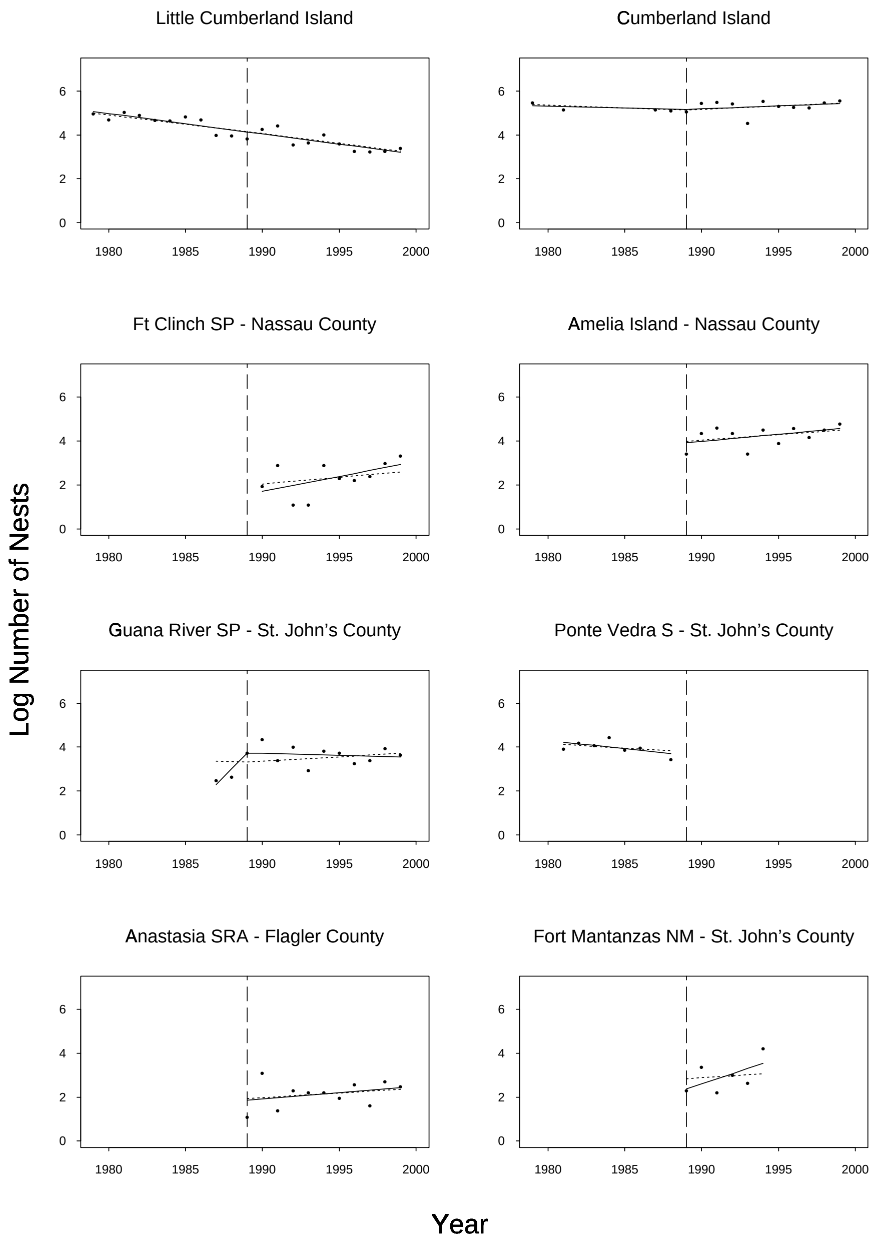
In this analysis we fit the data from 1978-1989 with one “r” and the data after with a second “r” (r^*) using a piecewise linear model. In the results below, the “r” for the early period is estimated, then the change in “r” is added on, all in the same mixed model.

error	separate error variance	year	estimate	se pred	df
lognormal	no	> 1978	$r = -0.026$	0.015	25
lognormal	no	> 1989	$r^* = 0.054$	0.022	18
lognormal	yes	> 1978	$r = -0.030$	0.012	25
lognormal	yes	> 1989	$r^* = 0.059$	0.017	18

The effect of the mixed model analysis for the northern US loggerhead populations is clear when examining the data (Fig. 1). Each point in the plot represents the number of log transformed nests. Note that when there are outliers, the mixed model fits downweight these outliers.




Ossabaw Island
St. Catherine's Island
Blackbeard Island
Sapelo Island
Sea Island
Little St. Simons Island
St. Simons Island
Jekyll Island
Log Number of Nests
Year
0
2
4
6
1980
1985
1990
1995
2000


Little Cumberland Island
Cumberland Island
Ft Clinch SP - Nassau County
Amelia Island - Nassau County
Guana River SP - St. John's County
Ponte Vedra S - St. John's County
Anastasia SRA - Flagler County
Fort Mantanzas NM - St. John's County
Log Number of Nests
Year
0
2
4
6
1980
1985
1990
1995
2000

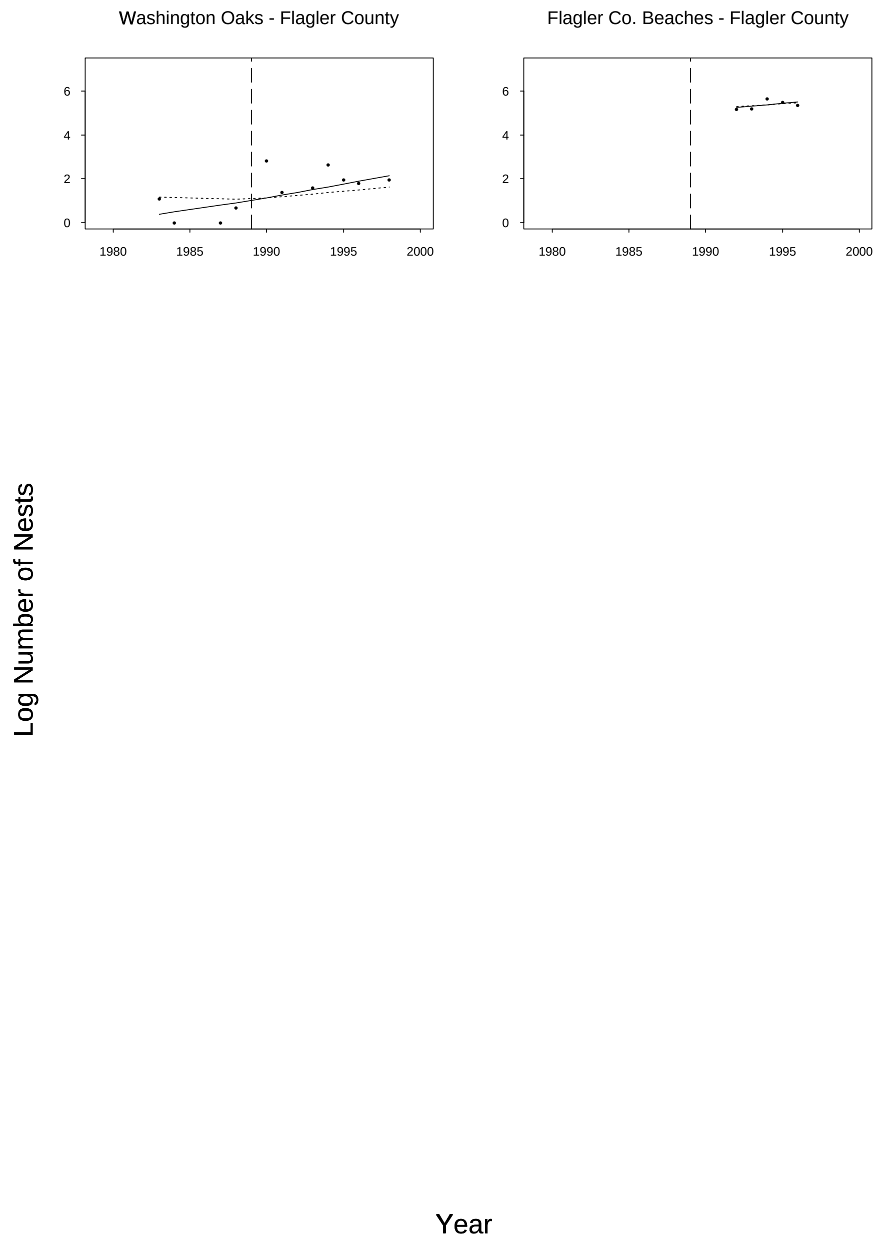


Figure 1: Plots of log transformed nest counts for the beaches in the northern US subpopulation of loggerhead turtles. Each point is an observation, the solid line is the ordinary least squares fit, and the dashed line is the BLUP from the mixed model. The mixed model fits come from a model that assumes a separate error variance for each beach. The vertical dashed line marks the year that TEDs were first employed.

The upshot is: either no change or a decrease from 1978 to 1989 (depending on which model you consider), and a probable increase from 1989 to 1999. The magnitude and statistical significance of the increase depends upon the exact implementation of the model, but the effect is suggestive in all analyses.

7.1.3 Northern US population - Georgia not included

One problem with the analysis of the northern US population is that the reliablity of the data from Georgia is not known. The other sites had both distance of beach surveyed and the start date of the survey, information that was missing from the Georgia data. To assess the robustness of the previous results we fit the same model as before, but this time omitted the Georgia sites from the analysis.

error	separate error variance	year	estimate	se pred	df
lognormal	no	> 1978	$r = -0.002$	0.026	12
lognormal	no	> 1989	$r^* = 0.049$	0.034	7
lognormal	yes	> 1978	$r = -0.011$	0.019	12
lognormal	yes	> 1989	$r^* = 0.048$	0.028	7

When Georgia is left out of the analysis the parameter estimates obtained are similar, resulting in similar trends, but these results are no longer statistically significant.

7.1.4 South Florida Loggerheads

The results for the south Florida loggerheads are:

error	separate error variance	year	estimate	se pred	df
lognormal	no	> 1978	$r = 0.054$	0.022	6
lognormal	no	> 1989	$r^* = -0.011$	0.028	1
lognormal	yes	> 1978	$r = 0.055$	0.014	6
lognormal	yes	> 1989	$r^* = -0.015$	0.021	1

In summary, for south Florida the model with the separate error variances for each beach, the population has been growing with a $\hat{r} = 0.054$ (s.e. 0.022) since 1979. When an additional term is added for the period since 1989, there is not a significant change (r^* is estimated to be -0.011 (s.e. 0.028)). Note that the direction of change is the opposite sign as for the northern population.

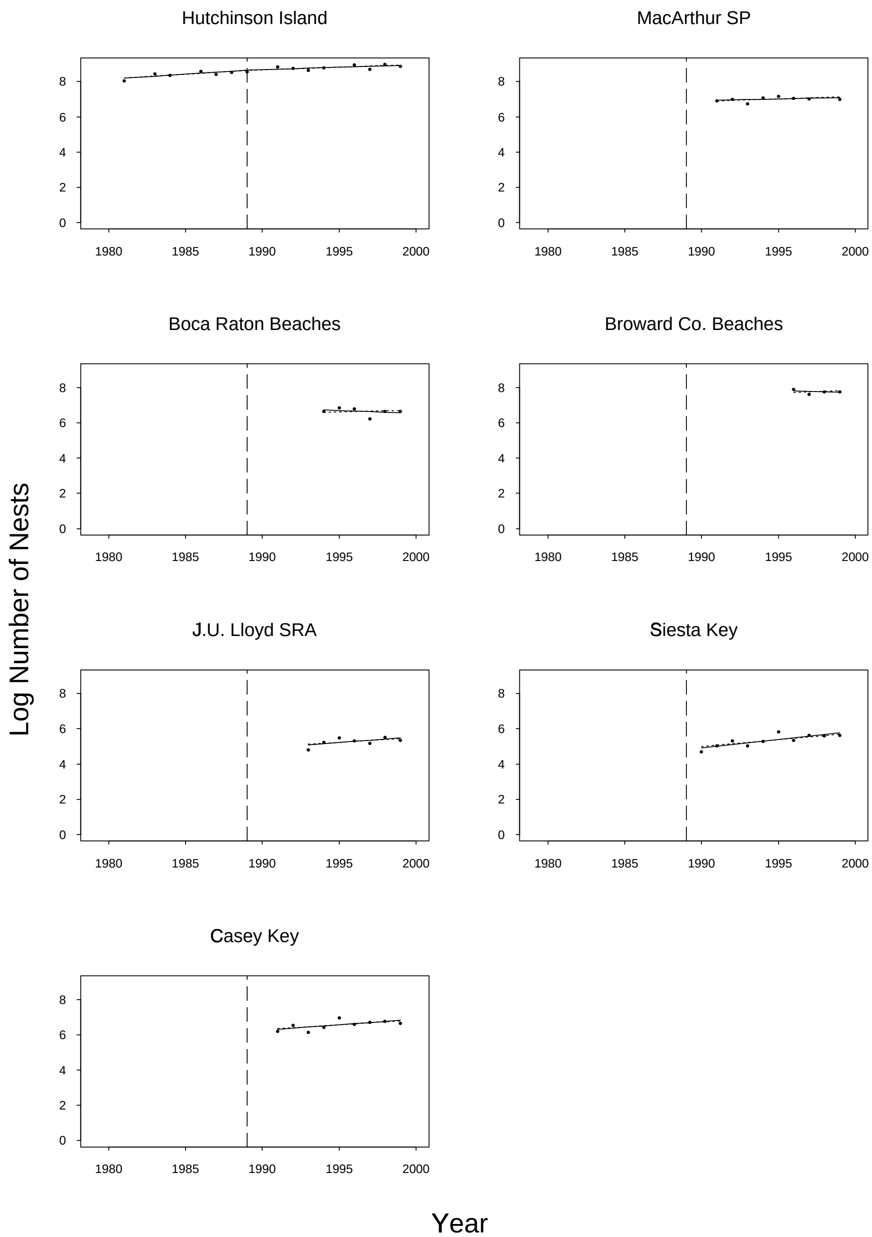


Figure 2: Plots of log transformed nest counts for the beaches in the southern US subpopulation of loggerhead turtles. Each point is an observation, the solid line is the ordinary least squares fit, and the dashed line is the BLUP from the mixed model. The mixed model fits come from a model that assumes a common error variance among beaches. The vertical dashed line marks the year that TEDs were first employed.

We also display the estimated total number for the northern and southern populations of loggerhead for the surveyed beaches (Fig. 3). In these plots, we summed the predicted numbers in the individual regressions and the mixed models estimates to estimate the total number in the areas surveyed.

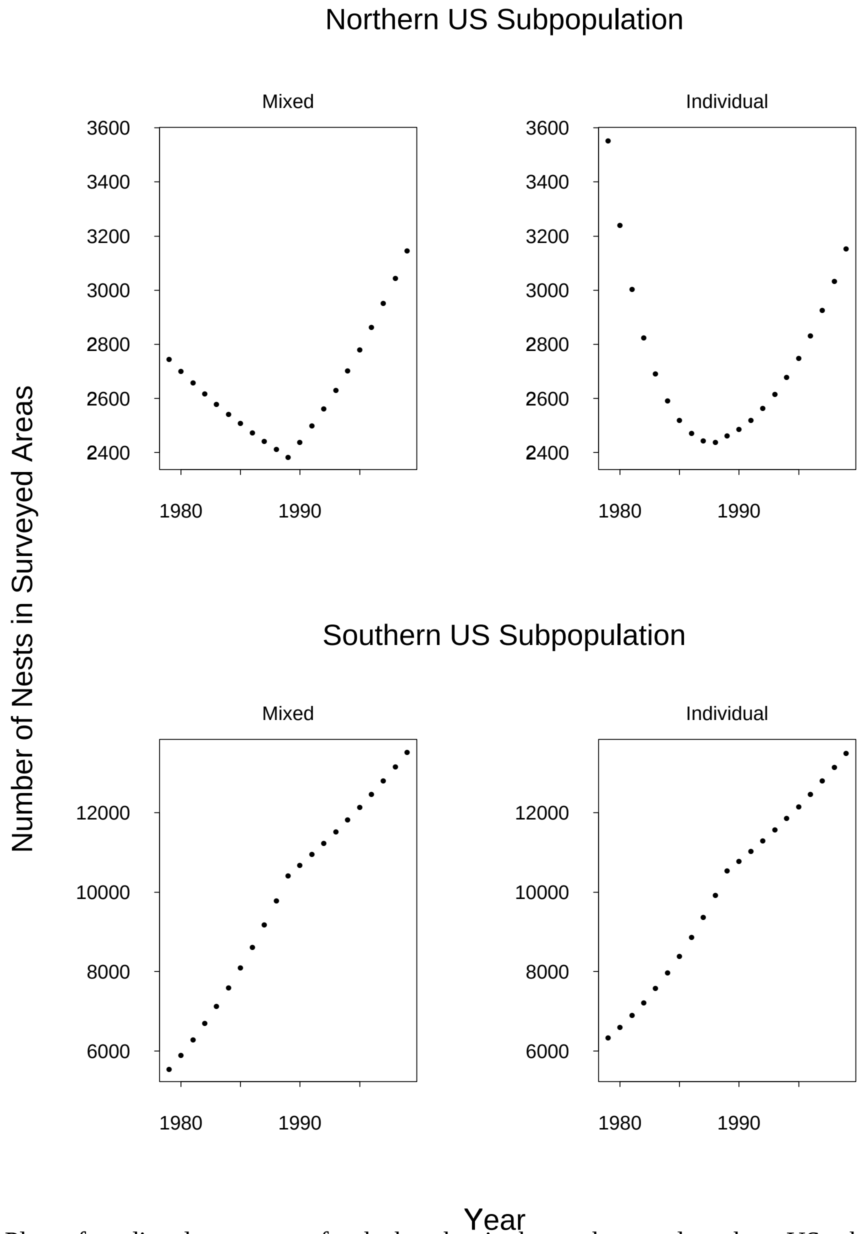


Figure 3: Plots of predicted nest counts for the beaches in the northern and southern US subpopulation of loggerhead turtles. The individual estimates are from the sum of the individual OLS regressions, and the mixed model estimates are from the sum of the Best Linear Unbiased Predictors for each beach.

7.2 Leatherbacks

For leatherbacks we treated the data from the Virgin Islands, South America, and Florida as separate groups, or populations. For the Virgin Islands and Florida we examined data from 1979 on, but used data from 1987 on for South America because of changes in local fishing policy.

For the US Virgin Island site, we carried out a simple linear regression on the log transformed nests to estimate the instantaneous rate of population change. The estimate was 0.078 (s.e.= 0.014). For the Florida sites,

error	separate error variance	estimate	se pred	df
lognormal	no	$r = 0.118$	0.056	6
lognormal	yes	$r = 0.109$	0.019	6
Poisson	no	$r = 0.095$	0.049	6
Poisson	yes	$r = 0.107$	0.059	6
gamma	no	$r = 0.122$	0.053	6
gamma	yes	$r = 0.117$	0.052	6

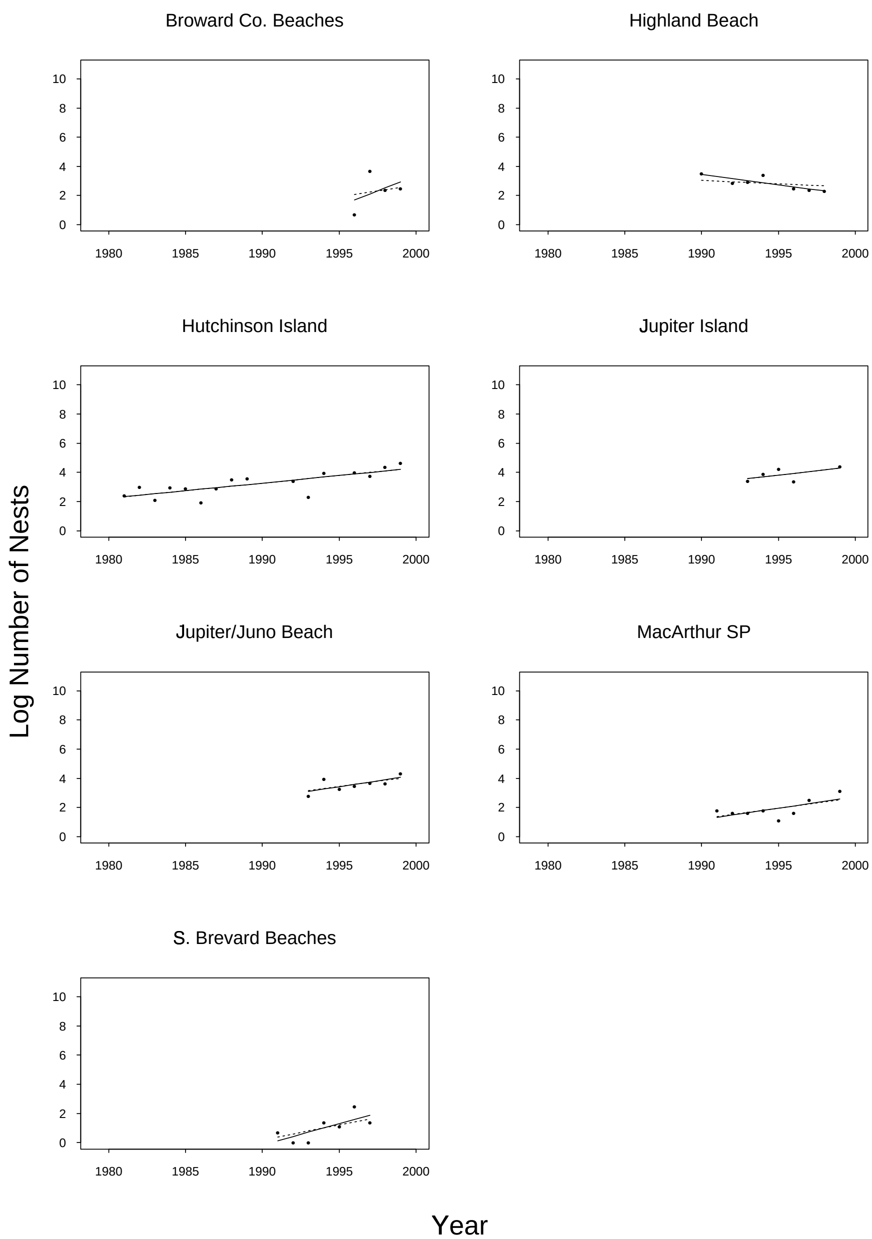


Figure 4: Plots of log transformed nest counts for the beaches in the Florida population of leatherback turtles. Each point is an observation, the solid line is the ordinary least squares fit, and the dashed line is the BLUP from the mixed model. The mixed model fits come from a model that assumes a common error variance among beaches.

For South America,

error	separate error variance	estimate	se pred	df
lognormal	no	$r = -0.190$	0.060	2
lognormal	yes	$r = -0.163$	0.041	2

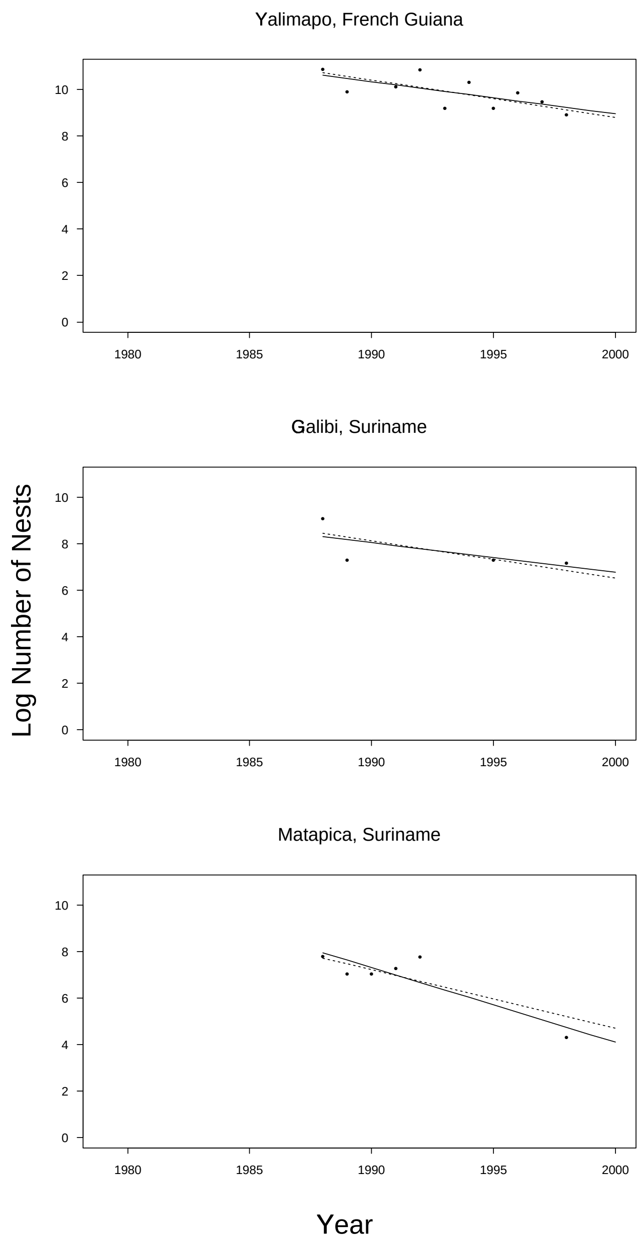


Figure 5: Plots of log transformed nest counts for the beaches in the South American population of leatherback turtles. Each point is an observation, the solid line is the ordinary least squares fit, and the dashed line is the BLUP from the mixed model. The mixed model fits come from a model that assumes a common error variance among beaches.

We also display the estimated total number for the northern and southern populations of loggerhead for the surveyed beaches (Fig. 6). In these plots, we summed the predicted numbers in the individual regressions and the mixed models estimates to estimate the total number in the areas surveyed.

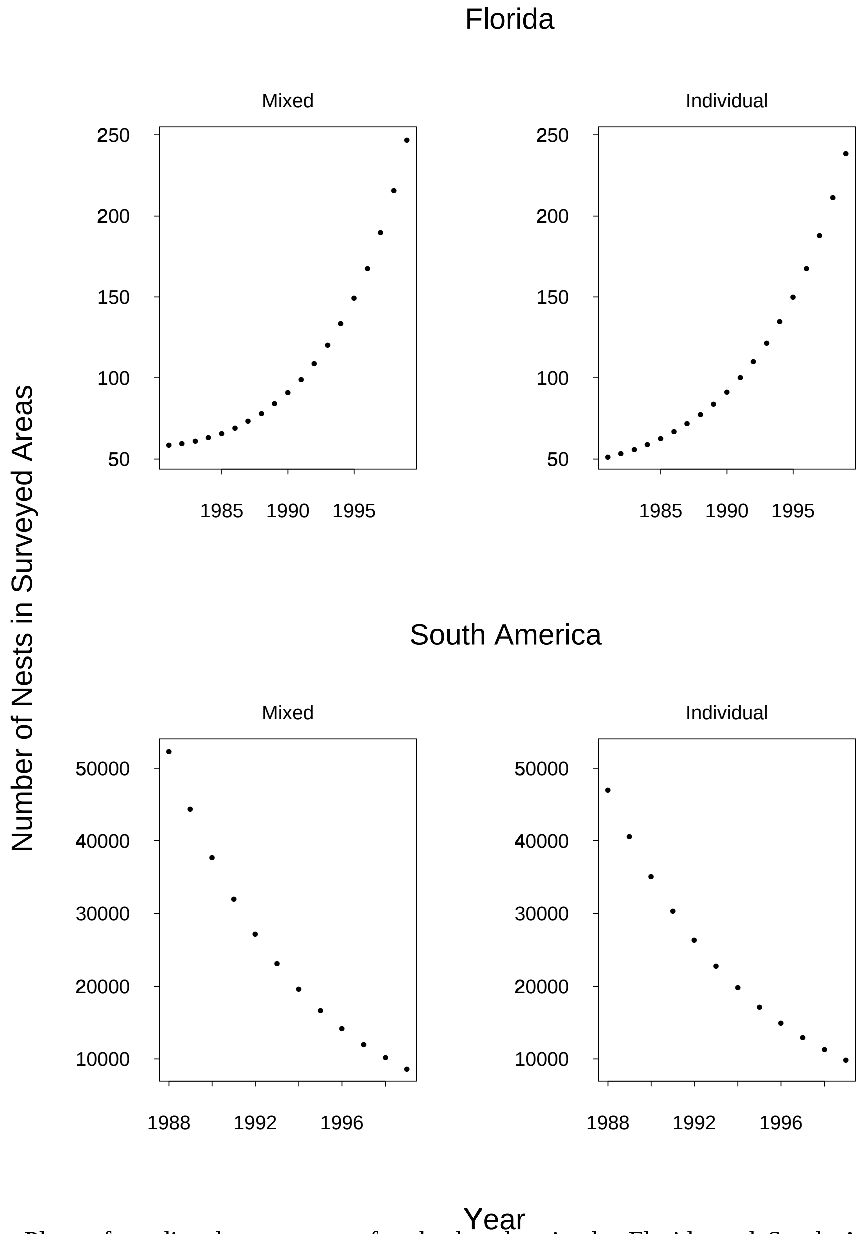


Figure 6: Plots of predicted nest counts for the beaches in the Florida and South America subpopulation of leatherback turtles. The individual estimates are from the sum of the individual OLS regressions, and the mixed model estimates are from the sum of the Best Linear Unbiased Predictors for each beach.

7.3 Limitations of the analysis

This study was limited by the inability to access the raw data to assess day by day counts and effort. Future analyses would be much more reliable if such data was made available.

7.4 Acknowledgements

We would like to acknowledge all the individuals and organizations that collected and contributed data that made this analysis possible. Melissa Snover and Lisa Csuzdi provided the nesting beach data. For Georgia we would like to thank Mark Dodd of the Georgia Department of Natural Resources, Jim Richardson for Little Cumberland Island, Jekyll Island Sea Turtle Project for Jekyll Island, The Lodge on Little St. Simon's Island, Georgia Department of Natural Resources for Sapelo Island and Ossabaw Island, Savanna Coastal refuges and the U.S. Fish and Wildlife Service for Blackbeard Island, the Caretta Research Project and the U.S. Fish and Wildlife Service for Wassaw Island and Pine Island, and the National Park Service for Cumberland Island. For North Carolina we would like to thank Ruth Boettcher of the North Carolina Department of Natural Resources, the North Carolina Wildlife Resources Commission, Sea Turtle Activities at Cape Hatteras National Seashore for Cape Hatteras National Seashore, North Carolina Division of Parks and Recreation and the Department of Environment and Natural Resources for Hammock's Beach State Park, University of North Carolina - Wilmington and the Bald Head Island Conservancy, U.S. Fish and Wildlife Service for Pea Island National Wildlife Refuge, and the Emerald Island Volunteer Program for Bogues Bank. Cape Romain National Wildlife Refuge provided the data for Cape Island. The Florida Fish and Wildlife Commission provided the Florida data. A special thank you to all the volunteers contributing to the nesting beach studies over the years.

