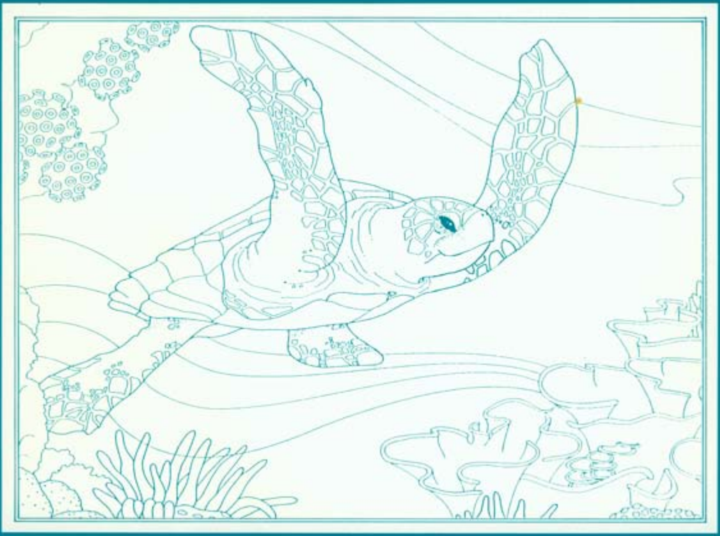
Sea Turtle & Shrimp Fishing Interactions:

A Summary and Critique of Relevant Information



Thomas M. Murphy
and
Sally R. Hopkins-Murphy

The Center for Marine Conservation is a nonprofit membership organization dedicated to protecting marine wildlife and their habitats, and to conserving coastal and ocean resources. The Center works with the conservation community, government, private industry, and private citizens to protect marine wildlife and to keep the marine environment healthy and safe for future generations. The Center is headquartered in Washington, D.C. Regional offices are located in St. Petersburg, Florida; Hampton, Virginia; Austin, Texas; and San Francisco, California.

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1989

Center for Marine Conservation
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FOREWORD

Nearly twenty years ago scientists identified the drowning of sea turtles in shrimp trawls as a major factor in the continuing decline of these threatened and endangered species. Since that time, the interaction of sea turtles and shrimp fishing has been a highly controversial issue. The industry has refused to use special gear in their nets to exclude trapped animals, claiming that shrimpers catch few sea turtles. A large body of evidence refutes these claims.

During the controversial years of 1986 and 1987, the Center for Marine Conservation recognized the need for a review of the research on sea turtle/shrimp fishing interactions. Under a contract to CMC, Tom Murphy and Sally Hopkins-Murphy summarized and critiqued the relevant studies. Their report draws upon years of research and clearly establishes the relationship between sea turtle mortality and shrimping operations. It is published here for the first time.

In the year and a half since this report was written, other relevant papers have been published. Of particular interest is "A Stage-Based Population Model for Loggerhead Sea Turtles and Implications for Conservation" (Crouse *et. al.*, 1987) which presents evidence that the focus of current management practices on eggs on nesting beaches is not as effective as protecting juvenile sea turtles. Larry Ogren and Terry Henwood of the National Marine Fisheries Service have also produced several excellent papers on the movements and distribution of sea turtles. The interested reader can request copies of these publications from CMC.

Clearly, the following report is an invaluable resource for everyone interested in promoting the conservation of sea turtles.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

ACKNOWLEDGEMENTS

The authors wish to thank J. Richardson, C. Pope and J. Coker for their technical assistance. We would also like to acknowledge B. Hart for preparation of the graphics, M. Latto and G. Klotz for typing of the manuscript, and Wordscape, Inc., for typesetting and production.

INTRODUCTION

The Endangered Species Act (ESA) lists five factors that may contribute to the decline and eventual extinction of a species. These are 1) alteration or destruction of habitat; 2) disease or predation; 3) overutilization for commercial, sport, scientific or educational purposes; 4) inadequacy of regulatory mechanisms; and 5) other natural or man-made factors.

One major man-made factor affecting sea turtles is the incidental capture and drowning in shrimp trawls. The negative interaction between the shrimping industry and sea turtle populations has been known for some time, but the magnitude of this problem has only recently come to light. The National Marine Fisheries Service estimates that the shrimping fleet throughout the Gulf of Mexico and the South Atlantic Region captures over 45,000 sea turtles annually, and of these over 11,000 die.