References

Hedges, L. V., and Olkin, I. 1980. Vote-counting methods in research synthesis. Psychological Bulletin **88**: 359–369.

Hedges, L. V., and Olkin, I. 1985. Statistical Methods for Meta-analysis. Academic Press, San Diego.

Searle, S. R., Casella, G., and McCulloch, C. E. 1992. Variance Components. John Wiley and Sons, New York, NY.

Wolfinger, R., and O'Connell, M. 1993. Generalized linear mixed models: a pseudo-likelihood approach. J. Statist. Comput. Simul. **48**: 233–243.

APPENDIX 2

SUMMARY OF OBSERVED, **ESTIMATED**, *INCIDENTAL*, (LETHAL), AND [STRANDINGS] TAKE LEVELS, SEA TURTLE LIFE STAGE, GEOGRAPHIC REGION OF ACTIVITY, AND REFERENCE FOR PERMITTED AND NON-PERMITTED SPECIFIC AND GENERALIZED ACTIVITIES IMPACTING SEA TURTLES IN THE U.S. ATLANTIC, CARIBBEAN, AND GULF OF MEXICO

Joanne Braun-McNeill
Wayne Witzell

APPENDIX 2.

Table 1. Summary of observed, **estimated**, *incidental*, (lethal), and [strandings] take levels, sea turtle life stage, geographic region of activity and reference for permitted and non-permitted specific activities in the U.S. Atlantic, Caribbean and Gulf of Mexico.

	Annual Observed, **Estimated**, *Incidental* (Lethal) and [Strandings] Take Levels [1]						Life Stage	Geographic Region	Reference
	Loggerhead	**Leatherback**	**Green**	**Kemp's**	**Hawksbill**	**Olive Ridley**			
Federal Permitted Activities - NMFS									
Coast Guard Vessel Operation	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*0*	Adult, Immature	Atlantic	NMFS 1995a, 1996b, 1998b
Navy – SE Ops Area[3]	*91(91)*	*17(17)*[2]	*16(16)*[2]	*16(16)*[2]	*4(4)*[2]	*0*	Adult, Immature	Atlantic, Gulf of Mexico	NMFS 1997b
Navy-NE Ops Area	*10(10)*	*0*	*1(1)*[2]	*1(1)*[2]	*0*	*0*	Adult, Immature	N. Atlantic	NMFS 1996f
Shipshock – Seawolf/Winston Churchill[4]	*276(58)*[2]	*276(58)*[2]	*276(58)*[2]	*276(58)*[2]	*276(58)*[2]	*0*	Adult, Immature	Atlantic coast of Florida	NMFS 1996c
COE Dredging-NE Atlantic	*29(29)*	*2(2)*	*7(7)*[2]	*6(6)*[2]	*0*	*0*	Adult, Immature	NE Atlantic	NMFS 1998i, NMFS 1998j, NMFS 2000g
COE Dredging – S. Atlantic	*35(35)*	*0*	*7(7)*	*7(7)*	*2(2)*	*0*	Adult, Immature	S. Atlantic	NMFS 1997f
COE Dredging - N & W Gulf of Mexico	*30(30)*	*0*	*8(8)*	*14(14)*	*2(2)*	*0*	Adult, Immature	N&W Gulf of Mexico	NMFS 1998k
COE Dredging - E Gulf of Mexico	*8 (8)* [5]	*5(5)*[5]	*5(5)*[5]	*5(5)*[5]	*5(5)*[5]	*0*	Adult, Immature	E. Gulf of Mexico	NMFS 1996g
COE Rig Removal, Gulf of Mexico	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*0*	Adult, Immature	Gulf of Mexico	NMFS 1997g
Wilmington Harbor Project - Blasting	*1(1)*	*1(1)*	*1(1)*	*1(1)*	*1(1)*	*0*	Adult, Benthic immature	8/1 - 1/31 New Hanover & Brunswick Co, NC	NMFS 2000f
Wilmington Harbor Project - Gill nets	*undeterm.*	*undeterm.*	*undeterm.*	*undeterm.*	*undeterm.*	*0*	Adult, Benthic immature	8/1 - 1/31 New Hanover & Brunswick Co, NC	NMFS 2000f
MMS Destin Dome Lease Sales	*1(1)*[2;6]	*1(1)*[2;6]	*1(1)*[2;6]	*1(1)*[2;6]	*1(1)*[26]	*0*	Adult, Immature	eastern Gulf of Mexico	NMFS 2000h

MMS Rig Removal, Gulf of Mexico	*10(10)*[7]	*5(5)*[2;7]	*5(5)*[2;7]	*5(5)*[2;7]	*5(5)*[2;7]	*0*	Adult, Immature	Gulf of Mexico	NMFS 1988, NMFS 1998l
NE Multispecies Sink Gillnet Fishery	*10(10)*	*4(4)*	*4(4)*	*2(2)*	*0*	*0*	Adult, Immature	Gulf of Maine, mid-Atlantic	NMFS 1989, 1993c, 1996d
NE Observer Program Sink Gillnet Fishery[8]	0-2(0)	0	0	0	0	0	Adult, Immature	NE Atlantic	NEFSC unpubl. data (Richard Merrick[9], Mike Tork[10], personal communication)
NE Observer Program Bottom Coastal Gillnet[8]	1-13(0-7)	0	0-2(0-2)	1-4(1-2)	0	0	Adult, Immature	Mid-Atlantic	NEFSC unpubl. data (Richard Merrick [9], Mike Tork [10], personal communication)
NE Observer Program Scallop Dredge[8]	0-1(0)	0	0	0	0	0	Adult, Immature	Mass-Va.	NEFSC unpubl. data (Richard Merrick [9], Mike Tork [10], personal communication)
ASMFC Lobster Plan	*10 (10)*	*4(4)*	*0*	*0*	*0*	*0*	Adult, Pelagic immature	Atlantic- Maine-NC	NMFS 1998c
Bluefish	*6(3)*	*0*	*0*	*6(6)*	*0*	*0*	Adult, Immature	Atlantic - Maine-Florida	NMFS 1999b
Herring	*6(3)*	*1(1)*	*1(1)*	*1(1)*	*0*	*0*	Adult, Immature	NE Atlantic	NMFS 1999d
Mackerel, Squid, Butterfish	*6(3)*	*1(1)*	*2(2)*	*2(2)*	*0*	*0*	Adult, Immature	NE and Mid-Atlantic	NMFS 1999a
Monkfish Fishery[7]	*6(3)*	*1(1)*	*1(1)*	*1(1)*	*0*	*0*	Adult, Immature	NE and Mid-Atlantic	NMFS 1998d
Dogfish Fishery	*6(3)*	*1(1)*	*1(1)*	*1(1)*	*0*	*0*	Adult, Immature	Atlantic-Maine-Fl	NMFS 1999c
Sargassum	*30(30)*[11]	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*1(1)*[2]	*0*	Adult, Pelagic immature	Atlantic	NMFS 1999i
Summer Flounder, Scup & Black Sea Bass	*15(5)*	*3(3)*[2]	*3(3)*[2]	*3(3)*[2]	*3(3)*[2]	*0*	Adult, Immature	NE and Mid-Atlantic	NMFS 1996a
Shrimp Fishery	**3450(3450)** [12]	**650(650)** [12]	**3450(3450)** [12]	**3450(3450)** [12]	**3450(3450)** [12]	**0**	Adult, Immature	Atlantic, Gulf of Mexico	NMFS 1998a

NE Observer Program - Otter Trawl [8]	0-1(0)	0	0	0	0	0	Adult, Immature	NE and Mid-Atlantic	NEFSC unpubl. data (Richard Merrick [9], Mike Tork [10], personal communication)
NE Observer Program - Mid-Atlantic Coastal Trawl [8]	3-15(1-4)	0	0	0-2(0)	0	0	Adult, Immature	Mid-Atlantic	NEFSC unpubl. data (Richard Merrick [9], Mike Tork [10], personal communication)
Weakfish	*20(20)*	*0*	*0*	*2(2)*	*0*	*0*	Adult, Immature	Atlantic	NMFS 1997h
HMS - Pelagic Longline Fishery [13]	*468*(7)	*358*(6)	*46*(2)	*23*(1)	*46*(2)	0	Adult, Immature	Atlantic, Gulf of Mexico	NMFS 2000i
HMS - Pelagic Longline Fishery [14]	**931**(1)	**918**(0)	0	0	0	0	Adult, Immature	Atlantic, Gulf of Mexico	Yeung *et al* 2000
NE Observer Program Longline Fishery [8]	8-119(0)	2-45(0)	0-2(0)	0	0	0	Adult, Pelagic immature	Maine-Florida	NEFSC unpubl. data (Richard Merrick [9], Mike Tork [10], personal communication)
HMS - Shark gillnet Fishery [15]	*20(20)*	*2(2)*	*2(2)*	*2(2)*	*2(2)*	*0*	Adult, Immature	Georgia, Florida coastal waters	NMFS 2000i
NE Observer Program - Pelagic Drift Gilnet[11a]	6-35(1-10)	5-27(2-12)	0-2(0-1)	0-1(0-1)	0	0	Adult, Immature	Maine-Florida	NEFSC unpubl. data (Richard Merrick [9], Mike Tork [10], personal communication)
HMS - Bottom Longline Fishery [15]	*12(12)*	*2(2)*	*2(2)*	*2(2)*	*2(2)*	*0*	Adult, Immature	Atlantic, Caribbean, Gulf of Mexico	NMFS 2000i
HMS - all other gears [15]	*3(3)*	*3(3)*	*3(3)*	*3(3)*	*3(3)*	*0*	Adult, Immature	Atlantic, Caribbean, Gulf of Mexico	NMFS 2000i
NRC – St. Lucie, FL [16]	*unlimited(2)*	*unlimited(1)*	*unlimited(3)*	*unlimited(1)*	*unlimited(1)*	*0*	Adult, Benthic immature	Florida	NMFS 1997a
NRC – Brunswick, NC	*50 (6)* [2]	*50* [2]	*50 (3)* [2]	*50 (2)* [2]	*50* [2]	*0*	Adult, Benthic immature	North Carolina	NMFS 2000j

NRC – Crystal River, FL	*55 (1)* [2]	*55 (1)* [2]	*55 (1)* [2]	*55 (1)* [2]	*55 (1)*[2]	*0*	Adult, Benthic immature	Florida	NMFS 1999j
Oyster Creek Nuclear Generating Station [17]	*10(3)*	*0*	*2(1)*	*3(1)*	*0*	*0*	Adult, Benthic immature	New Jersey	NMFS 1995b
Salem&Hope Creek Nuclear Generating Station	*30(5)*	*0*	*5(2)*	*5(1)*	*0*	*0*	Adult, Benthic immature	New Jersey	NMFS 1993a, 1998e
Sneads Ferry Shrimp Trawling, NCDMF	*2* - 0	*1* - 0	*1* - 0	*1* - 0	*1* - 0	0	Adult, Benthic immature	Sneads Ferry, North Carolina	NMFS 1996e Permit # 1008
Grays Reef National Marine Sanctuary	*30* - 1(0)	*0*	*0*	*0*	*0*	*0*	Adult	Georgia	NMFS 1997c Permit # 1030
Atlantic, Gulf of Mexico, U.S. Virgin Islands, Puerto Rico Research	*200* - 13(0)	*8* - 4(0)	*20* - 20(1)	*20* - 4(0)	*1* - 0	0	Adult	Georgia & Florida	NMFS 1997d Permit # 1033
Eastern Atlantic Ocean Research, Dr. Molly Lutcavage, New England Aquarium	*0*	*8* - 4(0)	*0*	*0*	*0*	*0*	Adult, Pelagic immature	Puerto Rico	NMFS 1997e Permit # 1053
Flower Gardens National Marine Sanctuary Research, Dr. David Owens	*15* - 3(0)	*0*	*0*	*10* - 0	*5* - 0	0	Adult	Texas	NMFS 1998f Permit #1106
Galveston Texas Research, Dr. Andre M. Landry, Jr.	*100* - 2(0)	*0*	*150* - 2(0)	*200* - 47(0)	*20* - 0	0	Adult, Immature	Calcasieu & Sabine Pass, TX	NMFS 1998g Permit # 1133
Pierce Inlet Indian River Lagoon Research, Bruce D. Peery and Michael J. Bressette	*25* - 13(0)	*0*	*100* - 64(0)	*5* - 0	*0*	*0*	Adult	Florida	NMFS 1998h Permit # 1144
Northwest Atlantic Ocean, Stepen M.H. Connett, St. George's School	*50* - 6(0)	*0*	*5* - 81(0)	*5* - 0	*5* - 37(0)	*0*	Adult, Immature	Bahamas	NMFS 1999e Permit # 1187
Florida Bay Research, Florida Fish and Wildlife Conservation Commission	*300* - 46(0)	*5* - 0	*250* - 5(0)	*100* - 2(0)	*25* - 0	*0*	Adult, Immature	Florida Bay	NMFS 1999f Permit # 1198
Florida Bay Research,Florida Fish and Wildlife Conservation Commission	*400* - 126(10) found dead	*0*	*0*	*0*	*0*	*0*	Hatchling	Florida Bay	NMFS 1999f Permit # 1198
Alabama Research, Dr. Thane Wibbels	*100* - 0	*0*	*100* - 0	*50* - 0	*0*	*0*	Benthic immature	Alabama	NMFS 1999g Permit # 1201
Mosquito Lagoon, Florida Research, Dr. Jane Provancha	*100* - 1(0)	*0*	*100* - 10(0)	*0*	*0*	*0*	Adult, Benthic immature	Florida	NMFS 1999h Permit # 1214
Indian River Lagoon Estuary Research, Dr. Llewellyn M. Ehrhart [18]	*135*	*1*	*600*	*3*	*2*	*0*	Adult, Benthic immature	Florida	NMFS 2000a Permit # 1231

Virgin Islands Research, Dr. Jack Musick, Virginia Institute of Marine Sciences[18]	*0*	*5*	*10*	*0*	*20*	*0*	Adult, Immature	US Virgin Islands	NMFS 2000b Permit # 1236
Trawling SC to FL Research , J. David Whitaker, SCDNR [18]	*200*	*1*	*1*	*23*	*0*	*0*	Adult, Immature	SC to Florida	NMFS 2000c Permit # 1245
Puerto Rico Research, Carlos Diez, PRDRNA[18]	*0*	*0*	*300*	*0*	*300*	*0*	Adult, Benthic immature	Puerto Rico	NMFS 2000d Permit # 1253
NC Flounder Gillnet Fishery ITP NCDENR, DMF [18,19]	*112* (*56*) [*14*] 8(2) **51.0(7.4)**	*2(2)* 0	*72 (36)* [*9*] 6(3) **93.1(43.5)**	*192* (*96*) [*24*] **34.5 (28.3)**	*2* (*2*)	*0*	Adult, Benthic immature	Pamlico Sound, NC	NMFS 2000e Permit # 1259
Federal Permitted Activities - FWS [20]									
Region 5 (NE) - Beach Nourishment - Colonel Robert Reardon, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	ACOE Va. Beach, VA	FWS,1996a
Beach Nourishment - Ms. Valerie Hilliard, USN	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	USN - Dam Neck, VA	FWS,1995a
Transportation of live stranded, injured - Ms. Dana Hartley, NE region Stranding Network coordinator	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	ME, Mass, Conn, NY, NJ, Del, Md, Va	FWS,1999d
Holding of turtles for rehabilitation and display purposes- Ms. Dana Hartley, NE region Stranding Network coordinator	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Mass, Va	FWS 1999d
Tagging of Nesting Females- Ms. Dana Hartley, NE region Stranding Network coordinator	*1*	*0*	*0*	*0*	*0*	*0*	Adult	Virginia	FWS 1999d
Region 4 (SE) - Beach driving Incidental Take Permit - County of Volusia, FL	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Volusia Co., Fl	FWS,1999i Permit#TE811813-4 Atlanta Ga field office
Collection of blood & tissue samples, Kathryn Craven, Texas A&M Univ, College Station, TX	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Florida & Texas	FWS 2000m Texas A&M Permit #TE025759-0
Collection of blood & tissue samples - Dr. Andrew Kemmerer, Regional Administrator, NMFS, SERO, St. Petersburg, FL	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Va to Fl, Gulf of Mexico, Caribbean	FWS 1999j SEFSC Permit #TE676379-2

Seismic Surveys	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Breton NWR, Louisiana	Informal consult. Debbie Fuller [21] Lafeyette, LA Field Office
Beach Nourishment - District Engineer, Mobile District, COE, Mobile, AL	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	City of Gulf Shores, AL	FWS 2000n Daphne, AL
Dune restoration - Brett Real Estate, Robinson Development Co, Inc	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Orange Beach, AL	FWS 1996c IT Permit PRT-809898 Daphne,AL
Construction - Brett Real Estate, Robinson Development Co, Inc	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Orange Beach, AL	FWS 1996c IT Permit PRT-809898 Daphne, AL
Emergency berm - District Engineer, Mobile District, COE, Mobile, AL	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	south shore of Dauphin Island, Mobile Co., AL	FWS 2000o Daphne, AL
Coast of Florida Study - Beach Nourishment - Colonel Terry Rice, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	27 projects spanning 93 km in Palm Beach, Broward & Dade Co, Fl	FWS 1996b Vero Beach, FL
Coast of Florida Study amendment- 63rd Street Beach Nourishment-James Duck, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	0.5 mile of beach, Miami-Dade Co, Fl	FWS 2000d Log# 4-1-00-F-701 Vero Beach, FL
Coast of Florida Study amendment- South Palm Beach Island Nourishment-Bryce McCoy, Project Manager, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	1.9 mile of beach, Palm Beach Co, Fl	FWS 2000e Log# 4-1-00-F-497 Vero Beach, FL
Coast of Florida Study amendment- Jupiter Inlet deposition of dredge spoil-Bryce McCoy, Project Manager, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	beach south of Jupiter Inlet, Palm Beach Co, Fl	FWS 2000c Log# 4-1-00-I-233 Vero Beach, FL
Lido Beach Shore Project - renourishment-Colonel Joe Miller, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	3,600 ft on Lido Key, Sarasota Co, Fl	FWS 2000f Log# 4-1-99-F-252 Vero Beach, FL
Lighthouse Point Beach Groin Construction-Colonel Joe Miller, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Sarasota Co, FL	FWS 2000g Log# 4-1-99-F-99 Vero Beach, FL

Fisher Island deposition of dredge spoil-Colonel Joe Miller, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	0.168 km Fisher Island, Miami-Dade Co, Fl	FWS 1999f Log# 4-1-98-F-643 Vero Beach, FL
Lee County Shore Project - nourishment - Colonel Joe Miller, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	11.7 km in Lee County, Fl	FWS 1999g Log# 4-1-99-F-812 Vero Beach, FL
US MMS-Central Gulf of Mexico Lease Sales-Assoc. Director for Offshore Leasing, MMS	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Central Gulf of Mexico nesting beaches	FWS 1997 Log# 4-P-97-075 Panama City, Fl
US MMS-Eastern Gulf of Mexico Lease-develop, produce and transport natural gas from the Destin Dome 56 Unit to Alabama near Mobile - Regional Dir. MMS, New Orleans, LA	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Eastern Gulf of Mexico nesting beaches	FWS 2000h Log# 4-P-00-003 Panama City, Fl
Beachfront construction-artificial lighting - Deputy Regional Director, FWS Atlanta, GA	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	427m of Gulf of Mexico beachfront	FWS 2000i June 8, 2000 Panama City, FL
FEMA Emergency Berm - Mr. Brett Bowen, FEMA, Atlanta, GA	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	May 1-19 24, 125 linear ft Okaloosa Co, Fl	FWS 2000j Log# 4-P-00-102 Panama City, FL
FEMA Emergency Berm - Mr. Brett Bowen, FEMA, Atlanta, GA	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	May 1-15 24,000 linear ft. Cape San Blas/St. Joseph Peninsula, Gulf Co, Fl	FWS 2000k Log# 4-P-00-103 Panama City, FL
Deposition of dredged material - Mr. J. Tracy Howell, South Walton Tourist Development Council	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Miramar Beach, Walton Co, Fl	FWS 2000l Log# 4-P-00-144 Panama City, FL
Panama City Beach Nourishment - Colonel Joe Miller, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	27 km of Panama Beach, Bay Co, Fl	FWS 1998g Log# 4-P-97-108 Panama City, FL
Theater Missile Defense systems testing -vehicles and lights on beach - US Air Force	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Eglin Air Force Base at Cape San Blas and Santa Rosa Island, Fl	FWS 1999h Panama City, FL

Tyndall Air Force Base - driving on beach - Brigadier General Gary Rubus, US Air Force	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Tyndell AFB beachfront (20.6km) Bay Co, Fl	FWS 1998e Log# 4-P-98-020 Panama City, FL
Lake Powell Outlet excavation - Colonel Joe Miller, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	1500 ft beach front, Camp Helen, Bay Co, Fl	FWS 1998f Log# 4-P-97-089 Panama City, FL
Renourishment	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	22 miles Brevard Co Fl	Don Palmer [22] Jacksonville Office, FL
Renourishment	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Patrick Air Force Base, FL	Don Palmer [22] Jacksonville Office, FL
ACOE revetment on beach	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Glynn Co., Georgia	FWS 1992 Log#4-4-93-032 Athens, Ga.
ACOE beach nourishment, breakwater, groin	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Glynn Co., Georgia	FWS 1995b Log#4-4-95-071 Athens, Ga.
Wilmington Harbor Project - nourishment- Colonel James DeLony, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Carolina Beach to Holden Beach, NC	FWS 2000b Raleigh, NC
Wilmington Harbor Project - deposition of dredged material	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Bald Head Island & Caswell Beach, NC	FWS 2000b Raleigh, NC
Deposition of dredged material on Nags Head- Colonel James DeLony, COE	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	Nags Head and South Nags Head, NC	FWS 1999e Raleigh, NC
Naval training exercises - Rear Admiral J.K. Moran, Commander Navy Region Southeast, Naval Air Station, Jacksonville, Fl, 32212	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Hatchling	eastern end of Vieques Island, PR	FWS 2000p Boqueron Field Office
Construction of buildings-Mr. William V. Mailloux, Culebra Northshore,SE	*0*	*2*	*0*	*0*	*2*	*0*	Adult & Hatchling	Tortola beach, Culebra Island, PR	FWS 2000q Incidental Take Permit# TE026114

Region 2 (SW) - Transport and rehabilitation of injured sea turtles- Mr. Anthony Amos, Univ. Texas at Austin	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Gulf coast of Texas	FWS 1999b Permit#TE30177-0 Albuquerque, NM
Transport and rehabilitation of injured sea turtles - Donna Shaver-Miller	*20*	*0*	*50*	*50*	*30*	*0*	Adult, Immature	Padre Island Nat'l Seashore, TX	FWS 2000a Permit#TE840727-0 Albuquerque, NM
Flipper tagging females - Donna Shaver-Miller	*10*	*10*	*10*	*30*	*10*	*0*	Adult	Padre Island Nat'l Seashore, TX	FWS 2000a Permit#TE840727-0 Albuquerque, NM
Incubation of eggs and release of surviving hatchlings - Donna Shaver-Miller[23]	*1000(10)*	*400(10)*	*1000(10)*	*4000(10)*	*400(10)*	*0*	Hatchling	Padre Island Nat'l Seashore, TX	FWS 2000a Permit#TE840727-0 Albuquerque, NM
Netting of juveniles - Donna Shaver-Miller	*0*	*0*	*150*	*0*	*5*	*0*	Benthic immature	Mansfield Channel, TX	FWS 2000a Permit#TE840727-0 Albuquerque, NM
Satellite tagging females - Donna Shaver-Miller	*0*	*0*	*0*	*6*	*0*	*0*	Adult	Padre Island Nat'l Seashore, TX	FWS 2000a Permit#TE840727-0 Albuquerque, NM
Attachment of sonic/radio tags, ultrasound and laparoscopic procedures - Dr. Andre Landry	*200*	*0*	*300*	*200*	*20*	*0*	Benthic immature	Gulf coast of Texas	FWS 1999a Permit#TE776123-0 Albuquerque, NM
MMS OCS oil and gas lease sales	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Gulf of Mexico Western Planning area	FWS 1998a
Seismic survey work - Mr. Phil Martin Legal Services/NRDA Section, Texas General Land Office, Austin, TX [24]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Coastal public land in Redfish, Aransas, Corpus Christi Bays, Texas	FWS 1998c
Seismic survey work - Mr. Phil Martin, Legal Services/NRDA Section, Texas General Land Office, Austin, TX [24]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Laguna Madre, Baffin Bay, Gulf of Mexico in Kleberg & Kenedy Co, TX	FWS 1999c
Seismic survey work - Mr. Phil Martin Legal Services/NRDA Section, Texas General Land Office, Austin, TX [24]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Laguna Madre & Corpus Christi Bay, Nueces & Kleberg Co, TX	FWS 1998d

Seismic survey work - Mr. Richard P. Courtemanche, Jr., Project Scientist Coastal Environments, Inc., Baton Rouge, LA [24]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Padre Island in Nueces & Kleberg, Co, Texas	FWS 1998b
State Permitted Activities									
N. Carolina - Tagging of Nesting Females: John Townsend, Camp Lejeune; D. Webster, UNC; K. Rittmaster, NC Maritime Museum; S. Bland, Hammocks Beach SP; George Baird, CP&L	No Data	No Data	No Data	No Data	No Data	No Data	Adult	N. Carolina	NCWRC (Ruth Boettcher personal communication [25])
Relocation of Turtle Nests: Pea Island National Wildlife Refuge; NC National Estuarine Research ; ACOE; Cape Lookout National Seashore; Cape Hatteras National Seashore; Mackay Island NWR; Oak Island Sea Turtle Project; Ocean Isle Sea Turtle Program; Caswell Beach Turtle Program; Sunset Beach Sea Turtle Project; Holden Beach Turtle Watch Program; Town of Emerald Isle; Wrightsville Beach Turtle Project; Topsail Sea Turtle Project; Atlantic Beach Sea Turtle Project; Pine Knoll Shores Sea Turtle Project; Carolina/Kure Bch. Sea Turtle Project; Figure Eight Sea Turtle Project; Emerald Isle Turtle Trotters; Network for Endangered Sea Turtles; Campbell University; John Townsend Camp Lejeune; D. Webster, UNC; K. Rittmaster, NC Maritime Museum; Hammocks Beach SP; Fort Fisher Recreation Area; Fort Macon State Park	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	N. Carolina	NCWRC (Ruth Boettcher, personal communication [25])
Clinical Trials - Craig A. Harms, D.V.M., Ph.D.	No Data	No Data	No Data	No Data	No Data	No Data	Immature	N. Carolina	NCWRC (Ruth Boettcher, personal communication [25])

Treatment of injured sea turtles: Claire F. Hohenwarter, DVM; Mary Burkhart, DVM; Bill Rabon, DVM; Dr. Michael Stoskopf, DVM; Christy Redfearn, DVM; Karen Beasley Sea Turtle Rescue and Rehabilitation Center; Cathy Kreis, DVM; Craig A. Harms, D.V.M., Ph.D.	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	N. Carolina	NCWRC (Ruth Boettcher, personal communication[25])

Transportation/possession of live turtles: Preston P. Pate, Jr., NCDMF; John Townsend Camp Lejeune; Donald Hoss,NMFS; D. Webster, UNC; K. Rittmaster, NC Maritime Museum; Hammocks Beach SP; Fort Macon State Park; Fort Fisher Recreation Area; Discovery Place, Inc.; Claire F. Hohenwarter, DVM; George Baird, CP&L; Ocean Isle Museum of Coastal Carolina; Natural Science Center of Greensboro; Ken Lohmann, UNC; William F. Shaw; Larry Crowder, Duke Marine Lab; Jennifer Keller, Duke Marine Lab; Pea Island National Wildlife Refuge; NC National Estuarine Research; ACOE; Cape Lookout National Seashore; Cape Hatteras National Seashore; Mackay Island NWR; Oak Island Sea Turtle Project; Ocean Isle Sea Turtle Program; Caswell Beach Turtle Program; Sunset Beach Sea Turtle Project; Holden Beach Turtle Watch Program; Town of Emerald Isle; Wrightsville Beach Turtle Project; Topsail Sea Turtle Project; Atlantic Beach Sea Turtle Project; Pine Knoll Shores Sea Turtle Project; Carolina/Kure Bch. Sea Turtle Project; Figure Eight Sea Turtle Project; Emerald Isle Turtle Trotters; Network for Endangered Sea Turtles; Campbell University; Kristy Long; Jockey Ridge State Park; Pricey T. Harrison; Richard Metz; Hatteras Rescue Squad; Brad Colaw; Cape Fear River Watch; Jackie Harris ; Jeannine S. Gurganus; Martha Pat Garber; Kim Horstman; Phil and Jacob Kouwe; Ron Metz; William A. McLellan; John Henderson; Barrier Island Kayaks; David L. Frum; Bill Vancura; Dee and Larry Hardham; Ralph Barile; Ray Midgett; Sidney Maddock; Kenny and Carisa Marshall; Gretchen Kreitler; Marcie Shoemaker; Angela Marshall; Lake Mattamuskeet National Wildlife Refuge	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	N. Carolina	NCWRC (Ruth Boettcher, personal communication[25])

Handling of Live Hatchlings- Larry Crowder, Duke Marine Lab	*120*	*0*	*0*	*0*	*0*	*0*	Hatchling	N. Carolina	NCWRC (Ruth Boettcher, personal communication[25])
Display of Live Hatchlings: NC Division of Aquariums	*15*	*0*	*0*	*0*	*0*	*0*	Hatchling	N. Carolina	NCWRC (Ruth Boettcher, personal communication[25])
Display of Live Juveniles - NC Division of Aquariums	No Data	No Data	No Data	No Data	No Data	No Data	Immature	N. Carolina	NCWRC (Ruth Boettcher, personal communication[25])
S. Carolina - Tagging of Nesting Females	88(0)	No Data	No Data	No Data	No Data	No Data	Adult	S. Carolina	SCDNR (Sally Murphy, personal communication [26])
Relocation of Turtle Nests	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	S. Carolina	SCDNR (Sally Murphy, personal communication [26])
Probing Nests	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	S. Carolina	SCDNR (Sally Murphy, personal communication[26])
Releasing Disoriented Hatchlings	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	S. Carolina	SCDNR (Sally Murphy, personal communication[26])
Holding of Live Turtles For Rehab	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	S. Carolina	SCDNR (Sally Murphy, personal communication[26])
Public Turtle Watches	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Hatchling	S. Carolina	SCDNR (Sally Murphy, personal communication[26])

Georgia - Tagging of Nesting Females - Kris Carrol, Caretta Research Project; Rebecca Bell, Little Cumberland Island Sea Turtle Project	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Georgia	GDNR (Mark Dodd, personal communication[27])
Relocation of Turtle Nests - Jennifer Bjork, Cumberland Island National Seashore; Carol Ruckdeschel, GADNR volunteer; Rebecca Bell, Little Cumberland Island Sea Turtle Project; Jan Caton Jekyll Island Sea Turtle Project; Donna Stewart, Jekyll Island 4-H Center; Catherine Quinn, St. Simons Island Sea Turtle Project; Tom Henslee, Sea Island Company; Eric Kellon, Little St. Simons Island; Sarah Gaines, GADNR sea turtle intern - Sapelo Island; Debra Keinath, USFWS - Blackbeard Island; Dr. Gale Bishop, St. Catherine Island Sea Turtle Project; Jordan Lundy & Liberty Moore, GADNR - sea turtle interns on Ossabaw Island; Kris Carrol, Caretta Research Project; Danny Carpenter, Tybee Island Public Works	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	Georgia	GDNR (Mark Dodd, personal communication [27])
Probing Nests - Jennifer Bjork, Cumberland Island National Seashore; Carol Ruckdeschel, GADNR volunteer; Rebecca Bell, Little Cumberland Island Sea Turtle Project; Jan Caton Jekyll Island Sea Turtle Project; Donna Stewart, Jekyll Island 4-H Center; Catherine Quinn, St. Simons Island Sea Turtle Project; Tom Henslee, Sea Island Company; Eric Kellon, Little St. Simons Island; Sarah Gaines, GADNR sea turtle intern - Sapelo Island; Debra Keinath, USFWS - Blackbeard Island; Dr. Gale Bishop, St. Catherine Island Sea Turtle Project; Jordan Lundy & Liberty Moore, GADNR - sea turtle interns on Ossabaw Island; Kris Carrol, Caretta Research Project; Danny Carpenter, Tybee Island Public Works	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	Georgia	GDNR (Mark Dodd, personal communication [27])

Florida - Tagging of Nesting Females - Kennard Watson, St. Andrew Bay Resource Management Assoc.; John McCarthy, Manasota Key Sea Turtle Project; Dr. Raymond Carthy, Univ. of Fla.; David Addison, The Conservancy of SW Florida; Jerris Foote, Mote Marine Lab;	>80	No Data	No Data	No Data	No Data	No Data	Adult	Florida	FFWCC (Beth Morford, personal communication [28]) Permit#TP038 Permit#TP062 Permit#TP094 Permit#TP116 Permit#TP126
Measuring coelomic pressure - Richie Moretti, Hidden Harbor Marine Environmental Project	*25*	*0*	*25*	*25*	*0*	*0*	Adult & immature	Florida	FFWCC (Beth Morford, personal communication [28]) Permit#TP103
Developmental ecology of immature turtles - Wayne Witzell, NMFS	4	0	1	44	1	0	Benthic immature	Gullivan Bay, Florida	FFWCC (Beth Morford, personal communication[28]) Permit#TP030
Relocation of Turtle Nests - Dr. David Nelson, USACOE	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	Florida	FFWCC (Beth Morford, personal communication[28]) Permit#TP070
Temperature Loggers in Nests - Dennis Kellenberger, Clearwater Marine Aquarium	120	0	0	0	0	0	Hatchling	Florida	FFWCC (Beth Morford, personal communication[28]) Permit#TP013
Satellite Tagging- Dr. Lew Ehrhart, Univ. Central Florida; Mark Nicholas, Gulf Islands National Seashore; Jerris Foote, Mote Marine Laboratory	*12*	*6*	*6*	*0*	*0*	*0*	Adult, Immature	Florida	FFWCC (Beth Morford, personal communication[28]) Permit#TP025 Permit#TP032 Permit#TP126
Magnetic Navigation By Hatchlings - Dr. Kenneth Lohmann, UNC-Chapel Hill; Dr. Jeanette Wyneken, Florida Atlantic University	328	0	0	0	0	0	Hatchling	Florida	FFWCC (Beth Morford, personal communication[28]) Permit#TP065 Permit#TP073
Nutritional/Behavior Studies - Dr. Jeanette Wyneken, Florida Atlantic University	*1205*	*30*	*35*	*0*	*0*	*0*	Hatchling	Florida	FFWCC (Beth Morford, personal communication[28]) Permit#TP073

Net Capture of Immature Turtles - Dr. Raymond Carthy, Univ. of Florida	No Data	No Data	No Data	No Data	No Data	No Data	Immature	St. Joseph Bay, Florida	FFWCC (Beth Morford, personal comm [28]) Permit#TP094
Turtles in Captivity For Rehab - Richie Moretti, Hidden Harbor Marine Environmental Project	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Florida	FFWCC (Beth Morford, personal comm [28]) Permit#TP103
Fibropapillomatosis Transmission Study - Dr. Lawrence Herbst, Institute for Animal Studies; Dr. Paul Klein, Univ. of Florida	*0*	*0*	*<10* (*lethal*)	*0*	*0*	*0*	Immature	Florida	FFWCC (Beth Morford, personal comm [28]) Permit#TP106 Permit#TP129
Caging Nests - David Addison, The Conservancy of SW Florida	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	Florida	FFWCC (Beth Morford, personal comm [28]) Permit#TP116
Collection of blood samples from netted sea turtles - Jerris Foote, Mote Marine Laboratory	0	0	0	2	0	0	Adult & Immature	Casey Key Beach, FL	FFWCC (Beth Morford, personal comm [28]) Permit#TP126
Relocating nests - Elaine C. Akers, Ivey, Harris & Walls, Inc.; Ana Barragan, Violetta Villanueva-Mayor, Phillipe Mayor, Rafe Boulon _ Sandy Point Leatherback Project; Zandy Hillis-Starr, Brendalee Phillips, Joyce Wakefield, Catherine Clark, Cat Jung, Myrto Argyropolou, VI National Park Service, St. Croix; Rafe Boulon, Thomas Kelly, Sheri Caseau, VI National Park Service, St. John; Amy Mackay, James Rebholtz, Sera Harold, Tom Mizak USFWS	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	USVI	USFWS, US Virgin Islands (Donna Griffin, personal communication[29])
Tagging Nesting Females - Ana Barragan, Violetta Villanueva-Mayor, Phillipe Mayor, Rafe Boulon _ Sandy Point Leatherback Project; Zandy Hillis-Starr, Brendalee Phillips, Joyce Wakefield, Catherine Clark, Cat Jung, Myrto Argyropolou, VI National Park Service, St. Croix	No Data	No Data	No Data	No Data	No Data	No Data	Adult	St. Croix	USFWS, US Virgin Islands (Donna Griffin, personal communication[29])

Collecting blood samples - Zandy Hillis-Starr, Brendalee Phillips, Joyce Wakefield, Catherine Clark, Cat Jung, Myrto Argyropolou, VI National Park Service, St. Croix	No Data	No Data	No Data	No Data	No Data	No Data	Adult	St. Croix	USFWS, US Virgin Islands (Donna Griffin, personal communication[29])
Caribbean Relocating nests - Hector Horta (DNER); Lesbia Montero (Sea Grant-UPR); Milagros Justiniano (DNER); Jovino Marquez (DNER); Carlos E. Diez (DNER); Ana Ruiz (grad student); Oscar Diez (Navy biologist); Robert van Dam (DNER)	No Data	No Data	No Data	No Data	No Data	No Data	Hatchling	USVI	DRNA-PR (Carlos Diez, personal communication[30])
Tagging nesting females - Hector Horta (DNER); Lesbia Montero (Sea Grant-UPR) Milagros Justiniano (DNER); Jovino Marquez (DNER); Carlos E. Diez (DNER); Robert van Dam (DNER)	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Humacao, Fajardo, Majagues Project, Caja de Muertos, Culebra, Puerto Rico	DRNA-PR (Carlos Diez, personal communication[30])
Moving injured sea turtles - Hector Horta (DNER); Debora Moore (private veterinary); Antonico Mignucci (Metropolitan University); Carlos E. Diez (DNER); Robert van Dam (DNER)	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	2 rehab facilities in PR	DRNA-PR (Carlos Diez, personal communication[30])
Collecting blood samples - Hector Horta (DNER); Debora Moore (private veterinary); Carlos E. Diez (DNER); Robert van Dam (DNER)	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Humacao, Fajardo	DRNA-PR (Carlos Diez, personal communication[30])
Non-Permitted Activities									
Massachusetts Bottom Trawl Gear [31]	1(0)	No Data	No Data	No Data	No Data	No Data	Immature	Mass state waters	Wellfleet Bay Wildlife Sanctuary (Robert Prescott, personal communication[32])

Massachusetts Lobster Pot Fishery[33]	No Data	[85] / [116]	No Data	No Data	No Data	No Data	Adult, Immature	Mass offshore waters	Prescott, 1988; Wellfleet Bay Wildlife Sanctuary (Robert Prescott, personal communication [32])
Massachusetts Pound Net (Weir) Fishery [34]	No Data	No Data	No Data	No Data	No Data	No Data	Benthic Immature	Nantucket Sound, MA	Wellfleet Bay Wildlife Sanctuary (Robert Prescott, personal communication [32])
Massachusetts pound net incidental captures[35]	0	1(0)	0	0	0	0	Benthic Immature	Massachusetts	STSSN (Wendy Teas, personal communication [36])
Massachusetts gill net incidental captures [35]	1(0)	0	0	0	0	0	Immature	Massachusetts	STSSN (Wendy Teas, personal communication [36])
Massachusetts non-shrimp trawl incidental captures [35]	0	0	0	1(0)	0	0	No Data	Massachusetts	STSSN (Wendy Teas, personal communication[36])
Massachusetts fish trap incidental captures[35]	1 (0)	0	0	0	0	0	No Data	Massachusetts	STSSN (Wendy Teas, personal communication[36])
Massachusetts Hook-and-line incidental captures [35]	1(0)	0	0	0	0	0	Immature	Massachusetts	STSSN (Wendy Teas, personal communication[36])
Massachusetts unknown capture method incidental captures	1(0)	0	0	0	0	0	Immature	Massachusetts	STSSN (Wendy Teas, personal communication[36])
Rhode Island Bottom Trawl Gear	occasionall y	0	0	0	0	0	Adult, Immature	Rhode Island state waters	Anonymous 1995

Rhode Island Gillnetting	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Rhode Island inshore and nearshore	Anonymous 1995
Rhode Island Large Fish Traps	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	off of Newport, RI	Anonymous 1995
Rhode Island Fish trap incidental captures[35]	2(0)	10(0)	0	0	0	0	Immature	Rhode Island	STSSN (Wendy Teas, personal communication[36])
Rhode Island Lobster Pots	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Rhode Island inshore and offshore	Anonymous 1995
Rhode Island pound net incidental captures[35]	0	2(0)	0	0	0	0	Immature	Rhode Island	STSSN (Wendy Teas, personal communication[36])
Rhode Island non-shrimp trawl incidental captures[35]	0	1(1)	0	0	0	0	Immature	Rhode Island	STSSN (Wendy Teas, personal communication[36])
Connecticut Bottom Trawl Gear	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Apr - Oct Block Island Sound, CT	Anonymous 1995
Connecticut Gillnetting	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Long Island Sound and adj marine waters, CT	Anonymous 1995
Connecticut Lobster Pots	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Long Island Sound and adj marine waters, CT	Anonymous 1995
New York Bottom Trawl Gear [37]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	offshore in state and fed waters, Long Island So, Block Island So, Peconic-Gardiners Bay	Anonymous 1995

New York Pound Net Fishery	144(0)	0	43(0)	52(0)	0	0	Immature	Long Island Sound, NY	Morreale and Standora 1998
New York Gillnet Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	New York	Anonymous 1995
New York fish trap incidental captures[35]	2 (0)	0	1 (0)	0	0	0	Immature	New York	STSSN (Wendy Teas, personal communication[36])
New York non-shrimp trawl incidental captures[35]	2(0)	2(2)	0	0	0	0	Immature-CC No Data for DC	New York	STSSN (Wendy Teas, personal communication[36])
New York fishing net incidental captures[35]	1(0)	0	0	0	0	0	Immature	New York	STSSN (Wendy Teas, personal communication[36])
New York gill net incidental captures[35]	1 (0)	0	1 (0)	0	0	0	Immature	New York	STSSN (Wendy Teas, personal communication[36])
New York Lobster Fishery	Mostly	Mostly	Fewer	Fewer	0	0	Adult, Immature	New York	Long Island Univ. (Sam Sadove, personal communication [38])
New York set net incidental captures[35]	0	0	0	1(0)	0	0	Immature	New York	STSSN (Wendy Teas, personal communication[36])
New Jersey Bottom Trawl Gear [39]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	offshore New Jersey	Anonymous 1995
New Jersey Gillnet Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	NJ State waters and offshore	Anonymous 1995
New Jersey non-shrimp trawl incidental captures[35]	2(0)	0	0	0	0	0	Immature	New Jersey	STSSN (Wendy Teas, personal communication[36])

New Jersey Hook-and-line incidental captures[35]	1(0)	0	0	0	0	0	Immature	New Jersey	STSSN (Wendy Teas, personal communication[36])
New Jersey pound net incidental captures[35]	16(0)	0	0	0	0	0	Immature	New Jersey	STSSN (Wendy Teas, personal communication[36])
New Jersey Unknown capture method incidental captures[35]	1(1)	0	0	0	0	0	Adult	New Jersey	STSSN (Wendy Teas, personal communication[36])
Delaware Horseshoe Crab Fishery - benthic trawls	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Benthic Immature	Delaware Bay	Spotila *et al.* 1998
Delaware non-shrimp trawl incidental captures[35]	9(1)	0	0	3(0)	0	0	Immature	Delaware	STSSN (Wendy Teas, personal communication[36])
Delaware Gillnet Fishery [40]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Benthic Immature	Delaware Bay	Anonymous 1995
Delaware Fish Trap Fisheries [41]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	EEZ off Delaware	Anonymous 1995
Hook-and-line Fisheries - Delaware Bay	12	0	0	0	0	0	Benthic Immature	Delaware Bay	Spotila *et al.* 1998
Delaware Drift net incidental captures[35]	2(0)	0	0	0	0	0	Immature	Delaware	STSSN (Wendy Teas, personal communication[36])
Maryland Bottom Trawl Gear	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Pelagic Immature	state water > 1nm	Anonymous 1995
Maryland Gillnet Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult,Immature	state offshore waters, Chesapeake Bay, MD	Anonymous 1995
Maryland Poundnet Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Benthic Immature	Chesapeake Bay, MD	Anonymous 1995

Maryland Poundnet Fishery incidental captures[35]	0	0	0	3(0)	0	0	Immature	Maryland	STSSN (Wendy Teas, personal communication[36])
Maryland Hook-and-line Fisheries	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Md. state waters	Anonymous 1995
Maryland non-shrimp trawl incidental captures[35]	1(0)	0	0	0	0	0	Immature	Maryland	STSSN (Wendy Teas, personal communication[36])
Maryland unknown capture method incidental captures[35]	2(0)	0	0	0	0	0	No Data	Maryland	STSSN (Wendy Teas, personal communication[36])
Va. Pound Net Fishery incidental captures[35]	82(1)	1(0)	0	6(0)	0	0	Immature	Virginia	STSSN (Wendy Teas, personal communication[36])
Va. Hook-and-line incidental captures[35]	4(1)	0	0	0	0	0	Immature	Virginia	STSSN (Wendy Teas, personal communication[36])
Va. fishing net incidental captures[35]	1(1)	0	0	0	0	0	Immature	Virginia	STSSN (Wendy Teas, personal communication[36])
Va. non-shrimp trawl incidental captures[35]	2(0)	0	0	0	0	0	Immature	Virginia	STSSN (Wendy Teas, personal communication[36])
Va. Gill net incidental captures[35]	1(1)	0	0	0	0	0	Immature	Virginia	STSSN (Wendy Teas, personal communication[36])
North Carolina Pound Net Fishery [42]	**2898** - 156(0)	0	**531** - 30(3)	**221** - 10(0)	0	0	Adult, Benthic Immature	Core & Pamlico Sound, NC	Epperly *et al.* 2000

North Carolina Hook-and-line Fisheries[35] [43]	70(0)	1	3	22(0)	0	0	Immature, Adult	North Carolina	NMFS unpublished data (Joanne Braun-McNeill, personal communication [44]) STSSN (Wendy Teas, personal communication[36])
North Carolina fishing net incidental captures[35]	2(1)	1(0)	0	1(0)	0	0	Immature	North Carolina	STSSN (Wendy Teas, personal communication[36])
North Carolina seine net incidental captures[35]	2(1)	0	0	0	0	0	Immature	North Carolina	STSSN (Wendy Teas, personal communication[36])
North Carolina gill net incidental captures[35]	34(4)	6 (2)	19(4)	10 (0)	1 (0)	0	Immature	North Carolina	NMFS unpublished data (Joanne Braun-McNeill, personal communication [44]) STSSN (Wendy Teas, personal communication[36])
North Carolina shrimp trawl incidental captures[35]	22(2)	0	2(0)	5(0)	0	0	Adult & Immature	North Carolina	STSSN (Wendy Teas, personal communication[36])
North Carolina non-shrimp trawl incidental captures[35]	53(6)	0	2(0)	31(1)	1(1)	0	Adult & Immature	North Carolina	STSSN (Wendy Teas, personal communication[36])
North Carolina unknown capture method incidental captures[35]	1(0)	0	1	0	0	0	Immature	North Carolina	STSSN (Wendy Teas, personal communication[36])
North Carolina Long Haul Seine Fisheries	13(0)	0	0	1(0)	0	0	Immature	North Carolina inshore waters	NMFS unpublished data (Joanne Braun-McNeill, personal communication[44])
North Carolina Beach Seine Fisheries	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Immature	North Carolina inshore and offshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Stop Net Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Immature	North Carolina offshore waters	Epperly and Thayer, unpubl. manuscript

North Carolina Purse Net Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Immature	North Carolina inshore and offshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Fish Traps Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Immature	North Carolina offshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Flynet Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Immature	North Carolina offshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Channel Net Fisheries	2(0)	1(0)	1(0)	1(0)	0	0	Immature	North Carolina inshore waters	NMFS unpublished data (Joanne Braun-McNeill, personal communication[44])
North Carolina Eel Pots Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Benthic Immature	North Carolina inshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Shrimp Pots Fishery	No Data	No Data	No Data	No Data	No Data	No Data	Benthic Immature	North Carolina inshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Crab Pot Fisheries	0	1(0)	0	0	0	0	Immature	North Carolina inshore waters	NMFS unpublished data (Joanne Braun-McNeill, personal communication[44])
North Carolina Pelagic Longline Fisheries	**0.0046-0.0218/1000 hooks**	**0.0116-0.1183/1000 hooks**	0	0	0	0	Adult & Pelagic Immature	North Carolina offshore waters	Epperly and Thayer, unpubl. manuscript
North Carolina Benthic Longline Fisheries	No Data	No Data	No Data	No Data	No Data	No Data	Benthic Immature	North Carolina inshore waters	Epperly and Thayer, unpubl. manuscript
South Carolina gill net incidental captures[35]	4(4)	0	1(1)	0	0	0	Immature	South Carolina	STSSN (Wendy Teas, personal communication[36])
South Carolina whelk trawling fishery[45]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	South Carolina	SCDNR (David Cupka , personal communication [46])
South Carolina Hook-and-line Fisheries[35]	0	0	0	2 (0)	0	0	Immature	South Carolina	STSSN (Wendy Teas, personal communication[36])
South Carolina shrimp trawl incidental captures[35]	1(1)	0	0	1(0)	0	0	Immature	South Carolina	STSSN (Wendy Teas, personal communication[36])

Georgia Shrimp bait fishery -otter trawls [47]	No Data	No Data	No Data	No Data	No Data	No Data	Immature	Georgia	GDNR (Mark Dodd [27], personal communication)
Georgia whelk fishery [48]	2	0	2	3	0	0	Immature	Georgia	GDNR (Mark Dodd [27], personal communication)
Georgia blue crab fishery (entanglements)	No Data	No Data	No Data	No Data	No Data	No Data	Immature, Adult	Georgia	GDNR (Mark Dodd [27], personal communication)
Georgia shrimp trawl incidental captures[35]	3(2)	0	0	2(1)	0	0	Immature	Georgia	STSSN (Wendy Teas, personal communication[36])
Georgia non-shrimp trawl incidental captures[35]	0	0	0	1(0)	0	0	No Data	Georgia	STSSN (Wendy Teas, personal communication[36])
Georgia Hook-and-line	No Data	No Data	No Data	No Data	No Data	No Data	Immature	Georgia	GDNR (Mark Dodd [27], personal communication)
Florida - Hook-and-line[35]	7(1)	0	30(0)	4(0)	0	0	Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])
Florida - Hook-and-line[35]	7(1)	0	1(0)	20(0)	0	0	Immature	Florida-Gulf	STSSN (Wendy Teas, personal communication[36])
Florida fish trap incidental captures[35]	1(1)	0	0	0	0	0	Adult	Florida-Gulf	STSSN (Wendy Teas, personal communication[36])
Florida try net incidental captures[35]	1(0)	0	2(0)	0	0	0	Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])
Florida shrimp trawl incidental captures[35]	4(1)	0	0	0	0	0	Adult & Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])

Florida shrimp trawl incidental captures[35]	0	0	0	7(1)	0	0	Immature	Florida-Gulf	STSSN (Wendy Teas, personal communication[36])
Florida non-shrimp trawl incidental captures[35]	5(0)	0	0	0	0	0	Adult & Immature	Florida-Gulf	STSSN (Wendy Teas, personal communication[36])
Florida fishing net incidental captures[35]	2(0)	0	0	0	0	0	Immature	Florida	STSSN (Wendy Teas, personal communication[36])
Florida gill net incidental captures[35]	1(1)	0	1(1)	0	0	0	Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])
Florida gill net incidental captures[35]	1(0)	0	2(1)	1(0)	0	0	Immature	Florida-Gulf	STSSN (Wendy Teas, personal communication[36])
Florida long line incidental captures[35]	2(2)	0	0	0	0	0	Adult & Immature	Florida-Gulf	STSSN (Wendy Teas, personal communication[36])
Florida cast net incidental captures[35]	0	0	1(0)	0	0	0	Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])
Florida set net incidental captures[35]	1(0)	0	12(0)	0	0	0	Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])
Florida unknown capture method incidental captures[35]	0	0	1(0)	0	2(0)	0	Immature	Florida-Atlantic	STSSN (Wendy Teas, personal communication[36])
Alabama shrimp trawl incidental captures[35]	0	0	1 (0)	1 (0)	0	0	Adult & Immature	Alabama	STSSN (Wendy Teas, personal communication[36])
Mississippi Hook-and-line incidental captures[35]	0	0	0	7(0)	0	0	Immature	Mississippi	STSSN (Wendy Teas, personal communication[36])
Mississippi shrimp trawl incidental captures[35]	3(0)	0	0	13(1)	1(0)	0	Immature	Mississippi	STSSN (Wendy Teas, personal communication[36])

Mississippi non-shrimp trawl incidental captures[35]	1(0)	0	0	0	0	0	Adult	Mississippi	STSSN (Wendy Teas, personal communication[36])
Mississippi gill net incidental captures[35]	0	1 (0)	0	0	0	0	Immature	Mississippi	STSSN (Wendy Teas, personal communication[36])
Mississippi unknown capture method incidental captures[35]	0	0	0	1(0)	0	0	Immature	Mississippi	STSSN (Wendy Teas, personal communication[36])
Louisiana shrimp trawl incidental captures[35]	2(0)	0	1(0)	12(5)	0	0	Immature	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana gill net incidental captures[35]	0	0	0	2(0)	0	0	Immature	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana fishing net incidental captures[35]	0	0	0	1(0)	0	0	Immature	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana set net incidental captures[35]	0	0	0	1(0)	0	0	Immature	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana non-shrimp trawl incidental captures[35]	1(1)	0	0	0	0	0	No Data	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana Hook-and-line incidental captures[35]	0	0	0	1(0)	0	0	Immature	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana seine net incidental captures[35]	2(0)	0	0	1(0)	0	0	Adult & Immature	Louisiana	STSSN (Wendy Teas, personal communication[36])
Louisiana unknown capture method incidental captures[35]	0	0	1(0)	0	0	0	No Data	Louisiana	STSSN (Wendy Teas, personal communication[36])
Texas Hook-and-line Fisheries [49]	0	0	0	288 (91)	0	0	Benthic Immature	Texas	Canon and Flannagan 1996, Cannon *et al*. 1994

Texas Hook-and-line incidental captures[35]	3 (0)	0	9(1)	99 (0)	4 (0)	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas fishing net incidental captures[35]	0	0	0	2(1)	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas gill net incidental captures[35]	0	0	7(4)	4(3)	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas cast net incidental captures[35]	0	0	3(0)	0	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas seine net incidental captures[35]	0	0	3(0)	0	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas set net incidental captures[35]	0	0	0	0	1(1)	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas trot line incidental captures[35]	0	0	1(0)	0	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas shrimp trawl incidental captures[35]	5(2)	0	2(0)	20(3)	1(0)	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas non-shrimp trawl incidental captures[35]	2(0)	0	0	1(0)	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Texas try net incidental captures[35]	0	0	0	1(0)	0	0	No Data	Texas	STSSN (Wendy Teas, personal communication[36])
Texas unknown capture method incidental captures[35]	0	0	1(0)	2(0)	0	0	Immature	Texas	STSSN (Wendy Teas, personal communication[36])
Boat strikes - USVI [50]	[0]	[0] / [42]	[38] / [42]	[0]	[4] / [42]	0	Adult & Immature	USVI	Boulon 2000
Poaching - USVI [51]	[0]	[4] / [16]	[4] / [16]	[0]	[8] / [16]	0	Adult & Immature	USVI	Boulon 2000

Entanglement in fishing gear - USVI [52]	[0]	[1] / [13]	[9] / [13]	[0]	[3] / [13]	0	Adult & Immature	USVI	Boulon 2000
USVI fish trap incidental captures[35]	0	0	2(1)	0	0	0	Immature	USVI	STSSN (Wendy Teas, personal communication[36])
Boat strikes - Puerto Rico	No Data	No Data	No Data	No Data	No Data	No Data	Adult & Immature	Puerto Rico	Maria Calixta Ortiz Rivera 2000
Poaching - Puerto Rico	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature, eggs	USVI, Puerto Rico	Boulon, 2000 Maria Calixta Ortiz Rivera 2000
Entanglement in fishing gear - Puerto Rico	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	USVI, Puerto Rico	Boulon, 2000 Maria Calixta Ortiz Rivera 2000
Puerto Rico Fishing net incidental captures[35]	0	0	2(0)	0	0	0	Immature	Puerto Rico	STSSN (Wendy Teas, personal communication[36])
Puerto Rico Hook-and-line incidental captures[35]	0	0	0	0	2 (0)	0	Immature	Puerto Rico	STSSN (Wendy Teas, personal communication[36])
Beach and coastal lighting - Caribbean	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Hatchling	USVI, Puerto Rico	DRNA-PR (Carlos Diez, personal communication [30]); Virgin Islands National Park (Rafe Boulon, personal communication[53])
Marine Debris in the Caribbean [54]	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Hatchling	USVI	Rafe Boulon, 2000
Foreign Activities									
Canada Longline	No Data	No Data	No Data	No Data	No Data	No Data	Pelagic Immature	NW Atlantic	James 2000
Canada Gillnet	No Data	No Data	No Data	No Data	No Data	No Data	Pelagic	NW Atlantic (coastal)	Goff & Lien 1988, Goff *et al.* 1994, Anonymous 1996
Uruguay Longline	No Data	No Data	No Data	No Data	No Data	No Data	Pelagic Immature	SW Atlantic	Achaval *et al.* 2000

Mexico Longline [55]	43	2	0	1	4	0	Pelagic Immature	Gulf of Mexico	Ramirez & Ania 2000
Spain Longline [56]	1098	2	0	0	0	0	Pelagic Immature	Western Med	Aguilar *et al.* 1995
Spain Longline [57]	443-8389 **1,953-19,987**	0	0	0	0	0	Pelagic Immature	Western Med	Caminas 1997
Spain Gillnet	24(1) **236**	2	0	0	0	0	No Data	Western Med	Silvani *et al.* 1999
Italy Longline [58]	650	0	0	0	0	0	Pelagic Immature	Central Med	Argano *et al.* 1992
Italy Gillnet [59]	397	0	0	0	0	0	Pelagic Immature	Central Med	Argano *et al.* 1992
Italy Longline [60]	275	"few"	0	0	0	0	Pelagic Immature	Central Med	DeMetrio & Megalfonou 1988
Italy Gillnet [61]	**16,000**	**0**	**0**	**0**	**0**	**0**	Pelagic	Central Med	DeMetrio & Megalfonou 1988
Italy Longline [62]	1817	6	0	0	0	0	Pelagic Immature	Central Med	DeMetrio *et al.* 1983
Malta Longline [63]	**1500-2500 (500-600)**	**0**	**0**	**0**	**0**	**0**	Pelagic Immature	Central Med	Gramentz 1989
Greece Longline [64]	116	0	0	0	0	0	Pelagic Immature	Eastern Med	Panou *et al.* 1991, Panou *et al.* 1992
French Guyana Gill net [65]	No Data	0	0	0	0	0	Pelagic Immature	French Guyana (coastal)	Chevalier *et al.* 1999
Portugal Bottom set line [66]	**500**	0	0	0	0	0	Pelagic Immature	Madeira	Dellinger and Encarnacao 2000
West Africa poaching	'large numbers taken'	0	0	0	0	0	Adult	Cape Verde nesting beaches	Cabrera *et al* 2000
West Africa nets, hook(gaff) and hand	No Data	No Data	No Data	No Data	No Data	No Data	Adult and Immature	Sao Tome coastal waters	Graff 1995, Castroviejo *et al*, 1994

Nicaragua gill net, spear	No Data	No Data	No Data	No Data	No Data	No Data	Adult and Immature	Nicaraguan coastal waters	Lagueux 1998, Lagueaux *et al.* 1998, Lima *et al.* 1999
Venezuela unknown gear	0	0	“often captured”	0	0	0	Adult and Immature	La Blanquilla Island, Venezuela	Fallabrino *et al.* 2000
Venezuela shrimp trawl [67]	15	6	16	0	11	0	Adult and Immature	NE coastal Venezuela	Marcano and Alio-M 2000
Cuba - unknown gear [68]	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Coastal Cube	Gavilan 2000, Alvarez 2000
Trinidad/Tobago gillnet [69]	[43]	[0]	[0]	[0]	[0]	[0]	Adult	Coastal Trnidad & Tobago	Newsday 2000, (Scott Eckert, personal communication[70]); Eckert and Lien 1999
Ghana [71]	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Ghana beaches	BBC News 2000
Belize nets (trawl & gill net), harpoon, hook, and spear [72]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and Immature	Coastal Belize	Smith *et al*, 1992
Suriname net (trawl, drift and set) and hand captures [73]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and Immature	Coastal waters and beaches of Suriname	Reichart and Fretey 1993
Antigua/Barbuda longline trammel nets, seines and gill nets [74]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and Immature	Coastal waters	Fuller *et al.* 1992
St. Lucia net and hand captures [75]	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Coastal waters and beaches	d’Auvergne and Eckert 1993
St. Kitts and Nevis turtle nets, gill nets, beach seines and hand captures [76]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and immature	Coastal waters and beaches	Eckert and Honebrink 1992
St. Vincent and the Grenadines turtle nets, spear gun and hand (longline) captures [77]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and immature	Coastal waters and beaches	Scott and Horrocks 1993
Netherland Antilles net (purse seine), longline and spear gun captures [78]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and immature	Coastal waters	Sybesma 1992
Aruba seine and longline captures [79]	No Data	No Data	No Data	No Data	No Data	No Data	Immature	Coastal waters	Barmes *et al.* 1993

Barbados net, spear and hand captures [80]	No Data	No Data	No Data	No Data	1440; 400	No Data	Adult and immature	Coastal waters and beaches	Horrocks 1992
British Virgin Islands net and hand (longline) captures [81]	No Data	No Data	No Data	No Data	No Data	No Data	Adult and immature	Coastal waters	Eckert *et al*. 1992, Cambers and Lima 1990, Tobias 1991

Achaval, F., Y. H. Marin, and L.C. Barea. 2000. Incidental capture of turtles with pelagic longline. NMFS-SCFSC-Tech Memo. 436:261.