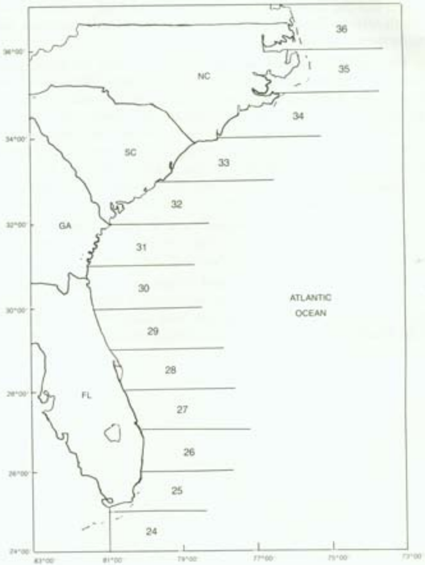
This report examines the interactions between sea turtle populations and the shrimping fleet, particularly from North Carolina to Florida, by analyzing major aspects of each that relate to this interaction. The major aspects examined are the density and distribution of: marine turtle nesting, marine turtle carcass strandings, incidental captures of marine turtles in shrimp trawls, shrimping effort, and aerial observations of turtles at sea. Each section on these major aspects looks at historic and current information, values and uses for the information and shortcomings and cautions regarding these data.

The data presented are summarized in either graphic or tabular form by shrimping statistical zones, which correspond to lines of latitude in the South Atlantic Region (Figure 1).

This report also summarizes and critiques the primary source documents upon which management and research decisions are made by the two federal agencies which have legal jurisdiction over sea turtles. And finally a bibliography of both cited literature and literature relevant to these issues is presented.

Figure 1. South Atlantic region with statistical zones

Zone 24	Andros Island, Bahamas to Key Largo, FL
Zone 25	Key Largo to Ft. Lauderdale, FL
Zone 26	Ft. Lauderdale to Hobe Sound, FL
Zone 27	Hobe Sound to Road 516 Indialantic Causeway, FL
Zone 28	Indialantic Beach to New Smyrna Beach, FL
Zone 29	New Smyrna to South Ponte Vedra Beach, FL
Zone 30	South Ponte Vedra Beach to St. Andrews Sound, GA
Zone 31	St. Andrews Sound to Tybee Island, GA
Zone 32	Tybee Island to Lighthouse Island, SC
Zone 33	Lighthouse Island to Kure Beach, NC
Zone 34	Kure Beach to Portsmouth Island, NC
Zone 35	Portsmouth Island to Kill Devils Hill, NC



NESTING DISTRIBUTION

Historic and Current Information

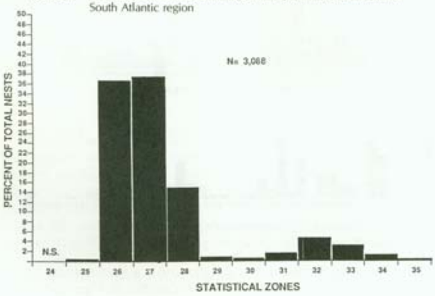
Nesting of sea turtles along the southeastern United States is comprised almost entirely of the loggerhead, *Caretta caretta*. This is one of the largest loggerhead rookeries in the world, second only to the one in Oman (Ross, 1981). Thus about 99% of the data presented here reflect the nesting of loggerheads. Green turtle nesting (about 300 nests/year) is restricted to south and central Florida with several nests occasionally laid in North Carolina or Georgia. Leatherback nesting occurs in early spring, usually in the southern part of Florida, and represents probably a dozen individuals (Hopkins and Richardson, eds., 1984).

No regional systematic surveys of nesting distribution for population estimates had been made before 1980. Most nesting data prior to this time was from individual tagging studies. During 1980, 1982 and 1983 aerial surveys were conducted on the Atlantic coast to obtain distribution of nests and population estimates (Powers, 1981; Thompson, 1983; Murphy and Hopkins, 1984), respectively. These are the most recent studies.

This is one of the largest loggerhead rookeries in the world, second only to the one in Oman (Ross, 1981).