Aguilar, R., J. Mas, X. Pastor. 1995. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *Caretta caretta* population in the Western Mediterranean. NOAA Tech. Memo. NMFS-SEFSC-361: 1-6.

Alvarez, B.L.A. 2000. Hawksbill turtle feeding habits in Cuban waters. 2000. NOAA Tech. Memo. NMFS-SEFSC-436:65.

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

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

Argano, R., R. Basso, M. Cocco, and G. Gerosa. 1992. Nouvi data sugli spostamenti di tartaruga marina comune (*Caretta caretta*) in Mediterraneo. Bollettino Musel Istitiuti Universita Genova 56-57:137-163.

d'Auvergne, C. and K.L. Eckert. 1993. WIDECAST sea turtle recovery action plan for St. Lucia. Sea turtle recovery action plan for St. Lucia. Caribbean Environment Program Technical Report 26:70 pp. United Nations Environmental Programme, Kingston, Jamaica.

Barmes, T., K.L. Eckert, and J. Sybesma. 1993. Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST). Sea turtle recovery action plan for Aruba. Caribbean Environment Program Technical Report 25: 58 pp. United Nations Environmental Programme, Kingston, Jamaica.

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

Boulon, R.H. 2000. Trends in sea turtle strandings, U.S. Virgin Islands: 1982 to 1997. NOAA Tech. Memo. NMFS-SEFSC-436:261-263.

Cabrera, I, D. Cejudo, and L.F.Lopez-Jurado. 2000 Human predation on marine turtles in the Archipelago of Cape Verdes, Western Africa. NOAA Tech. Memo. NMFS-SEFSC-443:217.

Cambers, G. and H. Lima. 1990. Leatherback turtles disappearing from the BVI. Marine Turtle Newsletter 49:4-7.

Caminas, J.A. 1997. Capturas accidentales de tortuga boba (*Caretta caretta*, L. 1758) en el Mediterránio occidental en la pesquería de palangre de superficie de pez espada (*Xiphias gladius* L.) International Commission for the Conservation of Atlantic Tunas Collective Volume of Scientific Papers 46:446-455.

Cannon, A.C. and J.P. Flanagan. 1996. Trauma and treatment of Kemp's ridley sea turtles caught on hook-and-line by recreational fishermen. Draft abstract submitted for the 18th Annual Sea Turtle Symposium. Hilton Head, S.C. February 1996.

Cannon, A.C. , C.T. Fontaine, T.D. Williams, D.B. Revera, C.W. Caillouet, Jr. 1994. Incidental catch of Kemp's ridley sea turtles (*Lepidochelys kempi*), by hook and line, along the Texas Coast, 1980-1992. U.S. Dept. Commer. NOAA Tech. Memo NMFS-SEFSC-341: 40-42.

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 of decline of leatherback turtles (*Dermochelys coriacea)* in French Guiana: a hypothesis. In: C. Miaud and R. Guyetant (eds), Current studies in herpetology. 480 pp. ISBN: 29514994-0X.

Dellinger, T. and H. Encarnacao. 2000. Accidental capture of sea turtles by the fishing fleet based at Madeira Island, Portugal. NOAA Tech. Memo. NMFS-SEFSC-443:218.

De Metrio, G. and P. Megalofonou. 1988. Mortality of marine turtles (*Caretta caretta* L. and *Dermochelys coriacea* L.) consequent to accidental capture in the Gulf of Taranto. Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration de la Mer Mediterranee 31(2): 285.

De Metrio, G., G. Petrosino, A. Matarrese, A. Tursi, and C. Montanaro. 1983. Importance of the fishery activities with drift lines on the populations of *caretta caretta* (L.) and *Dermochelys coriacea* (L.) (Reptilia, Testudines), in the Gulf of Taranto. Oebalia IX, N.S. 43-53.

Eckert, K.L and T.D. Honebrink. 1992. WIDECAST sea turtle recovery and action plan for St. Kitts and Nevis. CEP Tech. Rep. 17:116 pp. UNEP Caribbean Environment program, Kingston, Jamaica.

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 Tech. Rep. No. 2000-310. 7 pp.

Eckert, K.L., J.A. Overing, B.B. Lettsome. 1992. WIDECAST sea turtle recovery action plan for the British Virgin Islands. CEP Tech. Rep. 15: 116 pp. UNEP Caribbean Environment Programme, Kingston, Jamaica.

Epperly, S.P., J. Braun-McNeill, and A. Bass. 2000. In-water population index surveys: North Carolina, U.S.A. Proceedings of the Eighteenth Annual Sea Turtle Symposium, 3-7 March, 1998, Mazatlan, Mexico. U.S. Dep. Commer., NOAA Tech Memo. NMFS-SEFSC-436:62.

Epperly, S.P. and V. G. Thayer. Unpublished manuscript. Marine mammal and sea turtle/fisheries interactions in North Carolina. 10 pp.

Fallabrino, A., A. Rodriquez, A. Trujillo, and J. Marcano. 2000. Green turtle (*Chelonia mydas*) capture by Artesanal fishermen in la Blanquilla Island, Venezuela. NOAA Tech. Memo. NMFS-SEFSC-436:264.

Fish and Wildlife Service. 2000a. Permit#TE840727-0 issued to Ms. Donna Shaver-Miller, Padre Island National Seashore, Corpus Christi, TX 78480 by the FWS Albuquerque, NM office, April 30. Expires 4/30/2002.

Fish and Wildlife Service. 2000b. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed Preconstruction Modifications of Authorized Improvements for the Wilmington Harbor Project, New Hanover and Brunswick Counties, North Carolina. May 3. 61 pp.

Fish Wildlife Service. 2000c. Amendment to Endangered Species Act Biological Opinion for COE Coast of Florida Study (Log # 4-1-96-F-268), Region III beach nourishment and renourishment projects in Palm Beach, Broward and Dade Counties, Florida. Service Log # 4-1-00-I-233. February 8. 2 pp.

Fish Wildlife Service. 2000d. Amendment to Endangered Species Act Biological Opinion for COE Coast of Florida Study (Log # 4-1-96-F-268), Region III beach nourishment and renourishment projects in Palm Beach, Broward and Dade Counties, Florida. Service Log # 4-1-00-F-701. October 4. 4 pp.

Fish Wildlife Service. 2000e. Amendment to Endangered Species Act Biological Opinion for COE Coast of Florida Study (Log # 4-1-96-F-268), Region III beach nourishment and renourishment projects in Palm Beach, Broward and Dade Counties, Florida. Service Log # 4-1-00-F-497. October 31. 5 pp.

Fish and Wildlife Service. 2000f. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed Lido Beach Shore Protection Project located on Lido Key, Sarasota County, Florida. August 13. Log # 4-1-99-F-252. 21 pp.

Fish and Wildlife Service. 2000g. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed Lighthouse Point groin construction located in Longboat Key, Sarasota County, Florida. January 18. Log # 4-1-99-F-99. 22 pp.

Fish and Wildlife Service. 2000h. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed MMS outer continental shelf oil and gas leasing, exploration, development, production, and abandonment for the Destin Dome 56 Unit Plan in the Eastern Gulf of Mexico. August 7. Log# 4-P-00-003. 13 pp.

Fish and Wildlife Service. 2000i. Endangered Species Act Section 7 Consultation Biological Opinion regarding an incidental take permit for The Villages at Seagrove and Camp Creek, St. Joe Company, Walton County, Florida. June 8. 106 pp.

Fish and Wildlife Service. 2000j. Endangered Species Act Section 7 Initiation of consultation regarding the construction of a dune/berm system in Okaloosa County and the City of Destin in Okaloosa County, Florida. April 6. Log # 4-P-00-102. 5 pp.

Fish and Wildlife Service. 2000k. Endangered Species Act Section 7 Initiation of consultation regarding the construction of a dune/berm system 0n the St. Joseph peninsula, otherwise known as Cape San Blas, Gulf County, Florida. April 6. Log # 4-P-00-103. 5 pp.

Fish and Wildlife Service. 2000l. Endangered Species Act Section 7 informal consultation regarding the correction of drainage problems at the Miramar Public Beach access, Walton County, Florida. June 9. Log# 4-P-00-144 4 pp.

Fish and Wildlife Service. 2000m. Permit#TE025759-0 issued to Ms. Kathryn Craven, Texas A&M University, College Station, TX 77845 by the FWS Ecological Services, Atlanta, GA office. September 21. Expires 9/30/2002.

Fish and Wildlife Service. 2000n. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed COE implementation of a long-term beach management strategy which is predicated upon comprehensive beach restoration of the beaches in the City of Gulf Shores, Alabama. June 7. No Log# . 20 pp.

Fish and Wildlife Service. 2000o. Endangered Species Act Section 7 Consultation Biological Opinion regarding the construction of an emergency protective berm in the area of Dauphin Island, Mobile County, Georgia. March 22. 21 pp.

Fish and Wildlife Service. 2000p. Endangered Species Act Section 7 Consultation Biological Opinion regarding the proposed inert naval exercises and training at Vieques Inner Range in Vieques Island, Puerto Rico. July 27. 37 pp.

Fish and Wildlife Service. 2000q. FWS Endangered Species Incidental Take Permit#TE026114-0 issued to Mr. William Mailloux, Managing Partner Culebra Northshore, S.E., Culebra regarding the proposed residential development on approx. 64.8 acres at lot 4, Culebra Northshore, Barrio Isidoro, Culebra, Puerto Ricorto Rico. Expires 10/31/2012.

Fish and Wildlife Service. 1999a. Permit#TE776123-0 issued to Dr. Andre Landry, Texas A&M University-Galveston, Galveston, TX 77554 by the FWS Ecological Services, Albuquerque, NM office, April 16. Expires 4/30/2001.

Fish and Wildlife Service. 1999b. Permit#TE30177-0 issued to Mr. Anthony F. Amos, Marine Science Institute, University of Texas at Austin, Port Aransas, TX 78373 by the FWS Albuquerque, NM office, September 10. Expires 9/30/2001.

Fish Wildlife Service. 1999c. Endangered Species Act Informal Consultation No. 2-11-99-I-161 for a proposed Western Geophysical application for a geophysical permit to do seismic survey work on coastal public land in the Laguna Madre, Baffin Bay, and the Gulf of Mexico in Kleberg and Kenedy Counties, Texas. August 12. 5 pp.

Fish and Wildlife Service. 1999d. Subpermit of FWS Permit#697823-0 issued to Ms. Dana Hartley, NMFS, Northeast Region, One Blackburn Drive, Gloucester, MA 01930 by the FWS Region 5 Regional Office July 16. Expires 5/06/2003.

Fish Wildlife Service. 1999e. Endangered Species Act Informal Consultation for a proposed North Carolina Division of Water Resources to conduct dredging operations and spoil disposal in the waters of Roanoke Sound and Shallowbag Bay, NC. December 23. 14 pp.

Fish and Wildlife Service. 1999f. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed Fisher Island maintenance dredging project in the Visitor Marina on Fisher Island, Miami-Dade County, Florida. October 13. Log # 4-1-98-F-643. 22 pp.

Fish and Wildlife Service. 1999g. Endangered Species Act Section 7 Consultation Biological Opinion for a proposed Lee County Shore Protection Project in Lee County, Florida. September 29. Log # 4-1-99-F-812. 22 pp.

Fish and Wildlife Service. 1999h. Endangered Species Act Section 7 Consultation Biological Opinion for the proposed testing of Theater Missile Defense systems n the Eglin Gulf Test Range. August 5. (No FWS Log #). 43 pp.

Fish and Wildlife Service. 1999i. FWS Incidental Take Permit#TE811813-4 issued to County of Volusia, Florida related to vehicular use on public beaches FWS Region 4 Regional Office October 29. Expires 12/31/2001.

Fish and Wildlife Service. 1999j. FWS Endangered and Threatened Species Permit#TE676379-2 issued to Dr. Andrew Kemmerer, NMFS, SERO, St. Petersburg, FL by Regional Director, FWS, SE Region. May 4. Expires 05/31/2004.

Fish Wildlife Service. 1998a. Endangered Species Act Biological Opinion for OCS oil and gas lease sales 171, 174, 177, and 180, Gulf of Mexico Western Planning Area. March 9. 15 pp.

Fish Wildlife Service. 1998b. Endangered Species Act Informal Consultation No. 2-11-98-I-329 for a proposed 3-D Seismic Operation on Padre Island, in Nueces and Kleberg Counties. August 19. 2 pp.

Fish Wildlife Service. 1998c. Endangered Species Act Informal Consultation No. 2-11-98-I-330 for a proposed Western Geophysical application for a geophysical permit to do seismic survey work on coastal public land in Redfish, Aransas, and Corpus Christi Bays, Nueces, Aransas, and San Patricio Counties, Texas. August 21. 5 pp.

Fish Wildlife Service. 1998d. Endangered Species Act Informal Consultation No. 2-11-98-I-365 for a proposed Western Geophysical application for a geophysical permit to do seismic survey work on coastal public land in the Laguna Madre and Corpus Christi Bay, Nueces and Kleberg Counties, Texas. October 5. 5 pp.

Fish Wildlife Service. 1998e. Endangered Species Act Biological Opinion for US Armed Forces mission-related vehicle access and driving along Gulf of Mexico beaches except Shell Island, Tyndall Air Force Base in Bay County, Florida. June 24. Log# 4-P-98-020 30 pp.

Fish Wildlife Service. 1998f. Endangered Species Act Biological Opinion for COE management and excavation of the Lake Powell outlet to the Gulf of Mexico at Camp Helen in Bay County, Florida. July 31. Log# 4-P-97-089 34 pp.

Fish and Wildlife Service. 1998g. Endangered Species Act Section 7 Consultation Biological Opinion for Panama City Beach Nourishment Project located in Bay County, Florida. April 8. Log# 4-P-97-108. 21 pp.

Fish Wildlife Service. 1997. Endangered Species Act Biological Opinion for MMS outer continental shelf oil and gas leasing, exploration, development, production, and abandonment for multi-lease sales 169, 172, 175, 178, and 12 in the Central Gulf of Mexico. December 24. Log # 4-P-97-075. 37 pp.

Fish Wildlife Service. 1996a. Endangered Species Act Informal Consultation for the proposed Sandbridge Beach and Virginia Beach, Va., Hurricane Protection and Beach Erosion Control Projects. July 8. 5 pp.

Fish Wildlife Service. 1996b. Endangered Species Act Biological Opinion for COE Coast of Florida Study, Region III beach nourishment and renourishment projects in Palm Beach, Broward and Dade Counties, Florida.. Log # 4-1-96-F-268. October 24. 25 pp.

Fish and Wildlife Service. 1996c. Endangered Species Act Section 7 Consultation Biological Opinion regarding an incidental take permit for Brett Real Estate, Robinson Development Co., Inc. Orange Beach, Alabama. April 8. 29 pp.

Fish Wildlife Service. 1995a. Endangered Species Act Informal Consultation for the proposed Dam Neck Sand Dune and Beach Nourishment Project, Virginia Beach, Virginia. November 8. 2pp.

Fish Wildlife Service. 1995b. Endangered Species Act Biological Opinion for COE proposed beach nourishment project in Glynn County, Georgia. Log # 4-4-95-071. April 20. 23 pp.

Fish Wildlife Service. 1992. Endangered Species Act Biological Opinion for COE proposed revetment on beach in Glynn County, Georgia. Log # 4-4-93-032. November 5. 3 pp.

Fuller, J.E. K.L. Eckert, and J.I. Richardson. 1992. WIDECAST sea turtle recovery action plan for Antigua and Barbuda. CEP Tech. Rep. 16: 88 pp. UNEP Caribbean Environmental Program, Kingston, Jamaica

Gavilan, F.M. 2000. Impact of regulatory measures on Cuban marine turtle fisheries. NOAA Tech. Memo. NMFS-SEFSC-436:108-109.

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.

Graff, D. 1995. Nesting and hunting survey of the marine turtles of the island of Sao Tome. 1995. ECOFAC Report, 33 pp.

Gramantz, D. 1989. Marine turtles in the central Mediterranean Sea. Centro. 1(4):41-56.

Horrocks, J. 1992. WIDECAST sea turtle recovery action plan for Barbados. CEP Tech. Rep. 12: 61 pp. UNEP Caribbean Environmental Programme, Kingston, Jamaica.

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. Master of Science Thesis. Acadia University.

Lagueux, C.J. 1998. Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends. Ph.D. Dissertation, University of Florida, Gainesville, Florida. 215 pp.

Lagueux, C.J., C. Campbell, and L.H. Herbst. 1998. Demography of marine turtles harvested by Miskito Indians of Atlantic Nicaragua. NOAA Tech. Memo. NMFS-SEFSC-412:90.

Lima, E., C. Lagueux, D. Castro, and M. Marcovaldi. 1999. From one feeding ground to another: Green turtle migration between Brazil and Nicaragua. Marine Turtle Newsletter 85:10.

Marcano, L.A. and J.J. Alio-M. 2000. Incidental capture of sea turtles by the industrial shrimping fleet off northwestern Venezuela. NOAA Tech. Memo. NMFS-SEFSC-436:107.

Morreale, S.J. and E.A. Standora. 1998. Early life stage ecology of sea turtles in northeastern U.S. Waters. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SEFSC-413, 49 pp.

National Marine Fisheries Service. 2000a. Endangered Species Act section 10 Permit # 1231 issued to Dr. Llewellyn M. Ehrhart. May 31.

National Marine Fisheries Service. 2000b. Endangered Species Act section 10 Permit # 1236 issued to Virginia Institute of Marine Science. October 10.

National Marine Fisheries Service. 2000c. Endangered Species Act section 10 Permit # 1245 issued to J. David Whitaker, South Carolina Department of Natural Resources. May 19.

National Marine Fisheries Service. 2000d. Endangered Species Act section 10 Permit # 1253 issued to Carlos Diez, Puerto Rico Department of Natural Resources. September 22.

National Marine Fisheries Service. 2000e. Endangered Species Act section 10 Permit # 1259 issued to State of North Carolina, Department of Environmental and Natural Resources, Division of Marine Fisheries. October 5.

National Marine Fisheries Service. 2000f. Endangered Species Act section 7 consultation on the Preconstruction Modifications of Authorized Improvements (Involving Blasting and Dredging) in Wilmington Harbor, North Carolina. Biological Opinion, August 3. 64 pp.

National Marine Fisheries Service. 2000g. Endangered Species Act section 7 consultation biological opinion: Assateague State Park beach nourishment project. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed December 20, 2000. [Consultation No. NER/2000/01028]

National Marine Fisheries Service. 2000h. Endangered Species Act section 7 consultation biological opinion: Development and production plan, and right-of-way pipeline application for the Destin Dome 56 Unit. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed April 13, 2000. [Consultation No. SER/1999/01398]

National Marine Fisheries Service. 2000i. Endangered Species Act biological opinion regarding the reinitiation of consultation on the Atlantic Pelagic Fisheries for swordfish, tuna, shark and billfish in the U.S. EEZ: Proposed rule to implement a regulatory amendment to the HMS FMP; reduction of bycatch and incidental catch in the Atlantic pelagic longline fishery. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed June 30, 2000. [Consultation No. SER/2000/00540]

National Marine Fisheries Service. 2000j. Biological Opinion on the reinitiation of operation of the cooling water intake system at the Brunswick Steam Electric Plant, Carolina Power and Light Co. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed January 20, 2000. [Consultation No. SER/2000/00411]

National Marine Fisheries Service. 1999a. Endangered Species Act section 7 consultation on the Fishery Management Plan for Atlantic Mackerel, Squid, and Atlantic Butterfish Fishery and Amendment 8 to the Fishery Management Plan. Biological Opinion. April 28. 48 pp.

National Marine Fisheries Service. 1999b. Endangered Species Act section 7 consultation on the Fishery Management Plan for the Atlantic Bluefish Fishery and Amendment 1 to the Fishery Management Plan. Biological Opinion, July 2. 54 pp.

National Marine Fisheries Service. 1999c. Endangered Species Act section 7 consultation on the Fishery Management Plan for the Federal Spiny Dogfish Fishery. Biological Opinion, August 13. 59 pp.

National Marine Fisheries Service. 1999d. Endangered Species Act section 7 consultation on the Fishery Management Plan for the Federal Atlantic Herring Fishery. Biological Opinion. September 17. 62 pp.

National Marine Fisheries Service. 1999e. Endangered Species Act section 10 Permit # 1187 issued to Stephen M.H. Connett, St. George's School. April 4.

National Marine Fisheries Service. 1999f. Endangered Species Act section 10 Permit # 1198 issued to Florida Fish and Wildlife Conservation Commission. May 13.

National Marine Fisheries Service. 1999g. Endangered Species Act section 10 Permit # 1201 issued to Dr. Thane Wibbels. June 11.

National Marine Fisheries Service. 1999h. Endangered Species Act section 10 Permit # 1214 issued to Dr. Jane Provancha. May 25.

National Marine Fisheries Service. 1999i. Endangered Species Act section 7 consultation biological opinion: Proposed rule to implement the Fishery Management Plan for Sargassum Habitat of the South Atlantic Region. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed June 21, 1999. [Consultation No. SER/1999/00005]

National Marine Fisheries Service. 1999j. Endangered Species Act section 7 consultation biological opinion: Cooling water intake system at the Crystal River Energy Complex. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed June 16, 1999. [Consultation No. SER/1998/00067]

National Marine Fisheries Service. 1998a. Endangered Species Act section 7 consultation on shrimp trawling in the southeastern U.S. under the sea turtle conservation regulations. Biological Opinion, March 24. 32 pp.

National Marine Fisheries Service. 1998b. Endangered Species Act section 7 consultation on United States Coast Guard vessel and aircraft activities along the Atlantic coast. Biological Opinion, June 8, 1998. 45 pp.

National Marine Fisheries Service. 1998c. Endangered Species Act section 7 consultation on Federal American Lobster Fishery Management Plan under the Magnuson-Stevens Fishery Conservation and Management Act with a new plan under the Atlantic Coastal fisheries Cooperative Management Act. Biological Opinion, December 17. 45 pp.

National Marine Fisheries Service. 1998d. Endangered Species Act section 7 consultation regarding the Federal Monkfish Fishery. Biological Opinion, December 21. 48 pp.

National Marine Fisheries Service. 1998e. Endangered Species Act section 7 revised Incidental Take Statement for the Salem and Hope Creek Nuclear Generating Stations in the Lower Alloways Creek Township, Salem County, New Jersey. December 29. 10 pp.

National Marine Fisheries Service. 1998f. Endangered Species Act section 10 Permit # 1106 issued to Dr. David Owens, University of Charleston, Charleston, SC. January 15.

National Marine Fisheries Service. 1998g. Endangered Species Act section 10 Permit # 1133 issued to Dr. Andre Landry, Texas A&M University at Galveston, TX. May 1.

National Marine Fisheries Service. 1998h. Endangered Species Act section 10 Permit # 1144 issued to Michael J. Bressette and Bruce Peery. Quantum Resources, Inc. June 23.

National Marine Fisheries Service. 1998i. Endangered Species Act section 7 consultation biological opinion: Assateague Island short-term restoration project, Assateague Island long-term sand management project, Atlantic coast of Maryland Shoreline Protection Project, and Maryland coastal bay habitat restoration projects. Signed April 6, 1998. [Consultation No. NER/1998/00267]

National Marine Fisheries Service. 1998j. Endangered Species Act section 7 consultation biological opinion: Assateague Island Public Law 84-99 Emergency Response Action. Signed August 4, 1998. [Consultation No. NER/1998/00266]

National Marine Fisheries Service. 1998k. Endangered Species Act section 7 consultation biological opinion: Deepening of Galveston Bay Entrance Channel (Houston-Galveston Navigation Channels Project) using a hopper dredge. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed December 7, 1998. [Consultation No. SER/1998/00010]

National Marine Fisheries Service. 1998l. Endangered Species Act section 7 consultation biological opinion: Gulf of Mexico Outer Continental Shelf Oil and Gas Lease Sales: Central Planning Area Lease Sales 169, 172, 175, 178 and 182; Western Area Lease Sales 171, 174, 177 and 180. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed January 6, 1998. [Consultation No. SER/1998/00068].

National Marine Fisheries Service. 1997a. Endangered Species Act section 7 consultation on continued operation of the circulating water system of the St. Lucie nuclear generating plant. Biological Opinion. February 7. 39 pp.

National Marine Fisheries Service. 1997b. Endangered Species Act section 7 consultation on Navy Activities off the Southeastern United States along the Atlantic Coast, May 15. 73 pp.

National Marine Fisheries Service. 1997c. Endangered Species Act section 10 Permit # 1030 issued to Gray's Reef National Marine Sanctuary March 12.

National Marine Fisheries Service. 1997d. Endangered Species Act section 10 Permit # 1033 issued to U.S. Army Corps of Engineers, Waterways Experiment Station. March 23.

National Marine Fisheries Service. 1997e. Endangered Species Act section 10 Permit # 1053 issued to Molly Lutcavage, New England Aquarium. July 14.

National Marine Fisheries Service. 1997f. Endangered Species Act section 7 consultation biological opinion: The continued hopper dredging of channels and borrow areas in the southeastern United States. Signed September 25, 1997. [Consultation No. SER/1997/00070]

National Marine Fisheries Service. 1997g. Endangered Species Act section 7 consultation biological opinion: COE permits to Apache Corporation for explosive rig removals off Kleberg County Texas and to Chevron U.S.A. Inc. for explosive rig removals off Plaquemine and Lafourche Parish, Louisiana. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed June 10, 1997. [Consultation No. SER/1997/00037]

National Marine Fisheries Service. 1997h. Endangered Species Act section 7 consultation biological opinion: Regulations for Atlantic Coast Weakfish Fishery in the Exclusive Economic Zone (EEZ). Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed June 27, 1997. [Consultation No. FPR/1997/0043]

National Marine Fisheries Service. 1996a. Endangered Species Act section 7 reinitiation of consultation on the Summer Founder Fishery to Include the Scup and Black Sea Bass Fisheries. Biological Opinion, February 24. 42 pp.

National Marine Fisheries Service. 1996b. Endangered Species Act section 7 consultation on United States Coast Guard vessel and aircraft activities along the Atlantic coast. Biological Opinion, July 22. 32 pp.

National Marine Fisheries Service. 1996c. Endangered Species Act section 7 consultation on the proposed shock testing of the SEAWOLF submarine off the Atlantic Coast of Florida during the summer of 1997. Biological Opinion, December 12. 50 pp.

National Marine Fisheries Service. 1996d. Endangered Species Act reinitiation of section 7 consultation regarding current and proposed management activities conducted under the Northeast Multispecies Fishery Management Plan. Biological Opinion, December 13. 25 pp.

National Marine Fisheries Service. 1996e. Endangered Species Act section 10 Permit # 1008 issued to the State of North Carolina Division of Marine Fisheries. June 15.

National Marine Fisheries Service. 1996f. Endangered Species Act section 7 consultation biological opinion: Dredging by hopper dredge and beach replenishment along the U.S. Navy Fleet Combat Training Center at Dam Neck, Virginia Beach, Virginia. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed January 25, 1996. [Consultation No. NER/ 960002]

National Marine Fisheries Service. 1996g. Endangered Species Act section 7 consultation biological opinion: Dredging of the Tampa Harbor Navigation Channel, Tampa Bay, Florida. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed April 9, 1996. [Consultation No. SER/960016]

National Marine Fisheries Service. 1995a. Endangered Species Act section 7 consultation on United States Coast Guard vessel and aircraft activities along the Atlantic coast. Biological Opinion, September 15. 56 pp.

National Marine Fisheries Service. 1995b. Endangered Species Act section 7 consultation on Nuclear Regulatory Commission operation of the Oyster Creek Nuclear Generating Station in the Forked River and Oyster Creek, Barnegat Bay, New Jersey. Biological Opinion, September 21. 24 pp.

National Marine Fisheries Service. 1993a. Endangered Species Act section 7 reinitiation of a consultation on the Nuclear Regulatory Commission continued operation of the Salem and Hope Creek Nuclear Generating Stations in the Lower Alloways Creek Township, Salem County, New Jersey. Biological Opinion, May 14. 20 pp.

National Marine Fisheries Service. 1993b. Endangered Species Act section 7 consultation on Nuclear Regulatory Commission operation of the Oyster Creek Nuclear Generating Station in the Forked River and Oyster Creek, Barnegat Bay, New Jersey. Biological Opinion, September 21. 24 pp.

National Marine Fisheries Service. 1993c. Endangered Species Act section 7 consultation on proposed management activities conducted under Amendment 5 to the Northeast Multispecies Fishery Management Plan. Biological Opinion, November 30. 46 pp.

National Marine Fisheries Service. 1989. Endangered Species Act section 7 consultation concerning the issuing of exemptions for commercial fishing operations under section 114 of the Marine Mammal Protection Act. Decision Memorandum. July 5.

National Marine Fisheries Service. 1988. Endangered Species Act section 7 consultation biological opinion: Removal of certain outer continental shelf oil and gas structures in the Gulf of Mexico by the Minerals Management Service. Office of Protected Resources, National Marine Fisheries Service, Silver Spring, Maryland 20910. Signed July 25, 1988. [Consultation No. SER/1988/0026].

Newsday. 2000. 43 turtles and a whale found dead. Newsday Newspaper Monday August 7, 2000:2.

Panou, A. S. Moschonas, L. Tselentis, and N. Voutsinas. 1991. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Institute of Zoology, University of Munich, Seidlstrasser 25, 8000 Munich 2, Germany. Unpublished Report. 6 pp.

Panou, A., G. Antypas, Y. Giannopoulos, S. Moschonas, D., G. and Ch. Mourelatos, P. Toumazatos, L. Tselentis, N. Voutsinas, and V. Voutsinal. 1992. Incidental catches of loggerhead turtles, *Caretta caretta*, in swordfish long lines in the Ionian Sea, Greece. Institute of Zoology. University of Munich, Seidlstrasser 25, 8000 Munich 2, Germany. Unpublished Report. 8 pp.

Prescott, R.L. 1988. Leatherbacks in Cape Cod Bay, Massachusetts, 1977-1988. NOAA Tech. Memo. NMFS-SEFSC-214: 83-84.

Ramirez, P.A.U. and L.V.G. Ania. 2000. Incidence of marine turtles in the Mexican long-line tuna fishery in the Gulf of Mexico. NMFS-SEFSC Tech. Memo. 436:110.

Reichart, H.A. and J. Fretey. 1993. WIDECAST sea turtle recovery action plan for Suriname. CEP Tech. Rep. 24: 65 pp. ENEP Caribbean Environment Programme, Kingston, Jamaica.

Rivera, Maria Calixta Ortiz. 2000. Evaluacion de varamientos y mortandad de tortugas marinas en Puerto Rico e Islas Virgenes. Masters Thesis. PP. 81.

Schroeder, B.A. 1994. Florida index nesting beach surveys: are we on the right track? U.S. Dep. Commer. NOAA Tech. Memo. NMFS-SEFSC-351: 132-133.

Scott, N. and J.A. Horrocks. 1993. WIDECAST sea turtle recovery action plan for St. Vincent and the Grenadines. CEP Tech. Rep. 27: 80pp. UNEP Caribbean Environment Programme, Kingston, Jamaica

Silvani, L., M. Gazo, A. Aguilar. 1999. Spanish driftnet fishing and incidental catches in the western Mediterranean. Biological Conservation 90: 79-85.

Smith, G.W., K.L. Eckert, and J.P. Gibson. 1992. WIDECAST sea turtle recovery action plan for Belize. CEP tech. Rep. 18: 86 pp. UNEP Caribbean Environment Programme, Kingston, Jamaica.

Spotila, J.R., P.T. Plotkin, and J.A. Keinath. 1998. In water population survey of sea turtles of Delaware Bay. Final Report to NMFS, Office of Protected Resources for Work Conducted Under Contract #43AANF600211 and NMFS Permit No. 1007. 21 pp.

Sybesma, J. 1992. WIDECAST sea turtle recovery action plan for the Netherlands Antilles. CEP Tech. Rep. 11: 63 pp. UNEP Caribbean Environment Programme, Kingston, Jamaica.

Tobias, W. 1991. Turtles caught in Caribbean swordfish net fishery. Marine Turtle Newsletter 53: 10-12.

Yeung, C., S.P. Epperly, and C.A. Brown. 2000. Preliminary revised estimates of marine mammal and marine turtle bycatch by the U.S. Atlantic pelagic longline fleet, 1992-1998. NMFS, Miami Laboratory PRD Contribution Number 99/00-13.

Table 2. Summary of observed, **estimated**, *incidental*, (lethal), and [strandings] take levels, sea turtle life stage, and geographic region for generalized activities impacting sea turtles in the U.S. Atlantic, Caribbean and Gulf of Mexico. Reader should refer to Table 1 for details and references.

Generalized Activities	Annual Observed, **Estimated**, *Incidental* (Lethal) and [Strandings] Take Levels						Life Stage	Geographic Region
	Loggerhead	Leatherback	Green	Kemp's	Hawksbill	Olive Ridley		
Military	*287(69)*	*277(59)*	*278(60)*	*277(59)*	*277(59)*	*0*	Adult, Immature	Atlantic
	91(91)	*17(17)*	*16(16)*	*16(16)*	*4(4)*	*0*	Adult, Immature	Atlantic, Gulf of Mexico
Channel Maintenance (Dredging and Blasting: ACOE)	*65(65)*	*3(3)*	*15(15)*	*14(14)*	*3(3)*	*0*	Adult, Immature	Atlantic
	38(38)	*5(5)*	*13(13)*	*19(19)*	*7(7)*	*0*	Adult, Immature	Gulf of Mexico
Oil Activities - Lease Sales, Seismic Surveys, Rig Removal: MMS, ACOE[82]	*12(12)*	*7(7)*	*7(7*	*7(7)*	*7(7)*	*0*	Adult, Immature	Gulf of Mexico
Nuclear Power Plants	*145-unlim. (17)*	*105-unlim. (2)*	*112-unlim. (10)*	*113-unlim.(6)*	*105-unlim.(2)*	*0*	Adult, Immature	Atlantic
Fisheries								
Gillnets	*142(86),* 52(12), 7-50(1-17), **51.0(7.4),** [14]	*8(8),* 6(2) 5-27(2-12)	*78(42),* 34(12), 0-4(0-3), **93.1(43.5)** [9]	*196(100),* 10(0), 1-5(1-3), **34.5(28.3)** [24]	*4(4),* 1(0)	*0*	Adult, Immature	Atlantic
	1(0)	1(0)	9(5)	7(3)	0	0	Adult, Immature	Gulf of Mexico
	421(1) **16,236**	2(0)	0	0	0	0	Adult, Immature	Mediterranean
	[43]	[0]	[0]	[0]	[0]	[0]	Adult	Caribbean

Longline	*468(7)* **931**(1) **0.0046-0.0218/1,000 hooks**	*358(6)* **918**(0) **0.0116-0.1183/1,000 hooks**	*46(2)*	*23(1)*	*46(2)*	*0*	Adult, Immature	Atlantic, Gulf of Mexico
	12(12)	*2(2)*	*2(2)*	*2(2)*	*2(2)*	*0*	Adult, Immature	Atlantic, Caribbean, Gulf of Mexico
	8-119(0)	2-45(0)	0-2(0)	0	0	0	Adult, Immature	Atlantic
	45(2)	2	0	1	4	0	Adult, Immature	Gulf of Mexico
	3956(0) **3453-22,487 (500-600)**	11	0	0	0	0	Immature	Mediterranean
Trawling	*3450(3450)*	*650(650)*	*3450(3450)*	*3450(3450)*	*3450(3450)*	*0*	Adult, Immature	Atlantic, Gulf of Mexico
	32(30) 102(13) 3-16(1-4)	*2(1)*	*2(1)*	*2(1)*	*2(1)*	*0*	Adult, Immature	Atlantic
	19(3)	0	4(0)	47(9)	2(0)	0	Adult, Immature	Gulf of Mexico
	15	6	16	0	11	0	Adult, Immature	Caribbean
Pound Net	398(1) **2898**	4(0)	73(3) **531**	71(0) **221**	0	0	Adult, Immature	Atlantic
Hook-and-Line[82]	95(2)	1(0)	33(0)	28(0)	0	0	Adult, Immature	Atlantic
	10(1)	0	10(1)	415(91)	4(0)	0	Immature	Gulf of Mexico
	0	0	0	0	2(0)	0	Immature	Caribbean

Scallop Dredge	0-1(0)	0	0	0	0	0	Adult, Immature	Atlantic
Pot/Trap	*10(10)* 5(0)	*4(4)* 11(0) [201]	*0* 1(0)	*0*	*0*	*0*	Adult, Immature	Atlantic
	1(1)	0	0	0	0	0	Adult	Gulf of Mexico
	0	0	2(1)	0	0	0	Immature	Caribbean
Bottom Set Line	**500**	**0**	**0**	**0**	**0**	**0**	Immature	Atlantic
Set Net	1(0)	0	12(0)	1(0)	0	0	Immature	Atlantic
	0	0	0	1(0)	1(1)	0	Immature	Gulf of Mexico
Cast Net	0	0	1(0)	0	0	0	Immature	Atlantic
	0	0	3(0)	0	0	0	Immature	Gulf of Mexico
Trot Line	0	0	1(0)	0	0	0	Immature	Gulf of Mexico
Seine Net	15(1)	0	0	1(0)	0	0	Adult, Immature	Atlantic
	2(0)	0	3(0)	1(0)	0	0	Adult, Immature	Gulf of Mexico
Stop Net	No Data	No Data	No Data	No Data	No Data	0	Adult, Immature	Atlantic
Purse Seine	No Data	No Data	No Data	No Data	No Data	0	Adult, Immature	Atlantic
Fly Net	No Data	No Data	No Data	No Data	No Data	0	Adult, Immature	Atlantic
Channel Net	2(0)	1(0)	1(0)	1(0)	0	0	Immature	Atlantic
Try Net	1(0)	0	2(0)	0	0	0	Immature	Atlantic
	0	0	0	1(0)	0	0	Unknown	Gulf of Mexico

Unknown/Miscellaneous Gear	11(3)	1(0)	2(0)	1(0)	2(0)	0	Adult, Immature	Atlantic
	0	0	2(0)	6(1)	0	0	Immature	Gulf of Mexico
	0	0	2(0)	0	0	0	Immature	Caribbean**Error ! Bookmark not defined.**
Fisheries Utilizing Multiple Gears								
Bluefish (Gillnets, pound nets, trawls, troll lines)	*6(3)*	*0*	*0*	*6(6)*	*0*	*0*	Adult, Immature	Atlantic
Herring (gill net, purse seine, trawl)	*6(3)*	*1(1)*	*1(1)*	*1(1)*	*0*	*0*	Adult, Immature	Atlantic
Mackerel, Squid, Butterfish (dredge, gill net, longline, pot/trap, purse seine, trawl)	*6(3)*	*1(1)*	*2(2)*	*2(2)*	*0*	*0*	Adult, Immature	Atlantic
Monkfish (dredge, gill net, longline, pot/trap, trawls)	*6(3)*	*1(1)*	*1(1)*	*1(1)*	*0*	*0*	Adult, Immature	Atlantic
Dogfish (gill net, trawl)	*6(3)*	*1(1)*	*1(1)*	*1(1)*	*0*	*0*	Adult, Immature	Atlantic
Summer Flounder, Scup and Black Sea Bass (hook-and-line, longline, trawl)	*15(5)*	*3(3)*	*3(3)*	*3(3)*	*3(3)*	*3(3)*	Adult, Immature	Atlantic
Weakfish (gill net, hook-and-line, trawl)	*20(20)*	*0*	*0*	*2(2)*	*0*	*0*	Adult, Immature	Atlantic
Research	*1028*, 198(0)	*21*, 4(0)	*1102*, 84(0)	*176*, 68(1)	*28*, 5(0)	0	Adult, Immature	Atlantic
	1740, 574(0)	*30* 0	*35* 0	0	0	0	Hatchlings	Atlantic
	425, 5(0)	*10*, 0	*710*, 2(0)	*496*, 47(0)	*60*, 0	0	Adult, Immature	Gulf of Mexico
	1000 (10)	*400 (10)*	*1000(10)*	*4000(10)*	*4000(10)*	*0*	Hatchling	Gulf of Mexico

	50, 6(0)	*13*, 4(0)	*315*, 81(0)	*5*, 0	*325*, 37(0)	0	Adult, Immature	Caribbean
Beach Activities - beach nourishment, beach ligthting, beach construction, groins, beach driving, etc.	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Hatchling	Atlantic, Gulf of Mexico
Rehabilitation	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Atlantic, Gulf of Mexico
	20	*0*	*50*	*50*	*30*	*0*	Adult, Immature	Gulf of Mexico
	15	*0*	*0*	*0*	*0*	*0*	Hatchling	Atlantic
Entanglements	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature	Atlantic
	[0]	[1]/[13]	[9]/[13]	[0]	[3]/[13]	0	Adult, Immature	Caribbean
	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature, Hatchling	Caribbean
Boat Strikes[82]	[0]	[0]/[42]	[38]/[42]	[0]	[4]/[42]	0	Adult, Immature	Caribbean
Poaching	[0]	[4]/[16]	[4]/16]	[0]	[8]/[16]	0	Adult, Immature	Caribbean
	No Data	No Data	No Data	No Data	No Data	No Data	Adult, Immature, Egg	Caribbean
Ingestion	No Data	No Data	No Data	No Data	No Data	No Data	Adult	Caribbean
Foreign Countries Utilizing Multiple Gears								
West Africa (nets, hook, hand	No Data	No Data	No Data	No Data	No Data	No Data		
Nicaragua (gill net, spear)	No Data	No Data	No Data	No Data	No Data	No Data		
Belize (gill net, harpoon, hook, spear)	No Data	No Data	No Data	No Data	No Data	No Data		

Suriname (drift net, hand, trawl, set net,)	No Data	No Data	No Data	No Data	No Data	No Data		
Antigua/Barguda (gill net, longline trammel net, seines)	No Data	No Data	No Data	No Data	No Data	No Data		
St. Lucia (hand, net)	No Data	No Data	No Data	No Data	No Data	No Data		
St. Kitts and Nevis (gill net, hand, seines, turtle nets)	No Data	No Data	No Data	No Data	No Data	No Data		
St. Vincent and the Grenadines (longline, spear gun, turtle nets)	No Data	No Data	No Data	No Data	No Data	No Data		
Netherland Antilles (longline, purse seine, spear gun)	No Data	No Data	No Data	No Data	No Data	No Data		
Aruba (longline, seine)	No Data	No Data	No Data	No Data	No Data	No Data		
Barbados (hand, net, spear)	No Data	No Data	No Data	No Data	No Data	No Data		
British Virgin Isles (longline, net)	No Data	No Data	No Data	No Data	No Data	No Data		

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[1] Number in parenthesis represents lethal take and is a subset of the total incidental take; numbers less than whole are rounded up.
[2] The incidental take level may represent any combination of species and thus is tallied under each column (note: in most cases, it is expected that takes of turtle species other than loggerheads will be minimal.
[3] Includes Navy Operations along the Atlantic Coasts and Gulf of Mexico, Mine warfare center, Eglin AFB, Moody AFB
[4] Total incidental take level includes acoustic harassment.
[5] Up to 8 turtles total, of which, no more than 5 may be leatherbacks, greens, Kemp's or hawksbill, in combination
[6] Total incidental take is 3 turtles of any combination over a 30-year period
[7] Not to exceed 25 turtles, in total.
[8] Represents range of observed takes (range of observed lethal takes) for 1995-1999 data.
[9] Merrick, R. 2000. National Marine Fisheries Service, Northeast Fisheries Science Center, NE Observer Program data. Personal Communication to J Braun-McNeill. (Fax) November 28, 2000.
[10] Tork, M. 2000. National Marine Fisheries Service, Northeast Fisheries Science Center, NE Observer data. Personal Communication to J. Braun-McNeill. (Fax) November 29 & December 8, 2000.
[11] Incidental take level for post-hatchlings for total period June 21, 1999 through January 2001
[12] Represents estimated incidental take levels, however the Incidental take statement cites observed take (5 loggerheads, 2 leatherbacks, or 3 Kemp's ridleys or greens or hawksbills in any combination) as a representative of the incidental take. The incidental take represents any combination of species other than the leatherback.
[13] Represents incidental (observed lethal) take
[14] Represents **estimated** (observed lethal) take for 1999 data only
[15] Represents incidental (incidental lethal) take
[16] Incidental take levels for non-lethal were not identified because entrainment is a function of turtle abundance & environmental conditions; lethal take is also expressed as 1.5% of the total number entrained in the plant, whichever is greater. Represents a minimum number of turtles taken annually because the majority of the take is observed take and is not an estimate of true numbers that are taken; the 'unlimited' lethal take for St.Lucie Power Plant is not incorporated in the Total. The numbers for each species are not additive because the total incidental take, in many cases, represents a combination of species.
[17] NERO is in the process of reinitiating Oyster Creek
[18] No report of take available to date; new research for FY00
[19] Numbers represent Incidental Live Take - Estimated Lethal Take - Strandings
[20] FWS allows for 7% of nests needing relocation to be missed based on Schroeder, 1994.
[21] Fuller, D. 2000. Fish and Wildlife Service, Lafayette Field Office, Lafayette, LA . Personal Communication to J Braun-McNeill. (Phone) December 12, 2000.
[22] Palmer, D. 2000. Fish and Wildlife Service, Jacksonville Field Office, Jacksonville, FL. Personal Communication to J Braun-McNeill. (Phone) December 8, 2000.
[23] Max number of eggs to be removed (number of eggs allowed broken) each year
[24] FWS recommends activities be undertaken and completed between mid-Sept and March 31 to avoid impacting nesting sea turtles.
[25] Boettcher, R. 2000. North Carolina Wildlife Resources Commission, Gloucester, NC. Personal Communication to J. Braun-McNeill. (Email) November 28, 2000.
[26] Murphy, S. 2000. South Carolina Department of Natural Resources, Charleston, SC. Personal Communication to J. Braun-McNeill. (Phone) November 27, 2000.
[27] Dodd, M. 2000. Georgia Department of Natural Resources, Brunswick, GA. Personal Communication to J. Braun-McNeill. (Fax) December 8, 2000.
[28] Morford, B. 2000. Florida Fish and Wildlife Conservation Commission, Tequesta, Florida. Personal Communication to J. Braun-McNeill (Email) November 28, 2000.
[29] Griffin, D. 2000. US Fish and Wildlife Service, US Virgin Islands. Personal Communication to J. Braun-McNeill (phone) January 29, 2001.
[30] Diez, C. 2000. Programa de Especies Protegidas DRNA-PR San Juan, Puerto Rico. Personal Communication to J. Braun-McNeill (phone) December 7, 2000.
[31] 1999 was first year a loggerhead was reported captured by inshore dragger; state waters closed to trawling May-Oct
[32] Prescott R. 2000. Massachusetts Audubon Society's Wellfleet Bay Wildlife Sanctuary South Wellfleet, MA Personal Communication to J. Braun-McNeill (Email) December 1, 2000
[33] Numbers represent # leatherbacks stranded due to entanglement/total # leatherbacks stranded for period 1977-1996
[34] 200 lb leatherback captured in a weir several years ago; one dead loggerhead that washes ashore in Nantucket Sound each year assumed weir caught; 3 or 4 families that operate 12 weirs.
[35] Incidental capture data for 1980-1999; numbers represent live(dead) captures
[36] Teas, W.G. 2000. STSSN strandings data. Personal Communication to J.Braun-McNeill (Email of strandings data). December 12, 2000.
[37] Data from 1991 survey of 213 commercial fishermen; NYDMR conducted trawl/field surveys April-Nov since 1985 especially in Peconic Gardiner's Bay - no records of turtle takes or sightings
[38] Sadove, S. 2000. Long Island University, Southampton College, Southampton, New York (Phone) December 6, 2000
[39] Trawling is prohibited within 2 miles of the coastline, but summer sea turtle distribution co-occurs with this fishery.
[40] Majority of fishing activity occurs inside Delaware Bay
[41] No incidental take in this fishery are known; traps may not exceed 125 cubic feet and must have escape panel
[42] Numbers represent estimated take - observed (lethal) take. 1997 data
[43] Numbers represent observed take - fate of hooked turtles not known. From 1988-2000 data

[44] Braun-McNeill, J. 2000. National Marine Fisheries Service, SEFSC, Beaufort, NC, unpublished data. December 21, 2000

[45] Season opens in late winter and early spring when offshore bottom waters are > 55; one criterion for closure is water temperature: whelk trawling will close for the season and not reopen throughout the State 6 days after water temperatures first hit 64 deg F in the Fort Johnson boat slip - after 6 days have lapsed, the water temperature will be 68 deg F, the temperature at which turtles move into State waters.

[46] Cupka, D. 2000. South Carolina Department of Natural Resources, Marine Resources Division, Office of Fisheries Management, Charleston, SC personal communication to J. Braun-McNeill (email of the Management Plan for South Carolina's Offshore Whelk Trawling Fishery - updated January 1999) December 18, 2000.

[47]15 min tow times, but still take turtles

[48]Data from 28 observed tows in 1996 (18 tows) and 1997 (10 tows); CPUE=0.3097 turtles/100ft net hour; Fishery occurs mid-Dec to 4/1 within state waters; 10 vessels fish/day; TEDS required in state waters beginning 12/00; experimenting with a 'topless' net

[49]Numbers represent observed take (lethal + rehabilitated). 1980-1995 data

[50]Numbers represent #strandings due to boat strikes/total strandings

[51]Numbers represent #strandings due to poaching/total strandings

[52]Numbers represent #strandings due to entanglements/total strandings

[53] Boulon R. 2000. Resource Management, V.I. National Park, US Virgin Islands (Email to Joanne Braun-McNeill) December 7, 2000

[54]One green turtle reported tangled in a lounge chair; turtles (unknown species) reported falling into construction pit which resulted in changes in permitting requirements for coastal construction

[55]Numbers represent observed take; Data from 1994-95

[56]Numbers represent observed take; estimated 23,520 and 15,6000 loggerhead turtles captured in 1991 and 1992, respectively.

[57]Data from 1986-1995.

[58]Data from 1981-1990; loggerheads may be caught up to 8 times.

[59]Data from 1981-1990; mortality 73.6%

[60]Data from 1978-1986

[61]Data from 1978-1986; numbers represent estimated captured/year; 30% mortality

[62]Data from 1978-1981; vessels targeting tuna caught more and smaller turtles than vessels targeting swordfish

[63]Data from 1988; numbers reported are estimates caught (estimated killed)

[64]Data from 1989-1991; estimated 70-100 turtles captured annually; multiple recaptures noted

[65]Suspected cause for decline in leatherbacks

[66]500 estimated captured annually

[67]Numbers are observed taken in 13,600 trawls; mortality estimated at 19%; 1370 turtles est. captured/year with 260 dead

[68]Green, loggerhead and hawksbill turtles are commercially harvested; landing trends ranged from 1,300 tons in 1975 to about 150 tons.

[69]Number of leatherbacks that washed ashore; estimated 500-1,000 adult female leatherbacks are killed in gill nets annually; many of the turtles do not drown but are butchered to get them out of the nets.

[70] Eckert, S. 2000. Hubbs-Sea World Research Institute, 2595 Ingraham Street, San Diego, California. Personal Communication (telephone) to Sheryan Epperly (NOAA/NMFS/SEFSC, Miami, Florida). October 3, 2000

[71]Estimated "two-thirds of turtles that swim up onto the coast of Ghana are caught and slaughtered by local fishermen".

[72]500-800 turtles sold annually (60% green, 30% loggerhead and 10% hawksbill); hawksbills and greens mostly captured in shrimp trawls; longline fishing for sharks "reportedly catching leatherbacks".

[73]Incidental catch of green and leatherback turtles in shrimp trawls starts in Feb., peaks in March and May, ends July-Aug; net mortality is higher than trawl mortality.

[74]"Entanglement in pot line and longline perceived to be increasingly serious problem"; longline fishery estimated to catch "100 or more turtles each year, mostly loggerheads and leatherbacks"; hawksbill and green turtles captured intentionally for tortoise shell and meat.

[75]Small numbers of nesting leatherback, green and hawksbill turtles taken; green and hawksbill turtles incidentally taken on other (seine/gill nets?) fisheries.

[76]Turtle nets catch green and hawksbill turtles for meat and tortoise shell; a few nesting leatherbacks caught on the beach; expanding longline fishery, but no bycatch data.

[77]"at least 120 turtles landed each year", mostly green, hawksbill, and a few leatherbacks; some leatherbacks are also caught by longlines.

[78]An estimated 250 turtles taken annually for meat and tortoise shell; purse seine and longline vessels in area, but no bycatch data

[79]Small hawksbill turtles sometimes taken for tortoiseshell; foreign longline vessels in area, but no bycatch data.

[80]1440 hawksbills harvested between 1970-1986; 400 harvested in 1990.

[81]Local longliners at Anegada have caught some leatherbacks

[82] There was additional information of sea turtle interaction for which no quantitative data were available

APPENDIX 3

OBSERVED SEA TURTLE CAPTURES IN THE U.S. ATLANTIC PELAGIC LONGLINE FISHERY, 1999-2000

Cynthia Yeung

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
W07	10	21	1999	39	53	69	51	Leatherback	alive, injured	beak/mouth	0	0	2	150	hooked in mouth
W07	10	21	1999	39	53	69	51	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	2	60	swallowed hook
W07	10	23	1999	38	37	72	48	Loggerhead	alive, injured	head/neck (external)	0	0	2	65	hooked on side of mouth
W07	10	23	1999	38	37	72	48	Leatherback	alive, injured	unknown beak/mouth	1	0	0	150	spit hook of of mouth
W07	10	26	1999	39	54	70	34	Loggerhead	alive, injured	beak/mouth	0	0	1	80	hooked in tongue
W07	10	28	1999	39	25	69	31	Leatherback	alive, injured	not hooked		1	0	125	wrapped in mainline,untangled by crew
W07	10	31	1999	39	49	69	53	Loggerhead	fresh dead	beak/mouth		0	0	57	hooked in mouth
W07	11	1	1999	39	43	70	9	Loggerhead	alive, injured	beak/mouth	0	0	0	60	hooked in mouth,only hook left
W08	11	26	1999	37	43	74	4	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	4	60	swallowed hook
W08	11	27	1999	37	41	74	4	Loggerhead	alive, injured	beak/mouth	1	0	0	55	spit hook out of mouth, dove immediately,no gear attached
R02	12	4	1999	35	43	74	44	unknown	alive, injured	beak/mouth	0	0	5	150	hooked in mouth
S20	11	25	1999	25	19	89	34	Leatherback	alive, injured	flipper	0	0	2	180	hooked in left front flipper
S20	11	30	1999	24	14	83	52	Loggerhead	alive, injured	beak/mouth	0	0	2	140	hooked in mouth
P50	11	13	1999	26	36	92	28	unknown	alive, injured	beak/mouth	0	0		120	line cut short, hook in side of mouth,original id was hawksbill, but improbable
T44	4	23	1999	32	39	72	49	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	120	hooked in throat
T44	4	23	1999	32	39	72	49	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	70	hook in throat
F67	6	15	1999	32	13	78	23	Leatherback	alive, injured	flipper	0	0	6	152	hooked in flipper
F67	6	15	1999	32	13	78	23	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	48	hooked in mouth
T45	6	1	1999	32	29	78	5	Leatherback	alive, injured	flipper	0	1	48	182	hook location unknown,excellent condition
S14	5	30	1999	39	52	54	52	Loggerhead	alive, injured	unknown beak/mouth	1	0	0	56	Lip hooked, hook removed, released in excellent condition
S14	5	30	1999	39	52	54	52	Loggerhead	alive, injured	flipper	1	0	0	65	hooked right pectoral fin, excellent condition
S14	5	30	1999	39	52	54	52	Loggerhead	alive, injured	unknown beak/mouth	0	0	0	60	mouth hooked,released in good condition
S14	6	3	1999	41	36	51	25	Leatherback	alive, uninjured	unknown other	0	1	12	170	
S14	6	10	1999	42	22	51	27	Loggerhead	alive, injured	unknown beak/mouth	0	0	2	140	mouth hooked
S14	6	13	1999	41	10	51	24	Leatherback	alive, injured	flipper	0	0	15	200	right front flipper snagged

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
S14	6	16	1999	41	51	50	20	Leatherback	alive, injured	unknown beak/mouth	0	0		179	mouth hooked, some line left in with hook
S14	6	16	1999	41	51	50	20	Loggerhead	alive, injured	unknown beak/mouth	0	0		100	mouth hooked, some line left in with hook
S14	6	16	1999	41	51	50	20	Leatherback	alive, injured	unknown beak/mouth	0	0		180	mouth hooked, some line left in with hook
S14	6	17	1999	42	1	50	25	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	90	mouth hooked
S14	6	18	1999	41	59	50	24	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	3	80	hook swallowed
S14	6	18	1999	41	59	50	24	Loggerhead	alive, injured	unknown beak/mouth	0	0	2	65	mouth hooked
S14	6	18	1999	41	59	50	24	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	80	mouth hooked
S14	6	18	1999	41	59	50	24	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	4	100	swallowed hook
S14	6	18	1999	41	59	50	24	Loggerhead	alive, injured	unknown beak/mouth	0	0	0	80	mouth hooked
S14	6	19	1999	42	3	50	22	Loggerhead	alive, injured	unknown beak/mouth	0	0	10	70	mouth hooked
S14	6	20	1999	42	14	50	44	Loggerhead	alive, injured	unknown beak/mouth	0	0		120	mouth hooked, seemed in very bad shape
S14	6	22	1999	42	24	50	48	Leatherback	alive, injured	flipper	0	0		200	tail? hooked,swam off strong
S14	6	22	1999	42	24	50	48	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0		90	hook swallowed
S14	6	23	1999	42	24	50	38	Loggerhead	alive, injured	flipper	0	0		90	tail hooked
S14	6	23	1999	42	24	50	38	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0		90	hook swallowed
S14	6	23	1999	42	24	50	38	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0		110	hook swallowed
S14	6	23	1999	42	24	50	38	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0		125	hook swallowed, seemed in very bad shape
S10	1	27	1999	28	0	79	25	Leatherback	alive, injured	flipper	0	1	6	200	hooked in right pectoral fin
S10	1	30	1999	28	0	79	25	Leatherback	alive, injured	head/neck (external)	0	0	12	200	hooked by mouth
P43	3	1	1999	26	14	91	34	unknown	other, unknown	unknown other	0	1	20		tangled, maybe hooked but not in mouth
N34	2	27	1999	20	29	73	50	Loggerhead	alive, injured	unknown beak/mouth	0	0	1	70	hooked in mouth
N34	2	28	1999	20	25	75	50	Loggerhead	alive, injured	unknown beak/mouth	0	0	3	80	hooked in mouth
N34	2	28	1999	20	25	75	50	Loggerhead	alive, uninjured	not hooked		1	0	85	entangled in flipper,all line removed
N34	3	1	1999	20	27	73	50	Leatherback	alive, injured	unknown beak/mouth	0	0	2	100	hooked in mouth
N34	3	4	1999	20	25	73	52	Loggerhead	alive, injured	unknown beak/mouth	0	0	2	100	hooked in mouth
N34	3	4	1999	20	27	73	50	Leatherback	alive, injured	flipper	0	0	2	110	hooked in left front flipper
N34	3	9	1999	20	25	73	52	Loggerhead	alive, injured	unknown beak/mouth	0	0	3	65	hooked in mouth