For the purpose of this analysis, data on nesting distribution were taken from Murphy and Hopkins (1984) where aerial surveys were flown from Cape Hatteras, North Carolina to Key Biscayne, Florida during 1983. This study is believed to provide the best data, since these aerial surveys were conducted based on the most standardized technique for counting fresh nests and verification of aerial counts was made by precise ground truth (Pritchard *et. al.*, 1983). In Figure 2,

Figure 2. Percentage of the 1983 nesting effort by statistical zone for the South Atlantic region



these data were pooled into the statistical zones to give consistent comparison with the other data sets. In Figures 3, 4 and 5, the smaller aerial survey zones provide a more detailed picture of the nesting distribution within the three states in the region.

Figure 3. Number of fresh sea turtle nests observed during 6 flights in 1983 for 37 aerial survey zones in Florida and corresponding statistical zones

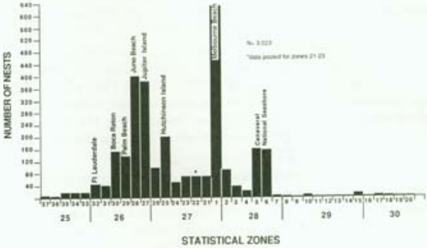
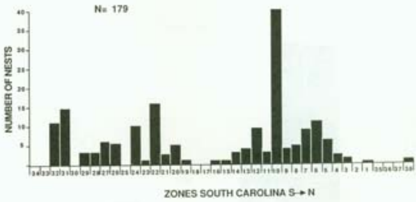


Figure 4. Number of fresh sea turtle nests observed during 4 flights in 1983 for 37 aerial survey zones in South Carolina

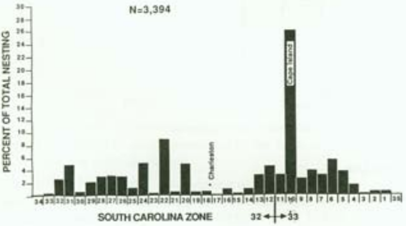


The precision of the flight data and the justification for using it here is shown by comparing flights from South Carolina in Figures 4 and 6.

When the nesting distribution from 4 flights in 1983 was compared to that obtained from 50 flights over 7 years, the distributional pattern was the same.

Figure 5. Number of fresh sea turtle nests observed during 4 flights in 1983 for 18 aerial survey zones in Georgia

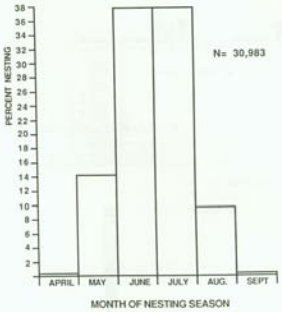
Figure 6. Percentage distribution of South Carolina nesting during 50 flights from 1980–1986, for 34 aerial survey zones



The aerial survey zones are important to include because they show that within each of the statistical zones, there are high- and low-density nesting areas and that these differences may be dramatic on adjacent areas. An example from Figure 3 would be Melbourne Beach (1) versus Pelican Island NWR (21). In South Carolina (Figure 4) Cape Island (10) and Murphy Island (9) are another example. Florida has greater than 90% of the nesting, South Carolina has 6% and Georgia and North Carolina comprise about 2% each. Over 86% of the nesting occurs between Boca Raton Inlet and New Smyrna Beach zones (1-6 and 21-30).

The seasonal distribution of nesting (Figure 7) was calculated from a seasonal nesting curve. This curve was created by accumulating *daily* nesting records from 9 different islands and/or beaches, and it represents a cumulative total of 40 years and 30,983 daily nesting records. The nesting season is essentially four months long with 75% of the nests being laid during June and July.

Figure 7. Percentage of the nestings by loggerheads occurring during each month of the nesting season



Values and Use

While one year of aerial survey is not adequate for making population estimates, it is of value to determine relative geographic distribution of nesting. Knowing the geographic distribution of nesting allows us to prioritize areas for protection and management of both the beaches and near shore waters. Seasonal distribution of nesting assists in determining the times when nesting adults are most vulnerable.

Shortcomings and Cautions

Percent distribution of nesting may change between years over time due to changes in nesting beach quality and quantity. Factors such as development, renourishment of beaches, erosion or construction of sea walls and local mortality of nesting adults could change nesting distributions.

Nesting distributions derived from aerial surveys must represent only fresh nests, *i.e.*, a single night of nesting. This is absolutely necessary because differences in the length of time a turtle track remains visible on the beach varies greatly between islands and with differing weather conditions.