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
W03	4	22	1999	28	37	79	29	Leatherback	alive, injured	unknown beak/mouth	0	0	9	160	hooked in mouth
Q09	8	11	1999	31	45	79	5	Leatherback	alive, uninjured	unknown other	0	0	60		dove as boat approached, line cut at clip,not known tangled or hooked
F69	7	16	1999	45	45	43	1	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	71	mouth hooked
F69	7	16	1999	45	45	43	0	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	56	mouth hooked
F69	7	16	1999	45	45	43	4	Loggerhead	alive, injured	unknown beak/mouth	1	0	0	51	mouth hooked
F69	7	17	1999	46	4	43	35	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	64	mouth hooked
F69	7	17	1999	46	4	43	35	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	71	mouth hooked
F69	7	17	1999	46	4	43	35	Loggerhead	alive, injured	flipper	0	0	0	48	
F69	7	19	1999	46	6	43	14	Loggerhead	alive, injured	unknown beak/mouth	1	0	0	46	mouth hooked
F69	7	19	1999	46	6	43	14	Loggerhead	alive, injured	unknown beak/mouth	0	0	3	66	mouth hooked
F69	7	19	1999	46	6	43	14	Loggerhead	alive, injured	unknown beak/mouth	0	0	3	71	mouth hooked
F69	7	19	1999	46	6	43	14	Leatherback	alive, injured	unknown beak/mouth	0	0	12	183	mouth hooked
F69	7	19	1999	46	6	43	14	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	71	mouth hooked
F69	7	20	1999	46	6	43	1	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	69	mouth hooked
F69	7	20	1999	46	6	43	1	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	69	mouth hooked
F69	7	20	1999	46	6	43	1	Loggerhead	alive, injured	unknown beak/mouth	0	0	2	71	mouth hooked
F69	7	20	1999	46	6	43	1	Leatherback	alive, uninjured	not hooked		1	0	168	tangled in radio buoy drop rope, untangled completely
F69	7	21	1999	45	59	42	46	Leatherback	alive, injured	flipper	0	0	9	183	
F69	7	21	1999	45	59	42	46	Leatherback	alive, injured	unknown beak/mouth	0	0	10	152	mouth hooked
F69	7	21	1999	45	59	42	46	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	69	mouth hooked
F69	7	21	1999	45	59	42	46	Leatherback	alive, injured	flipper	0	1	12	168	
F69	7	22	1999	42	2	42	36	Loggerhead	other, unknown	unknown other				66	did not see capture or release
F69	7	22	1999	46	2	42	36	Leatherback	other, unknown	unknown other				168	did not see capture or release, id by captain
F69	7	22	1999	46	2	42	36	Leatherback	other, unknown	unknown other				168	did not see capture or release
F69	7	22	1999	46	2	42	36	Leatherback	alive, injured	unknown beak/mouth	0	0	12	183	mouth hooked
F69	7	22	1999	46	2	42	36	Leatherback	other, unknown	unknown other				183	did not see capture or release
F69	7	22	1999	46	2	42	36	Leatherback	alive, uninjured	not hooked		1	0	168	tangled in mainline, line cut
F69	7	26	1999	46	18	42	39	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	66	mouth hooked
F69	7	27	1999	46	9	42	21	Loggerhead	alive, injured	head/neck (external)	0	0	8	183	

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
F69	7	28	1999	46	9	41	53	Loggerhead	alive, injured	unknown other	0	0	18	183	did not see capture
F69	7	28	1999	46	9	41	53	Loggerhead	alive, injured	unknown beak/mouth	0	0	3	66	mouth hooked
F69	7	28	1999	46	9	41	53	Leatherback	other, unknown	unknown other				168	did not see capture or release
F69	7	28	1999	46	9	41	53	Leatherback	other, unknown	unknown other				122	did not see capture or release
F69	7	28	1999	46	9	41	53	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	64	mouth hooked
F69	7	28	1999	46	9	41	53	Leatherback	alive, uninjured	not hooked		1	24	168	tangled in mainline and buoy drop;untangled from mainline,but bullet buoy and buoy drop remained tangled on animal
F69	7	29	1999	46	0	41	33	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	69	mouth hooked
F69	7	29	1999	46	0	41	33	Loggerhead	alive, injured	unknown beak/mouth	0	0	4	61	mouth hooked
F69	7	29	1999	46	0	41	33	Loggerhead	other, unknown	unknown other				64	did not see capture or release
F69	7	29	1999	46	0	41	33	Loggerhead	alive, injured	unknown beak/mouth	0	0	3	56	mouth hooked, animal remained on the surface of the water
F69	7	29	1999	46	0	41	33	Leatherback	alive, uninjured	not hooked		1	0	152	mainline tangled around neck,untangled from mainline,remained on the surface with head above surface
F69	7	29	1999	46	0	41	33	Leatherback	alive, injured	unknown other	0	0	12	168	hooked unknown, remained just below surface
F69	7	29	1999	46	0	41	33	Leatherback	alive, injured	flipper	0	0	12	183	
F69	7	29	1999	46	0	41	33	Leatherback	alive, uninjured	not hooked		1	0	168	tangled in mainline around neck and flipper, untangled completely
F69	7	29	1999	46	0	41	33	Leatherback	alive, injured	flipper	0		12	168	
F69	7	29	1999	46	0	41	33	Leatherback	other, unknown	unknown other				168	did not see capture or release
F69	7	29	1999	46	0	41	33	Leatherback	alive, injured	not hooked		1	0	152	tangled in mainline,gangion line and buoy drop,line cut at boat side
F69	7	30	1999	46	11	41	51	Leatherback	alive, injured	unknown beak/mouth	0	0	10	183	mouth hooked
F69	7	30	1999	46	11	41	51	Loggerhead	alive, injured	unknown beak/mouth	0	0	6	66	mouth hooked
F69	7	30	1999	46	11	41	51	Leatherback	alive, injured	flipper	0	0	5	183	flipper hooked
F69	7	30	1999	46	11	41	51	Leatherback	alive, injured	flipper	0	0	6	183	flipper hooked
F69	7	31	1999	46	5	41	33	Leatherback	other, unknown	unknown other				168	did not see capture or release
F69	7	31	1999	46	5	41	33	Leatherback	alive, injured	flipper	0	0	15	168	flipper hooked

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
F69	7	31	1999	46	5	41	33	Leatherback	alive, uninjured	not hooked		1	0	183	tangled in drop buoy, cut loose completely
F69	8	3	1999	46	15	41	54	Leatherback	alive, injured	flipper	0	0	6	152	flipper hooked
F69	8	3	1999	46	15	41	54	Loggerhead	alive, injured	unknown beak/mouth	0	0	5	71	mouth hooked
S17	10	2	1999	28	1	79	38	Loggerhead	alive, injured	beak/mouth	0	0	6	100	hooked in mouth
S18	10	22	1999	31	36	78	50	Loggerhead	alive, injured	beak/mouth	0	0	6	110	hooked in mouth
W07	10	21	1999	39	53	69	51	Loggerhead	alive, injured	beak/mouth	0	0	2	75	hooked in tongue
W07	10	21	1999	39	53	69	51	Loggerhead	alive, injured	unknown beak/mouth	1	0	0	75	spit hook out of mouth
W07	10	21	1999	39	53	69	51	Leatherback	alive, injured	flipper	0	0	2	135	hooked in right front flipper
M01018	1	16	2000	18	6	54	52	Loggerhead	alive, injured	head/beak	0	0	0.5	95	beak hooked;swam away strongly
M01018	1	18	2000	17	52	53	45	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	1	90	gut hooked;swam away strongly
T01049	1	19	2000	27	50	91	21	Loggerhead	alive, injured	unknown other	0	0	210		condition unknown
M01018	1	22	2000	17	55	53	8	Loggerhead	alive, injured	flipper	0	0	0.5	90	LF flipper hooked;swam away strongly
M01018	1	22	2000	17	56	53	8	Loggerhead	alive, injured	head/beak	0	0	0.2	90	beak hooked;swam away strongly
M01018	1	23	2000	18	20	53	20	Leatherback	alive, injured	unknown other	0	0	20	180	large turtle could not be brought alongside;not hooked in head
S01022	2	12	2000	28	15.5	74	10.7	Loggerhead	alive, injured	unknown other	2	0	?	60	minor injury caused by hook;hook in mouth,not past cavity;lengths estimated; ventral side not seen
S01023	3	8	2000	31	54.2	78	50.1	Leatherback	alive, injured	beak/mouth	0	0	10	150	hooked in mouth;swam off readily
S01023	3	9	2000	31	51.2	78	42.1	Leatherback	alive, injured	beak/mouth	0	0	30	170	hooked in mouth;lip shank visible; released alive and energetic
Q02005	3	21	2000	27	35.3	90	9.9	Leatherback	alive, injured	flipper	0	0	5	122	hooked in RF flipper
Q02005	3	22	2000	27	38.2	90	3.6	Loggerhead	alive, injured	head/beak	0	0	3	90	released with hook inside of beak
R01005	4	15	2000	28	28	79	3	unknown	alive, injured	ingested (throat/esophagus)	0	0	0	0	unidentified due to dangerous weather and conditions;fairly sure it was loggerhead
R01005	4	17	2000	28	16	78	55	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	6	125	
S01025	4	18	2000	28	39.1	79	3.8	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	6	100	hooked in throat;exhibited some difficulty breathing;swam off readily

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
S01025	4	21	2000	28	43.1	78	45.7	Loggerhead	alive, injured	beak/mouth	0	0	2	140	hooked in mouth;shank fully visible; seemed fine
A25006	4	22	2000	36	8	74	39	Loggerhead	alive, injured	unknown other	1	0	0	61	came off hook and swam away as it was pulled to boat head first
P01055	5	16	2000	26	50	89	34	Leatherback	alive, injured	carapace/plastron	0	0	1	0	very strong;appeared healthy; hooked under edge of shell midway,right side
J02001	5	28	2000	31	40	78	40	unknown	alive, injured	unknown other	0	1	6	90	leader was wrapped around LR flipper; when it broke there was ~6' of line and a dead dolphin fish attached but turtle swam away fine;unsure about i.d.
J02001	5	29	2000	31	45	79	40	Loggerhead	alive, injured	beak/mouth	0	0	1	70	hooked in top of mouth;line cut as close to mouth as possible but could not remove hook without further injuring turtle;swam away and seemed fine
K02001	5	31	2000	28	5	79	30	unknown	alive, injured	beak/mouth	1	0	0	90	hooked in mouth;not entangled;freed itself at boat;no gear attached when dove
P01056	6	5	2000	27	11	91	22	Leatherback	alive, injured	beak/mouth	0	0	1	140	
P01056	6	7	2000	27	7	89	30	unknown	alive, injured	unknown beak/mouth	0	0	12	0	turtle pulled hard against leader
P01056	6	11	2000	26	29	90	11	unknown	alive, injured	unknown other	0	0	20	0	turtle not brought close enough to ascertain condition,except it was alive
B56038	6	11	2000	37	56	68	46	Leatherback	alive, injured	unknown other	0	1	45	120	turtle surfaced ~15 yds from vessel;cannot see where hooked; line cut;swam away uninjured
P01056	6	12	2000	26	58	89	46	Leatherback	alive, injured	carapace/plastron	0	0	3	120	released at boat; short line; swam away strongly
P01056	6	14	2000	27	23	89	50	Leatherback	alive, injured	beak/mouth	0	0	2	120	hook in joint of jaws

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
J02003	7	12	2000	43	35	45	30	Loggerhead	alive, injured	beak/mouth	0	0	0	53	hooked in front of beak;netted and brought on board;biopsy punch sample of RR flipper;cut line from hook and left hook in turtle;swam away strongly
J02003	7	12	2000	43	31	45	37	Loggerhead	alive, injured	flipper	1	0	0	51	hooked in RF flipper;biopsy in RR flipper;tagged,measured;removed hook and line;seemed fine at release
J02003	7	12	2000	43	31	45	38	Loggerhead	alive, injured	beak/mouth	1	0	0	59	hooked in beak;biopsied and tagged RR filipper;hook and line removed;swam away strong
J02003	7	15	2000	43	11	51	20	Leatherback	alive, injured	flipper	0	0	4	120	caused a large tangle in the gear;hooked in the RF flipper and was pulling hard;swam away quickly
J02003	7	15	2000	43	13	51	24	Leatherback	alive, injured	flipper	0	0	0	150	hooked in right shoulder;leader broke at hook;quickly swam away
J02003	7	30	2000	48	40	43	4	Leatherback	alive, injured	flipper	0	0	2	120	hooked in right front shoulder;swam away quickly
Q02009	7	31	2000	26	39	92	29.1	Leatherback	alive, injured	head/neck (external)	0	0	4	122	injury considered minor;likely to survive;hooked in ventral neck area near carapace;swam away actively;no tags noticed;sub-adult
J02003	8	2	2000	49	25	42	27	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	55	swallowed bait (squid);brought on board in net; measured, tagged, biopsied each rear flipper;line cut even with mouth; id according to guide book
J02003	8	2	2000	49	25	42	24	Leatherback	alive, injured	unknown other	0	0	5	150	came up for air during haul-in; positive id; swam under boat and did not resurface; broke leader ~3' below swivel and swam away; believed foul hooked from the way it was pulling

												No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location		hook removed	entangled	line left (ft)	CL (cm)	additional comments
P01057	8	4	2000	26	19	90	58	Leatherback	alive, injured	carapace/plastron		0	0	2	130	turtle was very stong;had difficulty bringing close enough to release
O02008	8	7	2000	40	51.9	66	9.2	Loggerhead	alive, uninjured	beak/mouth		1	0	0	72	F1 tagged and released;sample LR flipper; hook easily removed as it was held in the mouth; no hook penetration; no gear attached; swam away strongly
P01057	8	7	2000	26	51	92	13.2	Leatherback	alive, injured	carapace/plastron		0	0	20	130	turtle extremely strong and heavy;could not get turtle to surface
P01057	8	7	2000	26	51	92	13	Leatherback	alive, injured	carapace/plastron		0	0	2	130	turtle released by side of vessel; very good condition; did not set this area again
T01054	8	9	2000	39	54	68	48	Loggerhead	alive, injured	ingested (throat/esophagus)		0	0	1	61	throat hooked;6" leader left attached
W01013	8	9	2000	39	55	69	20	Loggerhead	alive, uninjured	unknown other		0	0	0	45	believed not hooked,just feeding on bait,or spat out hook;turtle closely associated with gear;believed initially on the leader,came to surface at the stern because vessel stopped to pull on leader;spat out bait or escaped gear;swam away
T01054	8	10	2000	40	4	68	40	Loggerhead	alive, injured	beak/mouth		0	0	0	80	no leader;9/0 hook left
T01054	8	11	2000	40	1	68	37	Leatherback	alive, injured	flipper		0	0	0	152	excellent condition;no leader
W01013	8	11	2000	39	52	70	28	Loggerhead	alive, injured	beak/mouth		0	0	60	60	
T01054	8	12	2000	40	0	68	59	Loggerhead	other, unknown	unknown other		2	2	0	76	recorded on individual animal log;life history form not filled out at time of data submission;observer could not remember details of gear interaction during followup questioning
T01054	8	16	2000	40	36	66	50	Loggerhead	alive, injured	beak/mouth		0	0	2	90	
W01013	8	20	2000	39	40	72	3	Loggerhead	alive, injured	ingested (throat/esophagus)		0	0	1	50	
W01013	8	22	2000	39	47	71	36	Loggerhead	alive, injured	ingested (throat/esophagus)		0	2	45	0	

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
M01020	8	25	2000	46	17.1	44	54.3	Loggerhead	alive, injured	ingested (throat/esophagus)	1	0	0	0	biopsy collected from rear flipper; hook removed; very little bleeding; swam away strongly
M01020	8	27	2000	44	54.8	47	3.3	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	0	biopsy collected from rear flipper; gut hooked beyond view in oesophagus; no bleeding; leader cut inside mouth; swam away strongly
M01020	8	28	2000	44	42.5	47	23	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	0	biopsy "C-10" collected from rear flipper;hook beyond view in oesophagus;no bleeding;leader cut deep inside mouth;swam away vigorously
M01020	8	30	2000	44	44.2	48	23	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	0	hook in oesophagus,unseen;no bleeding;leader cut as far down throat as could be reached with cutters;biopsy "C-1" collected from rear flipper;more lethargic than turtles taken in warmer water;temp@ take 60.2F; temp@ release 61.2F;swam vigorously
M01020	9	3	2000	43	20.6	51	30.5	Loggerhead	alive, injured	beak/mouth	1	0	0	0	dipnetted aboard;lightly hooked in beak;hook easily removed with no bleeding with little injury;biopsy "C-8";take temp 69.8F;release temp 69.9F;swam away vigorously
S01028	9	4	2000	31	28	79	1	Loggerhead	other, unknown	unknown other	2	2	40	90	leader broke before turtle was close enough to accurately assess consition or hook location;alive and appeared robust

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
M01020	9	4	2000	43	13.7	51	28.9	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	0	gut hooked; unseen in oesophagus;no bleeding;leader cut deep inside mouth;biopsy "C-3";dipnetted aboard;swam away vigorously;take temp 68F;release temp 68.8F
Q02010	9	4	2000	26	59.5	93	46.9	Leatherback	alive, injured	unknown other	0	0	30	0	no time to estimate size before captain cut leader
M01020	9	5	2000	43	23.7	51	39.3	Leatherback	alive, injured	flipper	0	1	0	120	hooked in leading edge of RF flipper;several wraps of monofilament around flipper were untangled and removed before leader cut at hook;swam strongly;little injury;2 hooks adjacent to each other on flipper;not clear if hooks from same or different sets
M01020	9	5	2000	43	14.1	51	14.5	Leatherback	alive, injured	flipper	0	1	0	110	released at surface by cutting leader at hook; hooked RF flipper;several wraps of monofilament were removed before cutting leader;swam away vigorously with little injury
S01028	9	6	2000	31	22	78	55	Leatherback	alive, uninjured	not hooked	0	1	0	170	entangled in mainline;no hook involved;all mono removed at release
M01020	9	12	2000	43	13.9	51	27.5	Leatherback	alive, injured	flipper	0	0	0	130	RF filpper hooked;released at the surface by cutting leader at the hook;little injury;swam away vigorously

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
J02004	9	20	2000	39	56	70	41	Loggerhead	alive, injured	beak/mouth	0	0	1	60	saw hooked through in lower jaw;line cut close to hook;swam away;~60-70 lbs;hooked on single leader with no entanglement;positive id
J02004	9	21	2000	39	47	71	20	Loggerhead	alive, injured	beak/mouth	0	0	1	60	turtle came up on single leader and was hooked in the mouth;brown on top;yellow on bottom;square head;positive I.d.;~2' carapace length;line cut close to mouth;swam away
J02004	9	21	2000	39	46	71	34	Loggerhead	alive, injured	beak/mouth	0	0	1	45	hooked in the mouth on single leader;brown on top and yellow on bottom;hook stuck out from bottom of jaw;line cut and swam away;positive id
W01014	9	22	2000	39	53	68	27	Loggerhead	alive, injured	beak/mouth	0	0	1	50	swam away strongly upon release
J02004	9	22	2000	39	49	71	44	Loggerhead	alive, injured	beak/mouth	0	0	1	60	hooked in the mouth on single leader;swam away looking fine
J02004	9	23	2000	39	50	71	48	Loggerhead	alive, injured	beak/mouth	0	0	1	75	hooked in right lower jaw;swam away quickly with short piece of line sticking out of mouth
T01055	10	6	2000	37	20	74	20	Leatherback	alive, injured	flipper	0	0	3	152	right flipper hooked; 3' 400lb mono leader left attached;swam off in excellent condition
T01055	10	6	2000	37	22	74	20	Loggerhead	alive, injured	beak/mouth	0	0	6	120	swam away in good condition with 6' 400 lb line and leader
T01055	10	6	2000	37	25	74	20	Loggerhead	alive, injured	beak/mouth	0	0	5	100	swam off in excellent condition with 5' 400 lb line and leader attached
J02005	10	19	2000	45	29	45	21	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	61	swallowed single hook;line cut even with mouth and released;swam away quickly;took 2 bio-tissue samples,one from each rear flipper

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
J02005	10	19	2000	45	26	45	20	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	65	swallowed hook of single leader;reddish brown with algae al over shell;square head and 2 claws on each rear flipper;tissue sample from LR flipper;line cut even with mouth and released;swam straight down
J02005	10	19	2000	45	23	45	18	Leatherback	alive, injured	head/neck (external)	0	0	3	120	foul hooked under mouth;swam away as soon as leader cut
J02005	10	19	2000	45	24	45	18	Loggerhead	alive, injured	beak/mouth	1	0	0	59	hooked in the mouth on a single leader;hook removed, tagged, sample removed from RR flipper;seemed fine;swam away
J02005	10	19	2000	45	23	45	18	Loggerhead	alive, injured	beak/mouth	1	0	0	55	hooked on a single leader with hook in mouth;swam away quickly and seemed unharmed
J02005	10	24	2000	46	1	44	3	Loggerhead	alive, injured	beak/mouth	1	0	0	56	biopsy sample from RR flipper;seemed fine as it swam away
J02005	10	24	2000	46	0	44	3	Loggerhead	alive, injured	ingested (throat/esophagus)	0	0	0	61	swallowed hook of single leader;sampled RR flipper;cut leader inside mouth and released;swam away fast
J02005	10	24	2000	45	59	44	7	Loggerhead	alive, injured	beak/mouth	1	0	0	41	hooked in the mouth on single leader;turtle missing lower right part of dorsal shell,but the skin underneath was healed with no open wounds;bottom shell not damaged;might have been hit by boat in the past;hook easily removed;swam away fine
J02005	10	31	2000	41	36	51	9	Leatherback	alive, injured	flipper	0	0	1	120	hooked in RF flipper; caught on single leader;leader cut;swam away

											No/Yes/Unknown 0/1/2				LF=left front RF=right front LR=left rear RR=right rear
trip	m	d	y	lat deg	lat min	lon deg	lon min	species	condition	hook location	hook removed	entangled	line left (ft)	CL (cm)	additional comments
J02005	10	31	2000	41	38	51	14	Leatherback	alive, injured	flipper	0	0	3	150	very large;foul hooked in the right shoulder on a single leader;pulled hard on linet;line cut and it dove under boat immediately
J02005	10	31	2000	41	39	51	17	Leatherback	alive, injured	flipper	0	0	1	120	hooked in bottom of RF flipper on single leader;line cut and swam away fine
S01031	11	6	2000	26	46.2	79	53.8	Loggerhead	alive, injured	beak/mouth	0	0	3	80	hooked in side of beak; entire hook visible; leader cut close to animal; swam away strongly
S01031	11	8	2000	31	54	79	40.1	Loggerhead	alive, injured	flipper	0	0	6	80	hooked in LF flipper;leader cut;swam away strongly
S01031	11	10	2000	31	39.1	79	15.3	Leatherback	alive, uninjured	unknown other	1	0	0	150	turtle escapes,pulling out hook;no gear left on turtle;little apparent injury;associated with leader but leader unhooked while pulled towards the boat;swam away strongly
J02005	11	10	2000	40	47	66	36	Leatherback	alive, injured	head/neck (external)	0	1	1	120	foul hooked in the neck and tangled in a bullet drop; removed all tangled line; swam away
J02005	11	13	2000	40	49	66	35	Leatherback	alive, injured	unknown other	0	0	1	150	unable to confirm id from photos;foul hooked in LF flipper;swam away strongly; seemed unharmed
K02003	12	11	2000	40	32	66	59	Loggerhead	alive, injured	beak/mouth	0	0	0	45	brought to boat side on hook;line cut at eye of hook which was in beak;swam away quickly
S01032	12	13	2000	28	24.3	78	15.1	Leatherback	alive, injured	flipper	0	0	6	160	hooked LF flipper;released in good condition;black

APPENDIX 4

DOCUMENTATION FOR F/PR REVIEW OF POST HOOKING MORTALITY

APPENDIX 5. DOCUMENTATION FOR F/PR REVIEW OF POST HOOKING MORTALITY

ATTACHMENT A

Interim Guidelines for Determining Serious Injury of Sea Turtles Taken Incidentally by the Pelagic Longline Fisheries

The development of guidelines for determining serious and non-serious injuries is essential because NMFS is mandated to reduce the levels of mortality and serious injury as mandated by the Endangered Species Act. The pelagic longline fisheries, targeting swordfish and tuna, have interactions with leatherback and loggerhead sea turtles. Although there is a low rate of observed mortality, there is a high likelihood of serious injuries.

Leatherback turtles seldom consume baited hooks, but often become entangled in the gangions. Fishermen usually attempt to remove all entangled gear, but the large size and robust nature of the leatherback often make this dangerous and difficult to do. Loggerhead turtles, on the other hand, usually consume the baited hooks and are either hooked in the mouth or throat and are usually cut free with some monofiliment leader attached.

Criteria for determining serious and non-serious injuries of marine mammals have been developed (Angliss and Demaster, 1998). However, the criteria for marine mammals and sea turtles are undoubtedly different and need to be developed. Sea turtles, unlike marine mammals, are apparently able to sustain considerable injuries and still survive. Loggerhead turtles are able to keep feeding with multiple hooks imbedded in their mouths (Argano et al, 1992) and are even able to expel swallowed hooks (Aguilar et al., 1995). Loggerheads commonly survive severed limbs (Gramentz, 1989).

The injuries commonly observed and recorded by NMFS observers will be categorized as non-serious, serious, and serious with associated mortality.

I. Non-serious injuries:

1. Entanglement of monofiliment line (mainlines, gangion line, or float line) where there are no visible injuries (cuts and/or bleeding) and gear is completely removed.

II. Serious injuries meet any the following life threatening criteria:

1. Entanglement of monofiliment line (mainline, gangion line, or float line) could directly interfere with feeding
2. Entanglement of monofiliment line (mainline, gangion line, or float line) could interfere with mobility
3. Entanglement of monofiliment line (mainline, gangion line, or float line) resulting in substantial wounds (cuts, constriction, bleeding) on any body part.
4. An animal ingests hooks in beak or mouth (visible) could interfere with feeding.
5. An animal is hooked externally in neck or flippers resulting in wound.

III. Serious injuries (with associated mortality) are those animals that:

1.Animal is hooked inside throat/esophagus hooked (28.9%) (Aguilar et al., 1995)
2. Are beak/mouth hooked with substantial line attached (>3 feet loggerheads and >6 feet leatherbacks) (unknown mortality rate).

The following are commonly observed injuries and suggested injury classification:
NS= non-serious injury, SI= serious injury, SM= serious injury with associated mortality. unknown mortality rate)

<u>Leatherback turtles:</u>

Entangled (cut free)	NS
Entangled (line trailing>6 feet)	SI
Hooked Externally (line trailing>6 feet)	SI
Hooked Mouth (line trailing <6 feet)	SI
Hooked Mouth (line trailing >6 feet)	SM*

<u>Loggerhead (hard-shelled) turtles:</u>

Entangled (cut free)	NS
Hooked Externally (fine trailing)	SI
Hooked Externally (cut free)	SI
Hooked Externally (hook removed)	SI
Hooked Beak/mouth (line trailing <3 feet)	SI
Hooked Beak/mouth (fine trailing >3 feet)	SM*
Hooked Beak/mouth (cut free)	SI
Hooked Beak/mouth (hook removed)	SI
Hooked Throat/esophagus (line trailing)	SM*
Hooked Throat/esophagus (cut free)	SM (28.9%)
Hooked Throat/esophagus (hook removed)	SM (28.9%)

ATTACHMENT A

References

Aguilar, R., J. Mas, and X. Pastor. 1995. Impact of Spanish swordfish longline fisheries on the loggerhead sea turtle *caretta caretta* population in the western Mediterranean. NOAA-NMFS-SEFSC-Technical Memorandum 361:1-6.

Angliss, R.P. and D. P. DeMaster. 1998. Differentiating serious and non-serious injury of marine mammals taken incidental to commercial fishing operations-. Report of the serious injury workshop 1-2 April 1997, Silver Spring, Maryland. NOAA Technical Memorandum NMFS- OPR- 1 3, 48 p.

Argano, R., R. Basso, M. Cocco, and G. Gerosa. 1992. Novi dati spostamenti di tartaruga marina comune (Caretta caretta) in Mediterraneo. Bollettino Musel Istitiuti Universitita. Genova 56- 57:137-163.

Gramentz, D. 1989. Marine turtles in the Central Mediterranean Sea. Centro 1:41-56.

ATTACHMENT B

Developing Interim Guidelines for Determining Serious Injury of Sea Turtles Taken Incidentally by the Pelagic Longline Fisheries

Sea turtles are listed as either endangered or threatened under the U.S. Endangered Species Act (ESA). The National Marine Fisheries Service (NMFS) and U.S. Fish and Wildlife Service (USFWS) share jurisdiction for sea turtles under the ESA. Section 7 of the ESA requires federal agencies to consult with either NMFS or USFWS when their actions are likely to affect listed sea turtles. In the case of domestic pelagic longline fisheries managed under a federal Fishery Management Plan, the NMFS Office of Sustainable Fisheries must consult with the NMFS Office of Protected Resources relative to the effects of the fishery on sea turtles. Sea turtles are incidentally taken as bycatch in federally-managed pelagic longline fisheries. Observers accompany a small percentage of pelagic longline trips and record data on sea turtle bycatch, among other things. Since mid-1999 observers have used the attached observer reporting form to record the condition of bycaught turtles. Table I provides an example of the comments recorded by observers on board pelagic longline vessels. NMFS analyzes observer data to estimate the total lethal and non-lethal take of sea turtles in the fishery. These estimates are critical to understanding the population-level effects of this bycatch and the estimates are used to monitor sea turtle bycatch relative to take levels authorized in the Incidental Take Statement of the Section 7 Biological Opinion, under the ESA. While there is a low rate of observed mortality (i.e., turtles dead when the longline is hauled in), there is a high likelihood of serious injuries which may or may not eventually result in the death of the animal.

NMFS defined "Serious Injury" for marine mammals as "*any injury that will likely result in mortality"* and defined "Injury" as *"a wound or other physical harm. Signs of injury to a marine mammal include, but are not limited to, visible blood flow, loss of or damage to an appendage or jaw, inability to use one or more appendages, asymmetry in the shape of the body or body position, laceration, puncture or rupture of eyeball, listless appearance or inability to defend itself, inability to swim or dive upon release from fishing gear, or signs of equilibrium imbalance. Any animal that ingest fishing, gear, or any animal that is released with fishing gear entangling, trailing or perforating any part of the body will be considered injured regardless of the absence of any wound or other evidence of an injury*." (50CFR §229.2). Requirements of the Marine Mammal Protection Act (MMPA) resulted in the convening of a workshop to differentiate between serious and non-serious injuries of marine mammals (Angliss and Demaster, 1998 - enclosed). The definition of "injury" for marine mammals and sea turtles are not likely to be identical and, thus, NMFS recognizes the need to review its current methodologies and to develop sea turtle specific definitions and criteria to determine which interactions between sea turtles and pelagic longline gear are likely to result in injuries leading to mortality (serious injuries) and which are not.

The result of sea turtle interactions with pelagic longline gear include entanglement and/or hooking (external or internal). The at-sea "treatment" that a captured turtle receives is variable and depends on conditions including, but not necessarily limited to, federal regulatory requirements, turtle size and species, the presence of an observer, the sea/weather conditions, experience and motivation of the captain and crew, and nature of the interaction. A general description of the Atlantic pelagic longline fishery and a report of gear, environment and fishing practice parameters which may influence sea turtle interactions are enclosed for your information.

For discussion and review purposes the following categories are proposed:

I. Non-serious injuries:

1. Entanglement in monofilament line (mainlines, gangion line, or float line) where there are no visible injuries (cuts and/or bleeding), the gear is completely removed, and the turtle swims strongly away from the vessel.

II. Serious injuries that may or may not result in mortality when turtles are released alive after the interaction:

I . Entanglement in monofilament line (mainline, gangion line, or float line) that directly or indirectly interferes with mobility such that feeding, breeding or migrations are impaired.
2. Entanglement of monofilament line (mainline, gangion line, or float line) resulting in substantial wound(s) (cuts, constriction, bleeding) on any body part.
3. Hooking external to the mouth resulting in substantial wound(s) (cuts, constriction, bleeding) with or without associated external entanglement and/or trailing attached line.
4. Ingestion of hook in beak or mouth (visible), with or without associated external entanglement and/or trailing attached line.
5. Ingestion of hook in the mouth, throat area, esophagus or deeper with or without associated external entanglement. and/or trailing attached line.

NMFS is seeking comments and input on the effects of these types of interactions on the health and viability of turtles involved in such interactions. Recommendations on apportioning mortality based on detail-specific criteria are sought.

ATTACHMENT C

John Hoey- Comments on SEC initial draft criteria

Draft criteria for determining serious injury and/or mortality for sea turtle pelagic longline interactions (October 10, 2000 e-mail draft from Wayne Witzell).

This initial draft reflects the decision rules that were used in the June 20, 2000 biological opinion, i.e. that almost all sea turtle - longline interactions cause serious injuries. While only a few were coded as serious injury with associated mortality I think that there are additional non serious injury conditions that are reasonable and would help encourage careful handling. Given the limited post-release data available the assumption that "there is a high likelihood of serious injuries" seems questionable. Given the text references in the third paragraph to turtle hardiness and resilience, the phrase "high likelihood" should be replaced by "varying levels of risk depending on the species and type of interaction". This would seem to be more in line with NMFS Technical Memo - SEFSC-222 which appeared to emphasize internal wounds.

Despite reference in paragraph 3 to the serious injury workshop on marine mammals and the undoubtedly different" criteria for serious injury for sea turtles, the categorizations presented at the bottom of page 1 reflect discussions on marine mammal injuries and interactions primarily with gillnet gear and pot warps from lobster gear. As I mentioned at the serious injury workshop and in more recent discussions and written comments, there are very important gear differences between gillnets and lobster pot warps that must be acknowledged.

In the marine mammal serious injury discussions, the interaction types that are listed under item II - ie. Serious Injury with respect to entanglements that interfere with feeding, mobility and cause substantial wounds - referred specifically to heavy multi-filament nylon lines in single strands and multiple strands that wrapped around appendages with the resulting drag and friction cutting through soft tissue and bone. The diameter, number of strands, weight in water, and drag associated with these gears is very different than those same characteristics and others associated with the types of monofilanient lines used in the U.S. pelagic longline fishery.

The monofilament used by the longline fleet is designed to have negligible resistance and drag and extremely low weight despite having great strength. In 1998 and 1999 gangion pound tests were usually > 300 lb. test (only one set with 250 lb. test), whereas mainline pound tests were usually -e- 600 lb. test. These characteristics must be factored into the serious injury criteria along with the fact that very few longline observer comments (based on my partial examination of Atlantic interaction forms) note cutting or tearing, wounds on appendages, whereas this is frequently noted for marine mammal interactions with gillnets and lobster warps. I think it is critically important to draw a distinction between the different weights, pound tests, for the monofilament line that is associated with turtle interactions. George Balazs included information on monofilament strangulation for Hawaiian Green turtles on page 130 of the Honolulu lab program review 2000 document. The illustrated entanglement was attributed to recreational shoreline fishing with 6-lb. test monofilament. I believe there have been similar observations associated with jetty fishing in the Gulf of Mexico and Atlantic. It should be part of the standard sampling protocol for monofilament samples to be taken for all stranded or nesting turtles that have attached gear.

As I mentioned at the serious injury workshop and in discussions with SEFSC and PR turtle scientists, monofilament line has memory (stretch) characteristics, especially for the pound test used for mainlines (usually > 600 lb. test) and gangions (usually > 300 lb. test), that make it very difficult to knot or twist and tangle strands so that the knot or tangle will hold once tension is eliminated from the line. Because of these characteristics fishermen rely on crimps to connect sections of line, especially the heavier mainline. In those cases where entangled turtles are released with trailing loops of monofilament that do not include an attached hook that is impeded in an appendage or shell, it would be very likely that the gear will simply fall off once line tension is released.

In those cases where an external hooking has occurred or where the hook is in the beak, jaw, or tongue (externally visible) and the turtle is released with limited line attached, the size of the turtle and length of attached line should be considered. There are no reports that I am aware of that specifically identify a line length threshold of I meter for loggerheads and 2 meters for leatherbacks, nor is rational provided in the draft for these arbitrary length thresholds. These lengths may be reasonable targets now that the fleet is required to carry line cutters, but this hasn't been the case in the recent past and it should be discussed with observers who have experience with conditions aboard vessels especially freeboard height and hauling practices. Since the 1995 Hawaii workshop emphasis has been placed on not pulling or putting tension or pressure on the line that is entangling the turtle. Fishermen therefore chose to leave slightly more line on the turtle when freeboard was high or weather conditions limited the Captains ability to maneuver because they thought that was better for the turtle than dragging the turtle closer to the boat. This would be particularly true for leatherbacks especially when they were active. A 5 meter threshold for leatherbacks would reflect reasonable handling distances aboard US commercial vessels where an attempt to avoid straining the line and dragging the turtle is probably being made. Five meters of monofilament would probably weigh less than a pound or two in the water which would seem to be a negligible drag, on a several hundred pound leatherback. Some of this concern about a line length threshold relates to post-classification (after the fact) when NMFS has not provided clear guidance to the fishermen. The same can be said for classifying all turtles as hooked by ingestion including those clearly noted as hooked in the mouth when the observer guidance described in Technical Memo SWFSC - 222 indicated that hooks were considered ingested if the hook was "past the mouth cavity and in the esophagus".

If all turtles that are released **are all categorized similarly as seriously injured** whether they are trailing small lengths of monofilament (< I or 2 meters as drafted) after being either externally hooked or hooked in the jaw (hook left in), released with only the hook in the jaw (no trailing gear), and hooked turtles that are completely disentangled with the hook removed, **these criteria will undermine efforts to encourage careful handling and extra effort to maximize survival**. I can't see how this risk averse decision would be consistent with previous agency actions relative to other fisheries, handling, or resuscitation guidelines, and the limited post-release data that is available.

Post-release mortality studies include Aguilar's study of survival of **deeply hooked turtles** from the Spanish Mediterranean fishery which uses very small hooks and baits and provides the 28.9% mortality rate listed on page 2 of the draft. Information from tracking studies from the Hawaiian longline fishery **need to be reviewed**. In the Honolulu lab program review 2000 document (page 130) it is noted that satellite transmitters have been deployed on 38 loggerheads, 11 olive ridleys, and 3 green turtles (a total of 52). "Twenty seven of the deployments have resulted in pelagic trackings ranging from 0.2 to 8.2 months duration covering distances of 13 - 7,282 km. The remaining 13 deployments have produced no tracking data, and all of these involved turtles that were classified as "deeply hooked" (hook lodged in the esophagus and impossible to remove)." This last sentence seems to be an incomplete thought and the total of 27 and 13 is 40, so an obvious question remains about the remaining 12 tracks. The next two sentences in the program review are as follows: "Of the 39 tracked turtles, 22 were deeply hooked and 17 "lightly hooked" (the hook was in the jaw or elsewhere externally allowing easy removal). There were no significant differences between these two groups for the duration of transmissions in months or the distance the turtles traveled." Additional information on these tracking results are critically important. If all 13 of the turtle deployments that produced no tracks were deep hooked what other condition notes were recorded and are these included in the total of 22 listed as deeply hooked or in addition to the 22? What was the species breakdown for the lightly and deeply hooked turtles and for the no track turtles?

If the 13 no tracks are in addition to the 22 deeply hooked then we have 39 tracked turtles and 13 no track turtles (total 52) with 35 deeply hooked and 17 lightly hooked. If the 13 no tracks only reflect short-term mortality as opposed to transmitter or battery failure or another co-variate, then 37% of the deeply hooked turtles may have died. The obvious questions include what the additional condition notes might include and whether the no track deployments all share a common characteristic (same trip, same month, similar area, similar size and species, transmitter lot, battery lot, etc.). In any case given the number of observations in both the Anguilar and Balazs studies it would seem that this data could justify assigning a mortality rate between 30% and 40% for deeply hooked turtles. I would assume given similar tracking distances and speeds a much lower mortality rate (some might argue a negligible rate) would be justified for lightly hooked turtles. Those turtles that are completely disentangled should not be categorized as injured unless wounds or trauma are evident.

In light of the preceding I would offer the following alternative categorizations of interaction types:

1. **Not Injured** - Turtles that spit hooks and baits while the gear is being retrieved and entangled turtles where hooks are not involved and where the turtle is released with no gear attached.

2. **Non-serious Injury (lightly hooked).** - Disentangled externally hooked turtles (not in jaw, beak or tongue) released with limited[1] gear attached. Also include turtles hooked in the jaw, beak, or tongue (externally visible) if the hook was removed for those sizes of turtles that could be brought aboard with dipnets and there was no other tissue damage or bleeding noted. Externally hooked (not in jaw,

beak, tongue, or neck - only carapace, flippers or tail) large turtles released trailing gear longer than the limited[1] gear thresholds but less than 5 meters in length.

3. **Serious injury - level 1 (deeply hooked but limited gear).** - Hook lodged in the esophagus and impossible to remove with the turtle released with limited[1] gear attached and observer notes indicating active and reasonable condition. Externally hooked turtles released with limited[1] gear attached and with non-critical tissue damage or limited bleeding noted, including turtles hooked in the jaw, beak, or tongue (externally visible). Different mortality ranges should be provided for these two groupings.

4. **Serious Injury - level 2 (deeply hooked with excessive gear).** -Hook lodged in the esophagus and impossible to remove with the Turtle released with more than the limited[1] gear attached and/or wounds noted to the eyes or neck. If an attached buoy was left trailing that would be a serious injury level 2 along with any turtles where the observer notes reference struggling or weak condition or a visible serious wound more extensive than a hook puncture.

Assigning rough quantitative ranges for mortality rates to the preceding categories will require a thorough review of the condition notes associated with the Honolulu tracking studies and any other information that has been developed over the last few years. This should be a topic for more extensive discussions including a range of people with greater experience than I have on events at-sea as well as vets and other biologists. It would seem reasonable however for the mortality rates for serious injury - level I deeply hooked turtles and serious injury - level 2 deeply hooked turtles to be different and preliminary range estimates might be reasonably established once the tracking study results are more thoroughly reviewed. I would also obviously have a 5th category for dead turtles.

[1]Refers to line distances of <1 meter for loggerheads and <2 meters for leatherbacks.

COMMENTS FROM ELLIOT JACOBSEN

Developing Interim Guidelines for Determining Serious Injury of Sea Turtles Taken Incidentally by the Pelagic Longline Fisheries

Comments

1. It is clear from the Final Report 50EANA7QO063, that not only do the terms "injury, non-injury, and serious injury" need to be defined, but that the observations and nomenclature to describe the observations must be standardized. Here are some recommendations:

a. **Serious Injury**: having a negative effect on turtle survivorship or negative effect on the animal's contribution to the population.

b. Definition of **injury** for marine mammal and sea turtle should be the same. The causes may be different. Injury: damage inflicted to the body by an external force (from Doriand's Illustrated Medical Dictionary).

c. While by process of elimination, a **non-serious injury** would be an injury that is not defined as a serious injury, still this needs definition.

d. A definition of "**foul-hooking**" needs to be included in any document.

2. Major problem is that we can't determine the extent of injury without establishing criteria for a healthy marine turtle. A group has been formed at the University of Florida to establish the "gold standard" for sea turtle health assessment. This will take several years to define. So when an attempt is made to try and categorize or establish criteria for injury, both serious and non-serious, realize that we are limited in our ability to stringently categorize animals. Clearly an animal that is moribund and appears to be near death because of obvious massive injury is easy to categorize. The difficulty is with those animals that appear to have minimal external damage but may have significant internal damage or are septic as a result of the injury. As all of us in medicine know, trying to get a handle on these cases is extremely challenging. So everyone needs to know what the limitations are. To come up with a more meaningful way of categorizing these animals, ultimately turtles with certain types of injuries need to be followed through time using satellite monitoring, This will be the only way to get a scientifically based handle on, outcome of injured animals. Categories of injuries can be established and criteria then developed to allow some type of categorization. Hopefully this will be an outcome of your proposed meeting.

3. We believe that any animal that is released with an intact attached hook, is at risk, especially if line is still attached. The more line, the more risk of being snagged underwater and drowning. The level of risk of drowning is dependent on the size and robustness of the turtle, as well as the area hooked. Of the 30 stranded turtles evaluated in a study done by us, at least 10% had evidence of fishing line injury severe enough to explain the cause of death. One had swallowed line, resulting in imbrication of the intestinal tract. One had a hook lodged in the larynx, associated with necratizing laryngitis. One had an abscess ventral to the tongue, which could have resulted from a

fish look lodging there. I think the abscess impacted on the turtle's ability and desire to eat. It should be assumed that if a turtle is entangled, that a hook could be internalized. The only way to dismiss this would be to radiograph these turtles. Even if a hook was found externally, that would not preclude an internal hook. A turtle with a swallowed hook could be in grave danger.

4. Questions to be answered:

a. How long does it take for hooks to rust out?

b. How stable is the monofilament line relative to disintegrating in salt water?

c. Is it possible to salvage any of the turtles for rehab, to conduct a parallel study with radiotransmitters?

d. In the report, there was a suggestion that some turtles could be entangled multiple times in longlines. What is the likelihood of this happening?

e. How toxic are light-sticks if they are swallowed? Are they ever swallowed?

5. There was no mention in the "Description of Longline Fishery" paper of what is used to weigh down the lines in the water. I assume that no toxic metals (for e.g., lead) are used.

FROM Edward R. Gaw, HI-LINER FISHING GEAR AND TACKLE, INC.

November 16, 2000

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
National Marine Fisheries Service
Attn: Office of Protected Resources
Room 13630,
Silver Spring, MD 20910

Dear Ms. Conant,

Thank you for the opportunity to participate in your initial solicitation of input concerning sea turtle- pelagic long-line interactions. HI-LINER Fishing Gear is the largest US exporter of pelagic monofilament long-line materials to the world pelagic swordfish/tuna long-line fleets. We maintain several offices in many coastal nations to provide local inventory, product support and technical expertise. Currently, we remain the key supplier to a majority of pelagic long-line vessels fishing from Spain, Portugal, South Africa, Brazil, Uruguay, Mexico, Chile, Australia - to name a few. It is the purpose of this letter to establish the position and standing of -HI-LINER among the world-wide pelagic long-line fleets, principally those plying the North/South Atlantic oceans,

HI-LINER has maintained a long history of product introduction, development and extension. The evolution of this style of fishing equipment has not been limited to the US. Acceptance of this material by other more traditional fishing nations has produced advancements and improvements in both equipment and technique. HI-LINER's emphasis on the operational success of individual international fishing vessels has left us uniquely qualified to comment on long-line gear principles, dynamics and continued product evolution.

However, your solicitation specifically requested input concerning injuries and their relative short/long term implications. It remains my strong belief that our subjective contribution to this phase of your investigation would contribute little to the attainment of the true goal of your discussions, Minimization/Avoidance of Sea Turtle//Pelagic Long-line Harmful Interactions. I would formally request that HI-LINER be consulted directly prior to any discussion of gear modifications, operational gear parameters and dynamics relative to sea turtle interactions. Combinations of traditional foreign fishing techniques with modern monofilament pelagic long-line gear has proved the flexibility and malleability of this style of fishing.

At your convenience, your review would be greatly appreciated. Please advise your requirements. Thank you for your time and considerations.

Regards,

Edward R. Gaw
HI-LINER FISHING GEAR, Inc.

UNIVERSITY OF CHARLESTON
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November 18, 2000
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Dr. Donald R Knowles
Director
Office of Protected Species
NOAA/ NWS
Silver Spring, MD 20910

Dear Dr. Knowles,

I have received the packet of information on the concerned interactions between sea turtles and longline fishing gear. The following comments are my initial reactions to the materials sent in the packet as well as my general sense of the importance of this particular conservation issue. Other than the information you sent, I do not have a good knowledge of this particularly fishery.

Observations:

1. Generally speaking, sea turtles are robust animals and can recover eventually from superficial external injuries such as would occur from a hook that is removed.

2. Physiologically, it is my impression that the leatherbacks are not as resilient hardy as the hard shelled turtles. This is suggested because of softer epidermal tissue, softer heads and beaks, heavier body mass and generally softer bodied food sources. Thus such actions as hooking, lifting from the water, and ingestion of hooks and lines may have more damaging and long lasting impacts on an individual leatherback.

3. Ingestion of a hook and line (depending on size) is likely to have long term impact on survivability of any sea turtle. We see lots of "floaters" in South Carolina. These turtles generally have a peritoneal infection which is causing gas to accumulate in the body cavity. Eventually these animals weaken and die unless treated. While I do not know this for a fact, hooks could be an initial cause of this problem. My concern is that ingested hooks may provide a long term irritant and source or bacterial entry. In addition, if the hook lodges in heart or lung tissue, or results in occlusion of the gut, the turtle may die directly for the event.

4. Leaving several yards of monofilament line hanging from the mouth is another source of potential problem. The line can be fouled and cause drag, swallowed causing an occlusion of the gut or wrapped around a flipper or caught on another object. Feeding

will be impaired to some degree depending on several variables.

Recommendations:

1. A physiological study of naturally hooked animals could address some of these concerns. Variables to be evaluated are movement of hooks once the line is cut, impact on feeding ability, changes in stress hormone and reproductive hormone levels and susceptibility to local or internal infections. In an aquarium, under proper medical supervision animals could safely studied. If and when they appeared to be suffering or taking a serious turn for the worse, surgical and antibiotic treatment could be applied to insure survival and eventual release.

2. Several veterinarians have experience in removing hooks. Their observations and results could be instructive in this regard.

3. Whenever possible, the entire line and any portion of the hook which can be seen should be cut out prior to release of the animal.

4. Additional observer work would seem to be important in zones 5, 6 and 7 and possibly 2.

I believe this fishery interaction is a serious problem for sea turtles.

Sincerely,

David Wm. Owens
Professor and Director
Graduate Program in Marine Biology

FROM MOLLY LUTCAVAGE, PHD, SENIOR SCIENTIST, NEW ENGLAND AQUARIUM

Donald R. Knowles
Director, Protected Species
National Marine Fisheries Service
Silver Spring, MD 20910

24 November, 2000

Dear Dr. Knowles,

Thank you for the opportunity to submit comments on the materials that your office forwarded re. effects of interactions between longline fishing gear and sea turtles.

NMFS is doing the right thing by developing criteria describing long line gear interactions that are specific to sea turtles. Although marine mammals and sea turtles share the distinction of being air-breathing vertebrates, they have very different behaviors and susceptibilities or responses to human interactions. Since we don't have all of the answers regarding gear interactions and sea turtles, it will be productive to have a suite of descriptions that accurately characterizes a sea turtle's condition, and disposition of gear left on the animal. Only then will all parties have the necessary information to proceed with mitigation that will limit or eliminate harmful interactions, and reduce burdens for fishermen if and when it is appropriate to do so. Specific comments follow below:

I. " Non-serious injuries" This category is contradictory and misleading. A "non-serious injuries" cannot be equal to "no visible injuries". If the animal is not injured, the observation should clearly state it as such.

1. Suggested alternatives to non-serious injuries that would describe animals that have run into gear but that have no visible injuries and are not suspected to have had them:
Gear Interaction 1, resolved (trailing or entangling gear has been removed)
Gear Interaction 2, gear not completely removed.

2. "Visible injury, minor (superficial)

Any visible injuries such as cuts, minor lacerations- that are not likely to jeopardize the health or impair the movements or behavior of the turtle. This type of injury would be expected to spontaneously heal/resolve.

II. **Serious Injuries** The five types of interactions could all be construed as serious. However, there are still some grey areas. For example, Entanglement in monofilament line. That interferes with mobility... such that feeding, breeding or migrations are impaired." Does this mean that the turtle is released with the monofilament, or that it was impossible to free it of binding gear? If yes- then of course, this is serious injury. But if the animal were freed of the mono and then showed signs of strength and normal swimming/behavior, would the designation of serious injury still hold true? [I hope that we all are working to making this situation go away. If still alive, all badly entangled animals need to be freed of gear. I need to know/understand whether there are cases where a longliner crew would be unable to free the turtle? If the turtle is attached via float line to rest of gear, doesn't the boat always have some line to the animal that can be retrieved?]

Regarding 4. Ingestion of hook in beak or mouth... does this mean that the observer can see the hook? There are cases where sea turtles have hooks in the keratinized tomium, but because it's not in the soft tissue, there may be little or no impairment, and the hooks eventually get dislodged. This is different than cases where the hook is in the soft tissue, where it is likely to be pushed further into the tissue.

Possible alternatives could be
Gear Interaction- Hooking

1. Visible, external, no obvious injury [no mortality expected]
2. Visible, external, injured [injuries serious, mortality could result)
3. Internal/Gut hooked; serious injury suspected or likely. [mortality could result]

From Table 1 1999 NOAA Fisheries Sea Sampling Program observers can obviously provide descriptive information that can be used to make an assessment of a turtle's status, especially in regard to serious vs. non serious injury, and whether a turtle is injured at all. There's plenty of room for improvement. For example, "hooked in mouth"- does this mean in the tomium, or in the soft tissue? Another one "swam off readily, although seem tired." My impression is that with explicit training, observers could provide unambiguous information. Photographs are also useful as supporting information.

The information provided by the Hoey report was extremely helpful. His analysis provides a good place to start to examine environmental relationships between sea turtles and longline gear, and where they are most likely to converge. However, we need more details, as temperature ranges were quite broad. We had this same problem in trying to find relationships between leatherbacks and real-time ocean frontal conditions, using limited aerial survey data from right whale and other surveys. For example, depending on geographic area, leatherbacks were found in SST's ranging from 10 -23^0 C, even though the average SST from right whale survey databases was 16^0 C (Distribution of Leatherback Turtles in relation to the Environment, Cooperative Agreement #40GENF400929, report to NMFS SEFSC, M. Lutcavage). Most of our observations came from inshore surveys, and are not particularly helpful in identifying offshore habits. I understand that the NMFS SEFSC recently funded a study by Morreale to examine SST's and location of longline sets that had interactions with sea turtles. It would be very helpful if these results were made available for review. It would also be important to see Scott Eckert's results of diving habits and travel patterns of leatherbacks that he's tracked with satellite transmitters in the Atlantic and elsewhere, particularly if this study were funded by NWS and if a technical report were available for distribution.

I was dismayed to see NMFS incorrectly use a report prepared by Greenpeace (submitted to the Sea Turtle conference but not subjected to peer review), in the recent Biological Opinion (Jun 30,2000). Page 35 states "Perhaps a better way of looking at the data is to apply the 29% mortality estimate provided by Aguilar (1995) to the average annual estimated take of 715 animals (Yeung et al., *in prep*) which indicates that an average of 207 animals annually either die or are seriously injured by pelagic longlines in the U.S. fleet." There is no way of knowing whether the Yeung et al. data is convincing, because the reader is unable to see it. The Aguilar et al. paper provides useful (although very general) information on turtles taken in the Spanish longline fishery, but is extremely flawed as a scientific paper on post release mortality or survivorship. The data shown in their Table 1, which suggests that " 20-30% of sea turtles may die after having been captured by a longline" is based on turtle survivorship of animals kept in "large aquaculture pools with the aim of estimating the mortality rate of the individuals released with hooks still in their bodies ..." The authors of this study did not conduct necropsies to establish cause of death, which is an absolute requirement, nor did they conduct control experiments that would establish whether the captured turtles had a lower survivorship than animals not subject to capture but also held in the tanks. Anyone that has raised sea turtles in captivity knows that they are subject to infections, disease, and other problems that arise from culture. Without addressing all of these concerns, this study cannot be used to establish survivorship or post release mortality. It would not have passed peer review, and NWS needs to be honest about using it as "best available science" when it is clearly does not satisfy sufficient scientific standards for establishing cause of death. Similarly, the reference to Balaz unpublished data (page 60) on a "44% mortality estimate observed by Balaz (person. comm) needs to come forward for evaluation. A good scientist cannot simply accept an unsubstantiated estimate for this important issue. Without a report to evaluate, there is no credibility.

The report prepared by Augliss and DeMaster was comprehensive, accurate, and very well done. It clearly sets the agenda for sea turtle/longline interactions, and it should serve as a model and guide for discussion and process for establishing distinct sea turtle criteria. For example (page 4)" Participants stressed that a thorough necropsy is necessary to determine the cause of death of large cetaceans and the degree to which an entanglement may have contributed to the mortality... (and as a footnote.... was stressed for all marine mammals in general)." The section "Collecting data on injuries" was also extremely important and clear on what needs to be done- the same holds for sea turtles: "Workshop participants identified several actions that would improve the data that observers provide on incidental injuries, such as 1) improve the training for recording interactions with marine mammals, 2) include marine mammal scientists in the debriefing... 3) encourage observers to provide more detail ...". All of these points are relevant to sea turtle and long line interactions.

Although I've listed some comments above, I look forward to further discussion at our upcoming meeting. Thanks again for the opportunity to weigh in on this issue.

Sincerely,

Molly Lutcavage, Ph.D.
Senior Scientist, ERL

United States Department of the Interior

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November 20, 2000

FAX

TO: Therese Conant

FROM: Thierry Work

Total Pages : 3

Dear Ms. Conant

Thank you for the opportunity to review the material on long line and marine turtle mortalities. In an attempt to make this issue more tractable, consider the following simple model:

Line is set-->turtle is attracted to line-->turtle gets hooked-->turtle dies or survives

Line setting:

What factors are conducive to turtle being hooked and how could these be prevented? Contract report 50WANA700063 outlines some of these including depth of line, time of set, temperature, use of light sticks, area of set, date of set.

Attraction:

What is it exactly that attracts turtles to bait? Are there certain bait types that would be equally attractive to fish but less so to turtles? Could artificial baits be developed that are repellent to turtles but not target fish? Could sonic devices be placed around lines that repel turtles? This would call for research on olfactory and visual cues that attract turtles to bait.

Hooking:

According to the contract report, this appears to be one area where more information could be gathered.

Once an animal is hooked or entangled in the line, how severe is the injury? The NOAA-

NMFS-OPR-13 goes some way into defining that for marine mammals. Defining injury based on hook placement alone in marine reptiles may be misleading. For example, lightly hooked turtles (hook on beak only, no visible trauma) may drown from forced submergence. On the other hand, we saw turtles with traumatic amputations of the forelimb from fishing line that survive quite well. Also, some turtles considered deeply hooked and tracked by satellite have been shown to survive many months. Finally, an animal may be hooked in the flipper (survivable injury)but released with several feet of leader thus posing potentially lethal risk of the leader wrapping around limbs or neck and causing strangulation or limb amputation. Perhaps consider standardizing criteria to define an animal as uninjured, moderately or severely injured using something like the following criteria.

Uninjured-Animal vigorous, breathing is unremarkable, hook on beak only (easily removed with no visible trauma) and no evidence of external trauma from line or hook.

*Moderately inju*red- Visible trauma from hook on beak, flipper or shell. Visible trauma from line around flipper (e.g. abrasion or cutting into flipper). Animal vigorous, breathing is unremarkable.

Severely injured- Hook in soft tissue of mouth (tongue, soft palate), or deep into esophagus. Leader wound tightly around limb with a partial avulsion or amputation. Alternatively, no visible injuries but animal weak.

Documenting: Following data would probably be helpfu11 to standardize reporting. Items (*) are those used to decide whether animal is uninjured, moderately, or severely injured. Items(*,**) may be useful for long term prognostication.

- -Hook number and type
- -Date and time of set
- -Water temperature
- -Type of light stick used (color, make)
- -Hook location*
- -Photo of hook set in turtle or of line-induced injury*
- -Length of turtle
- -Hooked removed (Y/N)**
- -Animal (vigorous, weak, dead)*
- -If hook not removed, length of lead left on hook.**

Any dead animals should be stored frozen and returned to a laboratory for complete post-mortem exam. Alternatively, observer puts animal aside and performs a necropsy taking appropriate samples in formalin and frozen once catch is finished (how realistic this is depends on conditions on the boat). Perhaps NMFS needs to dedicate observers to do this task only (documenting extent of injuries and doing necropsies).

Other avenues of pursuit: Given that hooks are set in 24 hour periods, are there materials that can be used to make hooks that will have similar tensile strength as steel but will degrade or dissolve in, say 7-10 days? For example, some darts used to immobilize animals have a needle with a barb made of a material that dissolves once it contacts body fluids thus causing less injury when the dart is removed. Th key would be to find a would be to find a material that dissolve, just more slowly (>24 h) allowing desirable fish to be caught.

Turtle dies or survives.

Efforts should be made to satellite tag animals in uninjured, moderate, and severely injured category to evaluate long-term outcomes. Perhaps this could readily be done in fisheries that consistently catch large numbers of turtles. A model animal could be something not critically endangered like the loggerhead.

I hope this is of some use.

Sincerely

Thierry M. Work
Wildlife Disease Specialist

FROM JOSEPH P. FLANAGAN DVM, HOUSTON ZOOLOGICAL GARDENS

4 Dec 2000

Donald R. Knowles
Director
Office of Protected Resources

Dear Dr. Knowles,

I have been working with sea turtles for approximately 16 years through the National Marine Fisheries Service Galveston Laboratory. During that time I have seen a number of sea turtles (mostly Kemps Ridleys) which have been caught on hook and line in the recreational fisheries here on the upper Texas coast. These turtles by and large, have ingested hooks and are presented within a day of capture.

Presentation has varied with size of the turtle, type of hook (size, shape, material), presence or absence of a leader, and quantity of line present. My approach to treatment has varied with the actual location of the hooking, At presentation, the hook may be present in the oral cavity, any point in the esophagus, or in the stomach. The damage done by the hook will vary with the point in the body that is hooked, the depth of hook penetration, and the length of time the hook has been present. I am never presented with animals that have had hooks for more than a few days.

In general, with a simple hook, the deeper (farther into the esophagus or stomach) the animal is hooked, the greater the chance of damage or potential damage. important exceptions to this are animals that are hooked in the oral cavity with the point of the hook penetrating into the orbit or globe of the eye, or animals that are hooked into a major blood vessel. Hooks that penetrate through the gut wall can cause variable damage, depending on what area or which organ the hook impacts. I have observed hooks that have punctured the major vessels near the heart, resulting in nearly immediate death of the animal. The point of a hook may cause a localized infection at the point of penetration. This infection could remain quiescent, and ultimately resolve without long term harm to the animal, or could result in a generalized infection and death. It is possible that a hook without a significant length of attached line can pass through the digestive tract without harming the turtle. I cannot guess at what percentage of cases this may occur.