Numbers of nestings and their spatial and seasonal distribution represent only a portion of the nesting population each year. They do not provide information on non-nesting adult females, adult males or juveniles, which represent the vast majority of sea turtles in the population.

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CRITIQUE OF RELEVANT PAPERS

Powers, J.E. 1981. An estimate of nesting female loggerhead turtles on the south Atlantic coast of the United States in 1980. NMFS, Miami, Florida, 17 pp.

Powers derived estimates of nesting females based on the best data available at the time these numbers were calculated. An estimate of 18,297 nesting females was obtained. Of importance is the 95% confidence limits, since they encompass estimates of from 5,265 to 31,329 females. This represents a six-fold difference. The summary states correctly that the available data are not sufficient to yield unbiased estimates or estimates of the possible bias. Powers presents the best use of the available data. He carefully states assumptions and gives realistic confidence limits. These confidence intervals speak for themselves, in that the estimate is so imprecise as to be useless in monitoring the population for annual change.

Thompson, N.B. 1983. Abundance of female *Caretta caretta* (loggerhead turtles) nesting along the southeast U.S. coast 1982 nesting season. NMFS, Miami, Florida, 24 pp.

Summary: A second annual estimate was made based on three aerial survey flights of the southeast U.S. An estimate of 28,884 nesting females was obtained. This is 10,587 more nesting females than reported for the previous year (a 58% increase). These differences were not statistically different at $P = .05$. The lack of a significant difference is a result of the high variance terms associated with the means.

Estimates were based on three flights, flown at monthly intervals. These aerial counts were adjusted based on ground surveys.

Cautions: 1) The careful cautions about unmeasurable errors and high variance terms presented in Powers (1981) are omitted from this paper. 2) The adjustment of aerial counts to fresh nests for Georgia, South and North Carolina are apparently based on a total of 28 tracks monitored by ground surveys. Of these 28 tracks, only 12 were fresh nests. Thus the three-state estimate of 5,851 for the season was derived from observing 483 tracks from the air, of which only 146 were fresh nests. 3) The 95% confidence limits were reported as 15,740 to 42,028. This variance is so large as to be almost useless as a monitoring tool. It should also be recognized that additional variance was undocumented and certain assumptions were (of necessity) violated.

Murphy, T.M. and S.R. Hopkins. 1984. Aerial and ground surveys of marine turtle nesting beaches in the southeast region, U.S. Report to NMFS, Contract No. NA83-GA-C-00021, 73 pp.

Summary: Flights based on tidal cycles resulted in only 2.4% of the tracks being incorrectly aged, according to ground truth samples. Ground truth on 10 areas in the region provided a 16.6% sample of the 18 flight days. The net bias for nests between aerial and ground counts was only -4.2%. The 6 flights in Florida, 4 in Georgia and South Carolina and 2 in North Carolina represented a 5.65% sample of the total nesting effort of loggerheads in the region during 1983, based on an estimate derived from a composite nesting frequency distribution. An estimate of 14,150 nesting for the season (based on 4.1 nests/female/season) was obtained. The estimate for total nesting females was 35,375 based on a 2.5 year remigration interval.

Thompson, N.B., T. Henwood and W.E. Stuntz. 1986. A summary of information on three species of marine turtles in U.S. waters. NMFS Report, Miami, Florida, 43 pp.

Part I. Nesting estimates only.

Summary: This report summarizes the available data on loggerheads including estimates of nesting females, estimates of all loggerheads greater than 60 cm, and incidental catch mortality. This report also examines sources of mortality and the distribution of strandings. The authors correctly conclude that an evaluation of the status of stocks of loggerheads cannot be quantitatively assessed due to a lack of a long time series for any population statistic.

Cautions: 1) The variance (95% CI) reported after the mean number of females (20,640) does not reflect the true variances of the three estimates individually. The estimate of Powers for 1980 was 18,297 females. The high variance produced a 95% CI that extended from 5,265 to 31,329 nesting females. Thus the estimate was little more than an educated guess due to a lack of technical refinement at the time of data collection. 2) The 1981 estimate of nesting females given by Thompson was 28,884. But the 95% CI were also wide and ranged from 15,740 to 42,028. This means that the population would have to nearly double or decline by 50% before the change would be significant at 95% confidence. This is true of the estimates for 1980 and 1981. These confidence intervals should be considered conservative, and the actual CI are undoubtedly wider than reported. The estimate given by Murphy and Hopkins (1984) was between 44,499 and 66,254 nests ($\overline{X}$ = 58,016). If divided by 2.0 nests/female/season (the number used by Powers and Thompson) to estimate nesting female loggerheads, the minimum range would be 22,250 to 33,127. 3) Two nests/female/season is a minimum figure.