Hooks anywhere in the gastro-intestinal system that trail fishing line can lead to placation of the intestines and potential peritonitis (coelomitis) with a linear foreign body. I consider any length of trailing line to be a significant risk to the health of a turtle as the line passes into the intestinal tract. Long lengths of line trailing from the oral cavity can entangle the turtles neck or appendages and result in physical harm to the animal. Loss of a flipper may reduce the animals feeding efficiency, its ability to evade predators, or impact its ability to reproduce.

Animals hooked in locations other than the gastro-intestinal system have a lower risk of adverse health effects due to the hooking incident. Hooks penetrating skin or superficial muscle groups are likely to establish a localized infection, but are likely to slough with infected tissue. The turtle will heal albeit with a defect where it was hooked. If hooked in or near a joint, the injury will be more severe. Penetration of a joint may impact the animal's mobility and is more likely to result in systemic infection.

Hooked turtles can suffer from harm caused indirectly as a result of their capture. Animals that are hooked and fight the hook may over-exert themselves, exhausting muscle energy sources and causing a severe metabolic acidosis. These animals may appear normal may fight with great force when handled, but may not have the ability to recover if returned to the sea in an exhausted condition. The longer an animal fights, or the greater the intensity of the fight, the more likely it will have problems recovering from the hooking incident.

If an animal is hooked and is unable to surface, it will obviously drown within a relatively short period of tome. The time will depend on the length of time since the animal last surfaced, the water temperature, the size of the turtles and the amount of struggling the animal does on the line.

Turtle interactions with hooks are traumatic incidents. Although some individuals may survive relatively unharmed, the vast majority will suffer significant injury and potential mortality as a result of being hooked.

If you have any further questions please contact me directly. I apologize that this response is tardy, but I was away when the package of information arrived.

Sincerely,

Joseph P. Flanagan DVM
Senior Veterinarian
Houston Zoological Gardens
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houzoovet@juno.com

Robert A. Morris, MS, DVM
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November 24, 2000

Mr. Donald R. Knowles, Director
Office of Protected Resources
National Marine Fisheries Service
Silver Spring, MD 20910

Dear Mr. Knowles:

In response to your request on sea turtles and fishing gear, I offer the following observations as a contract veterinarian for sea turtles for the National Marine Fisheries in Honolulu.

1. Some hooks remain unchanged for months in the intestinal tract of turtles with no evidence of dissolving (followed with X-rays).
2. Turtles have been seen with ingested hooks and are apparently healthy. On the other hand, hooks that perforate the G.I. Tract can cause death.
3. Hooked turtles trailing monofilament line can cause serious problems with line wrapped around the flipper, resulting in tissue and bone necrosis. We have done numerous flipper amputations because of this problem. Ingestion of the monofilament line can also cause serious problems to the intestinal tract.

The most important aspect for the survival of hooked turtles is removal of the hook, and if that is not possible, cut the trailing line as short as possible. Any hooked turtle with trailing mono line is in serious trouble.

If you require additional information, let me know.

Sincerely,

Robert A. Morris, MS, DVM

APPENDIX 5

OUTPUT FROM GLM WEEK/SQUARE ANALYSIS FROM LOGBOOK AND OBSERVER DATA (J. CRAMER, PERSONAL COMMUNICATION)[1]

[1] Jean Cramer, National Marine Fisheries Service, SEFSC, Miami, Fla. Personal Communication (E-Mail) to Karyl Brewster-Geisz, National Marine Fisheries Service, ST, Silver Spring, Md., August 28, 2000.

APPENDIX 6. OUTPUT FROM GLM WEEK/SQUARE ANALYSIS FROM LOGBOOK AND OBSERVER. The observer data were not adequate for LSMEAN calculattion so paramater estimates are included. Justification of any specific week/square closures based on these analyses is not recommended. Also included are summaries of catch and effort by week and square.

observer data - GLM estimates - GLM could not calculate LSMEANS

week	square	estmate		T for HO:	Pr > |T|	Std Err
5	4448	5	B	2.43	0.1356	2.056875
3	4444	4	B	3.61	0.0689	1.108042
2	4446	2.666727	B	1.92	0.1955	1.392376
4	4444	2	B	1.59	0.2522	1.255585
4	4448	2	B	0.99	0.425	2.012003
1	4644	1.666727	B	1.35	0.309	1.232779
1	4840	1.666727	B	0.83	0.4935	2.006322
2	4644	1.414617	B	1.21	0.3496	1.168261
3	4644	1.052996	B	0.98	0.4314	1.077162
3	4248	1	B	0.41	0.724	2.462898
6	4246	1	B	0.41	0.7214	2.437285
7	4448	1	B	0.5	0.6676	2.006051
3	4252	0.666727	B	0.33	0.7712	2.006322
3	4642	0.666727	B	0.34	0.7693	1.988218
1	4842	0.148777	B	0.15	0.8961	1.007371
1	4446	0	B	0	1	1.920636
1	5042	0	B	0	1	1.716277
1	5044	0	B	0	1	1.464651
2	4444	0	B	0	1	1.716277
2	4842	0	B	0	1	1.716277
2	4844	0	B	0	1	1.808528
2	5044	0	B	0	1	0.936151
2	5046	0	B	0	1	1.528656
3	4838	0	B	0	1	1.344445
3	5244	0	B	0	1	2.489428
4	4446	0	B	0	1	2.463896
4	4842	0	B	0	1	1.219153
5	4060	0	B	0	1	1.716277
5	4444	0	B	0	1	1.638742
5	4646	0	B	0	1	1.638742
6	4252	0	B	0	1	0.944764
6	4448	0	B	0	1	2.24065
7	4252	0	B	.	.	.
8	4448	0	B	.	.	.
2	4452	-12	B	-4.32	0.0496	2.776546
2	4454	-12	B	-3.86	0.061	3.108006
3	4250	-12	B	-3.92	0.0593	3.061154
4	4252	-12	B	-4.14	0.0538	2.901391
4	4452	-12	B	-3.79	0.0631	3.165595

observer by week and square data

year	week	square	turtles	hooks	swordfish kept	tuna	mako sharks	swordfish dead disc	blue sharks
1992	1	4446	0	700	19	2	2	3	24
1992	1	4842	0	2900	90	41	1	7	52
1992	1	5042	0	900	34	10	0	3	13
1992	1	5044	0	1300	24	25	0	1	11
1992	2	4444	0	900	50	0	1	7	2
1992	2	4644	0	900	46	0	1	8	85
1992	2	4842	0	900	45	2	0	1	59
1992	2	4844	0	800	11	0	0	4	50
1992	2	5044	0	4400	92	167	0	1	28
1992	2	5046	0	1175	20	23	1	0	9
1992	3	4444	4	2650	120	0	3	37	40
1992	3	4644	2	1800	64	2	10	22	29
1992	3	4838	0	1600	10	4	0	2	133
1992	3	5244	0	400	1	8	0	1	6
1992	4	4444	2	1900	42	0	3	6	35
1992	4	4842	0	2050	26	4	4	5	68
1992	5	4060	0	900	5	13	4	6	54
1992	5	4444	0	1000	13	0	0	0	14
1992	5	4646	0	1000	2	0	0	0	52
1992	6	4252	0	4270	22	65	6	5	56
1992	7	4252	0	6800	37	204	4	13	47
1993	1	4644	1	7677	252	51	3	7	365
1993	1	4840	1	833	26	16	3	2	30
1993	1	4842	0	833	24	36	4	3	20
1993	2	4446	2	3234	58	9	9	3	140
1993	2	4644	1	5050	83	6	6	11	144
1993	3	4252	0	833	0	0	0	0	99
1993	3	4642	0	855	9	3	0	0	25
1993	3	4644	0	4413	99	47	0	6	136
1994	3	4248	1	977	10	5	3	5	74
1994	4	4446	0	975	12	10	0	3	37
1994	4	4448	2	6184	103	9	2	13	380
1994	5	4448	5	4172	41	17	12	15	622
1994	6	4246	1	1031	6	2	3	9	45
1994	6	4448	0	1733	27	16	0	7	148
1994	7	4448	1	6601	29	109	0	13	504
1994	8	4448	0	638	0	6	0	1	145
1995	2	4452	0	2491	37	42	2	27	63
1995	2	4454	0	810	2	14	2	9	83
1995	3	4248	13	3328	28	7	8	16	230
1995	3	4250	0	900	5	4	0	4	40
1995	4	4252	0	1420	6	0	0	1	114
1995	4	4452	0	720	6	0	0	0	47

pelagic logbook
GLM

rank	week	square	LSMEAN	Std Err	p < |T|
1	1	4248	38.04656	3.476512	0.0001
2	4	4444	13.70773	2.109026	0.0001
3	1	4448	11.94983	3.432202	0.0006
4	1	4444	9.167189	4.229116	0.0314
5	1	4246	6.591974	5.89828	0.2651
6	3	4448	6.546262	2.159462	0.0028
7	2	4248	5.966448	2.294713	0.01
8	3	4248	5.742755	2.574909	0.0269
9	4	4446	4.334416	2.122479	0.0425
10	1	4644	4.097727	1.727501	0.0187
	1	4446	4.08015	1.815838	0.0258
	2	4446	4.071254	1.619608	0.0128
	2	4448	3.632665	2.038123	0.0763
	5	4250	3.575505	4.163747	0.3916
	3	4644	3.021021	2.034206	0.1391
	1	4642	2.793801	2.061334	0.1769
	5	4252	2.722604	2.851401	0.3409
	3	4446	2.625707	2.150802	0.2236
	4	4448	2.579225	2.071762	0.2147
	2	4646	2.555904	4.472763	0.5684
	5	4448	2.266134	2.030568	0.2658
	4	4254	2.18361	12.46683	0.8611
	6	4242	2.18361	11.75824	0.8529
	8	4050	2.18361	12.87327	0.8655
	8	4254	2.18361	5.676411	0.7009
	9	4050	2.18361	16.6006	0.8955
	9	4252	2.18361	4.837753	0.6522
	6	4446	2.050717	2.549333	0.4221
	5	4248	1.988738	2.183946	0.3636
	2	4644	1.970357	2.193176	0.3701
	6	4250	1.86782	4.413338	0.6726
	5	4246	1.863365	3.619301	0.6073
	9	4254	1.855847	3.787676	0.6247
	6	4246	1.843074	7.14484	0.7967
	8	4052	1.826013	8.193979	0.8239
	4	4248	1.408435	2.676202	0.5993
	4	4642	1.350205	6.401193	0.8332
	1	4048	1.336023	11.75383	0.9096
	3	4246	1.336023	9.360587	0.8867
	8	4248	1.336023	7.20122	0.853
	4	4644	1.328913	3.60866	0.7131
	8	4252	1.28315	4.193874	0.76
	3	4444	1.250512	2.9182	0.6687
	4	4246	1.03153	4.191992	0.8059
	1	4844	0.991732	20.32625	0.9611
	1	5042	0.991732	6.563621	0.8801
	1	5044	0.991732	4.822412	0.8373
	2	4840	0.991732	14.39344	0.9451
	2	4844	0.991732	5.366931	0.8536
	2	5042	0.991732	9.49212	0.9169
	2	5044	0.991732	3.440961	0.7735
	2	5046	0.991732	6.915489	0.8861
	2	5244	0.991732	13.33209	0.9408
	3	4442	0.991732	15.38173	0.9487
	3	4838	0.991732	12.47697	0.9367
	3	4840	0.991732	13.83207	0.9429
	3	5042	0.991732	8.497955	0.9072
	5	4060	0.991732	11.64148	0.9322
	5	4644	0.991732	13.83207	0.9429
	5	4646	0.991732	12.47697	0.9367
	6	3646	0.991732	14.39344	0.9451
	6	4646	0.991732	14.39344	0.9451
	7	3646	0.991732	10.20679	0.9227
	7	4050	0.991732	13.33209	0.9408
	8	3652	0.991732	15.02987	0.9475

Pelagic Logbook by week/square
information

year	week	square	turtles	hooks	swordfish kept	tuna	mako sharks
1992	1	4250	0	475	4	1	1
1992	1	4452	0	1275	25	1	0
1992	1	4646	0	900	17	2	1
1992	1	4840	0	600	12	0	2
1992	1	4842	0	19885	715	93	0
1992	1	4844	0	300	46	8	0
1992	1	5042	0	2950	181	34	0
1992	1	5044	0	5600	203	77	0
1992	2	4250	0	1713	28	3	1
1992	2	4444	0	1800	99	0	0
1992	2	4446	4	1857	94	2	2
1992	2	4448	0	650	45	0	0
1992	2	4644	0	2350	91	0	1
1992	2	4840	0	600	7	0	0
1992	2	4842	0	9965	265	14	1
1992	2	4844	0	4475	108	3	0
1992	2	5042	0	1390	28	4	0
1992	2	5044	0	11600	287	191	0
1992	2	5046	0	2650	51	50	0
1992	2	5244	0	700	1	0	0
1992	3	4442	0	525	15	0	0
1992	3	4444	0	6715	230	1	13
1992	3	4446	1	9173	209	3	12
1992	3	4452	1	800	10	0	1
1992	3	4640	0	600	33	0	0
1992	3	4642	0	1650	60	0	8
1992	3	4644	0	4750	145	1	9
1992	3	4646	0	1200	38	1	0
1992	3	4838	0	800	2	0	0
1992	3	4840	0	650	25	0	0
1992	3	4842	0	1200	38	0	0
1992	3	5042	0	1740	47	5	0
1992	4	4248	0	4475	65	9	1
1992	4	4250	0	700	8	3	0
1992	4	4444	2	5675	147	0	1
1992	4	4446	0	4357	86	10	3
1992	4	4452	0	800	5	4	0
1992	4	4644	0	1200	23	0	2
1992	4	4646	0	546	14	1	0
1992	4	4842	0	3300	60	5	2
1992	5	4060	0	920	5	8	1
1992	5	4248	1	5750	107	3	16
1992	5	4252	0	800	9	15	1
1992	5	4446	2	6602	134	0	2
1992	5	4642	0	600	5	0	1
1992	5	4644	0	650	7	1	0
1992	5	4646	0	800	2	0	0
1992	6	3646	0	600	0	0	1
1992	6	4246	0	700	22	0	1
1992	6	4248	0	1000	20	2	3
1992	6	4250	0	700	10	30	2
1992	6	4252	0	13269	92	215	10
1992	6	4446	7	5200	138	2	4
1992	6	4448	1	600	12	0	1
1992	6	4646	0	600	13	1	3
1992	7	3646	0	1200	0	0	0
1992	7	4050	0	700	2	17	0
1992	7	4250	0	2100	23	57	2
1992	7	4252	0	12180	86	288	5
1992	8	3652	0	550	8	0	0
1992	8	4252	0	1300	9	6	2
1992	9	3652	0	1400	22	2	1
1993	1	4248	0	700	27	0	0
1993	1	4446	3	10103	403	53	12
1993	1	4642	1	17363	400	82	1

9	3652	0.991732	9.458607	0.9166
6	4448	0.987413	3.116216	0.7517
7	4248	0.917757	7.241926	0.8993
1	4452	0.90495	4.700001	0.8475
5	4446	0.901864	1.828119	0.6223
6	4248	0.856986	3.165948	0.7869
1	4842	0.842021	1.934716	0.6639
1	4646	0.838079	5.002197	0.8671
7	4254	0.819685	5.739307	0.8866
7	4250	0.760192	3.622224	0.834
3	4640	0.55606	8.347488	0.947
6	4252	0.529315	2.116877	0.8028
5	4642	0.514853	7.533691	0.9456
3	4646	0.508295	3.212907	0.8745
1	4442	0.452922	11.18048	0.9677
5	4444	0.415727	10.63696	0.9689
2	4444	0.388213	3.151279	0.9021
1	4254	0.336023	13.22502	0.9798
1	4426	0.336023	15.74838	0.983
2	4450	0.336023	9.063057	0.9705
3	4254	0.336023	12.46267	0.9785
4	4440	0.336023	12.46267	0.9785
5	4048	0.336023	12.52512	0.9786
5	4442	0.336023	12.09258	0.9779
6	4048	0.336023	9.146854	0.9707
6	4050	0.336023	19.92372	0.9866
7	4048	0.336023	6.220446	0.957
7	4446	0.336023	12.46267	0.9785
7	4448	0.336023	3.131405	0.9147
8	4048	0.336023	12.22195	0.9781
8	4448	0.336023	7.980808	0.9665
9	3624	0.336023	13.3187	0.9799
4	4442	0.101257	8.871961	0.9909
7	4252	0.074759	1.77076	0.9664
4	4646	-0.003579	4.303882	0.9993
1	4840	-0.013541	4.846092	0.9978
3	4642	-0.079081	4.10617	0.9847
2	4642	-0.106997	3.078485	0.9723
2	4842	-0.132768	2.379078	0.9556
4	4842	-0.206355	4.132621	0.9602
3	4452	-0.256974	3.579916	0.9428
4	4252	-0.780433	3.126416	0.8031
3	4842	-0.895688	3.559009	0.8016
6	4444	-0.936157	3.601823	0.7952
1	4250	-0.989438	3.367858	0.7692
1	4252	-1.044962	3.66705	0.776
2	4242	-1.136635	12.47794	0.9275
4	4058	-1.136635	8.336204	0.8917
4	4256	-1.136635	12.47794	0.9275
4	4258	-1.136635	11.17144	0.9191
7	4452	-1.136635	8.901383	0.8985
7	4642	-1.136635	10.89459	0.917
7	4842	-1.136635	15.33897	0.941
8	4452	-1.136635	8.358926	0.892
9	4452	-1.136635	11.77002	0.9232
2	4252	-1.199624	4.442209	0.7874
2	4452	-1.259475	3.64673	0.7302
1	4640	-1.382719	8.853452	0.8761
2	4454	-1.382719	7.284791	0.8497
3	4252	-1.418203	5.120237	0.7821
2	4250	-1.457348	3.370972	0.666
5	4452	-1.579442	7.101895	0.8242
4	4250	-1.599746	4.050886	0.6933
6	4254	-1.621699	6.626616	0.8069
4	4452	-1.953195	4.533314	0.6671
6	4256	-2.009572	4.115112	0.6259
5	4254	-2.118888	5.714885	0.7112
6	5242	-2.382719	7.93314	0.7642
7	5242	-2.382719	7.93314	0.7642
3	4250	-2.697149	4.980931	0.5888
5	4454	-2.754489	10.17243	0.7868
4	4454	-2.896713	5.910216	0.6246

1993	1	4644	0	17240	701	143	9
1993	1	4646	0	900	40	0	0
1993	1	4842	0	1600	43	39	2
1993	2	4248	0	3500	73	2	2
1993	2	4250	0	800	16	2	0
1993	2	4444	0	900	10	0	0
1993	2	4446	0	14221	343	83	19
1993	2	4448	0	3332	98	31	5
1993	2	4642	0	1755	39	1	0
1993	2	4644	1	14715	387	23	11
1993	3	4248	0	3700	111	7	9
1993	3	4252	0	800	0	0	0
1993	3	4446	0	3900	98	9	4
1993	3	4448	0	4200	124	6	7
1993	3	4644	0	7813	179	75	0
1993	4	4248	0	1592	54	4	3
1993	4	4250	0	1650	15	13	0
1993	4	4252	0	1002	16	7	0
1993	4	4254	0	800	9	2	1
1993	4	4444	0	1700	70	11	1
1993	4	4446	0	4600	206	10	4
1993	4	4448	0	3900	101	8	2
1993	4	4642	0	1500	29	8	0
1993	4	4644	0	4725	106	41	5
1993	4	4646	0	1625	54	18	1
1993	5	4248	2	6280	220	22	13
1993	5	4250	5	3400	35	33	0
1993	5	4252	4	8876	175	42	6
1993	5	4446	0	10650	243	52	11
1993	5	4448	0	3800	140	34	5
1993	6	4242	0	900	8	0	0
1993	6	4246	0	1750	36	0	0
1993	6	4248	0	8400	256	7	2
1993	6	4250	0	4250	73	1	0
1993	6	4252	0	5689	90	12	0
1993	6	4446	0	900	32	0	0
1993	7	4248	0	750	7	0	3
1993	7	4250	0	1500	31	1	5
1993	7	4254	0	1000	8	10	1
1993	8	4050	0	750	14	1	0
1993	8	4052	0	1500	58	2	0
1993	8	4252	0	3950	86	43	3
1993	8	4254	0	3950	57	55	2
1993	9	4050	0	450	4	0	0
1993	9	4252	0	5500	43	77	1
1993	9	4254	0	8217	39	197	8
1994	1	4048	1	900	14	0	0
1994	1	4246	8	2816	35	0	5
1994	1	4248	2	2412	7	2	5
1994	1	4250	1	1716	10	1	1
1994	1	4254	0	710	5	1	1
1994	1	4426	0	500	0	122	0
1994	1	4444	0	1110	15	0	5
1994	1	4446	1	4983	128	0	7
1994	1	4448	0	1620	6	0	1
1994	1	4642	0	900	8	1	1
1994	1	4644	5	10655	173	11	3
1994	1	4646	0	900	23	0	0
1994	1	4842	3	6675	121	44	3
1994	2	4248	4	8268	91	16	23
1994	2	4252	0	700	12	8	1
1994	2	4444	2	1760	30	3	0
1994	2	4446	8	16700	401	83	26
1994	2	4448	0	2020	57	33	1
1994	2	4450	0	1520	37	0	0
1994	2	4452	0	720	5	0	0
1994	2	4642	1	3276	75	23	6
1994	2	4644	1	6776	153	41	1
1994	2	4646	1	2252	41	1	0
1994	2	4842	1	1437	31	11	0
1994	3	4246	1	1424	30	3	7
1994	3	4248	2	1697	40	8	3

3	4450	-3.022163	18.84143	0.8727
4	4450	-3.022163	12.91007	0.8152
4	4648	-3.022163	12.91007	0.8152
5	4256	-3.022163	10.24921	0.7684

1994	3	4254	0	800	6	4	5
1994	3	4444	1	5512	113	15	16
1994	3	4446	1	5990	214	27	4
1994	3	4448	10	18251	510	135	18
1994	3	4640	0	1188	28	16	3
1994	3	4642	0	3030	37	12	8
1994	3	4644	0	1692	16	1	0
1994	4	4246	0	3960	82	13	9
1994	4	4248	0	3400	36	6	20
1994	4	4252	0	2362	16	29	3
1994	4	4440	0	800	20	3	8
1994	4	4442	1	792	9	11	10
1994	4	4444	4	8784	216	25	32
1994	4	4446	5	11987	278	28	24
1994	4	4448	3	24781	535	84	39
1994	4	4642	2	750	15	4	3
1994	4	4644	0	2160	51	17	6
1994	5	4048	0	792	7	0	0
1994	5	4248	1	7089	69	18	10
1994	5	4250	1	3121	52	6	1
1994	5	4442	0	850	8	0	0
1994	5	4444	0	350	2	0	0
1994	5	4446	0	10750	228	36	2
1994	5	4448	6	9763	115	51	16
1994	5	4642	0	1600	16	0	0
1994	6	4048	0	1492	22	1	0
1994	6	4050	0	312	1	0	0
1994	6	4248	0	800	14	2	0
1994	6	4250	0	800	3	0	1
1994	6	4252	0	2700	15	4	1
1994	6	4254	0	800	7	4	2
1994	6	4256	0	1056	1	0	0
1994	6	4444	0	1400	19	1	0
1994	6	4446	0	900	6	0	0
1994	6	4448	1	8512	84	133	6
1994	7	4048	0	3264	28	27	6
1994	7	4248	0	1632	13	7	1
1994	7	4250	0	6180	48	50	6
1994	7	4252	2	8248	41	36	5
1994	7	4254	0	2820	25	9	0
1994	7	4446	0	800	8	10	0
1994	7	4448	0	13768	82	356	6
1994	8	4048	0	832	0	7	0
1994	8	4052	0	360	3	7	0
1994	8	4248	1	2422	32	21	4
1994	8	4252	0	1056	4	0	0
1994	8	4448	0	1966	8	13	1
1994	9	3624	0	700	.	6	0
1995	1	4250	0	3400	48	50	3
1995	1	4252	0	6600	74	183	8
1995	1	4444	0	700	15	0	0
1995	1	4446	6	12890	278	10	19
1995	1	4448	4	2460	46	0	4
1995	1	4452	0	1700	51	22	12
1995	1	4640	1	1600	37	7	1
1995	1	4642	4	2580	63	0	0
1995	1	4644	9	6490	175	6	2
1995	2	4248	11	5862	175	6	6
1995	2	4250	0	8014	73	114	8
1995	2	4252	1	5871	65	139	3
1995	2	4444	1	2588	80	4	0
1995	2	4446	2	5842	155	3	2
1995	2	4448	9	7848	157	3	5
1995	2	4452	1	9321	176	111	9
1995	2	4454	1	2380	31	51	7
1995	2	4644	0	900	27	0	0
1995	3	4248	24	5899	104	8	14
1995	3	4250	0	2610	15	12	0
1995	3	4252	0	3221	36	10	0
1995	3	4444	0	500	9	1	0
1995	3	4452	2	8710	158	20	4
1995	3	4644	9	12164	349	4	1

1995	3	4646	4	1350	47	3	0
1995	4	4252	0	1620	5	1	0
1995	4	4452	0	5485	32	16	3
1995	4	4454	0	720	9	2	0
1995	4	4646	3	700	42	2	0
1995	5	4252	0	3332	1	5	1
1995	5	4254	0	1050	1	0	0
1995	5	4448	0	3000	6	2	3
1995	5	4452	0	882	1	0	0
1995	5	4454	0	504	0	1	1
1995	6	4252	0	5610	7	92	5
1995	6	4254	0	2058	3	7	3
1995	6	4256	0	6638	5	75	3
1995	6	5242	0	2000	5	25	0
1995	7	4252	1	18456	35	263	7
1995	7	5242	0	2000	4	4	0
1996	1	4448	5	1670	42	0	4
1996	1	4642	0	8251	183	306	3
1996	1	4644	20	2552	38	14	2
1996	1	4840	1	4900	80	116	0
1996	1	4842	0	9050	203	218	0
1996	2	4242	0	800	20	30	0
1996	2	4250	0	960	4	0	0
1996	2	4444	1	4875	110	4	9
1996	2	4446	5	5835	64	1	7
1996	2	4642	0	7029	110	355	3
1996	2	4644	0	1458	18	11	0
1996	2	4646	0	900	6	0	0
1996	2	4842	0	13265	107	235	0
1996	3	4248	0	800	3	0	2
1996	3	4252	0	800	13	0	0
1996	3	4446	0	1910	15	0	1
1996	3	4452	0	800	11	0	0
1996	3	4642	0	2860	39	71	0
1996	3	4644	0	4950	61	19	0
1996	3	4646	0	4450	65	25	2
1996	3	4842	0	9400	157	184	0
1996	4	4058	0	1810	8	45	0
1996	4	4246	3	3311	34	1	15
1996	4	4252	0	8454	80	34	6
1996	4	4256	0	800	2	3	0
1996	4	4258	0	1000	0	0	0
1996	4	4442	0	790	6	2	1
1996	4	4444	34	9700	153	22	21
1996	4	4446	10	4490	96	3	6
1996	4	4448	0	792	3	1	0
1996	4	4642	0	800	4	2	0
1996	4	4646	0	4000	102	28	6
1996	4	4842	0	4250	32	103	0
1996	5	4246	3	10395	119	4	31
1996	5	4252	0	1352	12	1	6
1996	5	4446	0	11062	141	22	8
1996	5	4448	0	5980	98	21	7
1996	5	4452	0	1600	12	14	0
1996	6	4444	0	8884	110	106	6
1996	6	4446	1	12304	163	80	6
1996	6	4448	0	800	10	3	0
1996	7	4252	0	3160	14	9	0
1996	7	4452	0	1584	13	2	0
1996	7	4642	0	1052	1	1	0
1996	7	4842	0	528	1	0	0
1996	8	4252	0	900	11	25	0
1996	8	4452	0	1800	8	27	0
1996	9	4254	0	900	1	4	2
1996	9	4452	0	900	2	0	0
1997	1	4252	0	2024	6	1	0
1997	1	4446	0	4569	93	3	9
1997	1	4448	0	840	19	1	6
1997	1	4452	0	3276	22	27	7
1997	6	4250	0	700	3	0	1
1997	6	4252	0	700	0	2	0
1998	1	4246	0	800	30	1	0

1998	1	4248	0	800	27	9	1
1998	1	4252	0	1000	17	10	0
1998	1	4442	0	1000	25	0	0
1998	1	4444	12	5444	158	2	4
1998	1	4446	6	6473	234	15	8
1998	1	4448	5	1100	62	6	0
1998	1	4642	12	3200	139	110	1
1998	1	4644	1	6000	296	31	4
1998	1	4646	0	2330	99	8	2
1998	2	4248	0	525	11	0	0
1998	2	4444	1	950	45	12	0
1998	2	4446	2	6671	267	0	1
1998	2	4448	5	10511	347	2	1
1998	2	4644	0	1850	75	12	0
1998	2	4646	4	3200	157	14	6
1998	3	4444	2	2564	98	0	4
1998	3	4446	5	7941	299	2	5
1998	3	4448	0	1350	82	0	0
1998	3	4644	0	950	16	6	0
1998	3	4646	1	5550	170	4	2
1998	4	4248	0	600	29	0	0
1998	4	4444	8	4393	179	0	1
1998	4	4446	2	4190	120	0	2
1998	4	4448	1	1200	47	0	0
1998	4	4644	0	1700	68	5	0
1998	5	4252	0	600	15	5	1
1998	5	4444	0	750	17	0	0
1998	5	4446	1	2150	35	16	0
1998	5	4448	2	8515	295	25	5
1998	6	4252	0	1600	39	28	1
1998	6	4446	0	1600	48	3	0
1998	6	4448	0	3500	104	53	0
1998	7	4252	0	2400	54	36	2
1999	1	4248	61	7090	294	3	9
1999	1	4250	2	5940	126	2	10
1999	1	4448	40	2907	118	0	5
1999	1	4644	1	3000	197	33	5
1999	1	4842	0	1000	35	2	1
1999	2	4248	11	6998	257	0	5
1999	2	4446	2	1582	34	11	2
1999	2	4448	3	8031	238	1	6
1999	2	4642	2	1650	58	8	1
1999	3	4248	0	7894	268	14	5
1999	3	4250	0	2525	118	3	2
1999	3	4448	2	5631	193	10	2
1999	3	4450	0	350	16	0	0
1999	4	4248	5	8518	251	37	8
1999	4	4250	0	5664	125	62	3
1999	4	4448	0	2306	36	22	1
1999	4	4450	0	750	21	6	0
1999	4	4454	0	2950	59	32	1
1999	4	4648	0	750	20	0	0
1999	5	4248	4	9075	418	22	7
1999	5	4250	0	800	5	18	3
1999	5	4252	0	1000	18	0	0
1999	5	4254	1	2864	40	9	2
1999	5	4256	0	1198	16	5	0
1999	5	4448	0	1270	39	3	0
1999	5	4454	0	700	10	13	3
1999	6	4248	0	2800	100	8	1