Value and Use

The estimate of the number of nests laid during the 1983 season should be considered the most reliable because it was derived from the most flights, with the largest sample size, the most extensive ground truth, and the closest agreement between aerial and ground counts.

Conclusions and More Cautions

The authors' conclusion that these three surveys suggest that the nesting population of loggerheads has been stable since 1980 may be suggested by the similarity of the means. However, the variance terms associated with these means indicate that these similarities are probably fortuitous and that the accuracy of these estimates precludes reasonable assessment of the nesting population.

Standardized nest beach surveys are needed over a consecutive three-year period to properly assess the current population. The 95% CI reported is apparently ± 2 standard errors of the mean estimates for 1980, 1981 and 1983. **This is an expression of "between-year" variability and has little to do with the accuracy of the estimates.** It should be remembered that the turtles nesting during 1980 and 1981 were almost an entirely different group of turtles since consecutive year nesting by a female loggerhead is less than 2%.

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THOMPSON, N.B. 1983. Abundance of female *Caretta caretta* (Loggerhead turtles) nesting along the Southeast U.S. Coast 1982 nesting season. Report to NOAA/NMFS Southeast Fisheries Center, Miami, FL. 24 pp.

STRANDINGS

Historic and Current Information

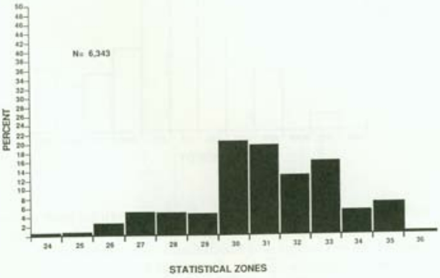
The problem of stranded sea turtles appearing on south Atlantic beaches in relation to the activities of the shrimp fleet was first documented on South Carolina and Georgia beaches in the early 1970s (Richardson and Hillestad, 1978; Ulrich, 1978; Talbert *et. al.*, 1980; Ruckdeschel and Zug, 1982). On Kiawah Island, South Carolina from 1972-1976, an average of 34.0 ± 3.7 N=170 dead sea turtles washed ashore on the 16km beach each year. "No dead turtles washed ashore more than 2 days before or five days after the opening and closing dates of the inshore shrimping season in any year during the study" (Talbert *et. al.*, 1980). Data from Cumberland Island, Georgia showed a dramatic increase in the number of carcasses from 21 in 1974 to 187 in 1979 (Ruckdeschel and Zug, 1982).

"No dead turtles washed ashore more than 2 days before or five days after the opening and closing dates of the inshore shrimping season in any year during the study"

A statewide stranded carcass network was started in 1979 in Georgia (Richardson, 1981), and under coordination by the NMFS, other states began networks in 1980. Thus, beginning in 1980, there was a regional, systematic data collection format, although the efficiency of each state network varied.

Data for Figure 8 were taken from the Sea Turtle Stranding and Salvage Network (STSSN) as presented by Schroeder (1986). This includes 6,343 reports from 1980 through October 1986. Only Zones

Figure 8. Percentage of strandings by statistical zone in the South Atlantic region



30-33 each constitute more than 10% of the strandings. Figure 9A shows the frequency of strandings by month for the entire region. The months of May, June, July and August each exceed 10% of the strandings. July alone accounts for nearly a third of the total annual strandings.

Figure 9A. Number of turtle strandings by month for the South Atlantic coast

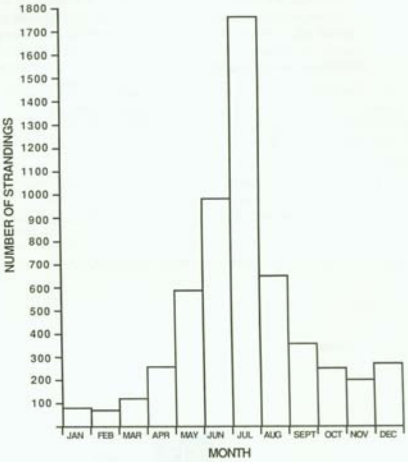


Table 1 shows the numbers of strandings by month for each of the four states in the South Atlantic Region. Strandings in Florida occur all year. Those in Georgia and South Carolina are seasonal with the highest number recorded in July. Strandings in North Carolina also occur all months of the year, but those occurring during the winter probably result from the fishing for flounder since shrimping does not take place during this time (R. Carpender, pers. comm.).

Table 1. Monthly Sea Turtle Strandings in North Carolina, South Carolina, Georgia, and Florida 1980–1985*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	%
NC	26	25	16	21	101	166	133	84	33	102	100	183	990	17.65
SC	0	1	5	133	130	233	689	157	52	10	0	0	1,410	25.14
GA	5	1	1	14	239	318	663	282	179	57	54	14	1,827	32.57
FL	54	43	90	87	124	265	278	120	99	94	51	77	1,382	14.64
Total #	85	70	112	255	594	982	1,763	643	363	263	205	274	5,609	
Total %	1.52	1.25	2.00	4.55	10.59	17.51	31.43	11.46	6.47	4.69	3.66	4.89	100	100

*Source: NMFS data from Bob Mahood Council Graphs

Table 2 compares quarters of the year divided by calendar months versus groupings by turtle activity patterns which relate to nesting and water temperatures. When examined this way the percentage of summer strandings is even more pronounced.

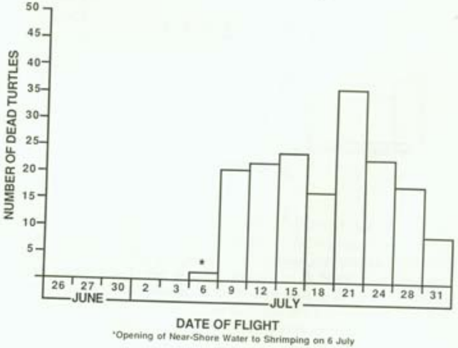
Table 2. Percentage of Strandings for Four Calendar Quarters (Henwood and Stuntz) Compared to Four Seasonal Sea Turtle Patterns

	Calendar Quarters %		Seasonal Turtle Patterns %
Jan.–Mar.	4.77	Dec.–Feb.	7.66
Apr.–June	32.65	Mar.–May	17.14
July–Sept.	49.36	June–Aug.	60.40
Oct.–Dec.	13.24	Sept.–Nov.	14.82

Figure 9B, redrawn from Richardson and Hillestad (1978), clearly illustrates the temporal relationship of carcass arrivals and the opening of the shrimping season.

Data from South Carolina for the years 1980-1986 were also used to determine stranding levels prior to the onset of shrimping activity of the season (Hopkins-Murphy, unpub.). To do this, numbers of carcasses

Figure 9B. Temporal distribution of strandings in Georgia, 1977



recorded during the 2-week period before the opening date were compared with the number of carcasses recorded during the 2-week interval after the opening day of the season. During 1980-86, the opening date of the shrimping season ranged from 15 May to 26 June. There were a total of 38 carcasses stranded during the 2-week interval before the season opened compared to 190 during the 2-week interval after the season opened. This is a fivefold difference. The difference was even more dramatic during 1984-86 because the early season carcasses from the sturgeon set net fishery were reduced, no longer contributing to the totals. The totals for the 2-week intervals during 1984-86 are 11 carcasses prior to the opening of the season and 101 after. This is a ninefold difference.

The number of stranded sea turtles represents a minimum measure of mortality.

The number of stranded sea turtles represents a minimum measure of mortality. Beginning in 1980, when carcasses were measured, they were either spray painted or buried to prevent duplicate counts. In addition to the recorded strandings, a significant number of stranded carcasses are not reported. This is related to the efficiency of beach coverage by the stranding network. Perhaps the most important relationship we need to know is the relationship between reported strandings and actual at-sea mortality. Little is known about this relationship. Ulrich (1978) reported that of 13 dead turtles tagged by observers on board commercial shrimp trawlers and set adrift, only 4 were reported as strandings on the beach. During 1980, nine loggerhead carcasses were radio equipped in an attempt to document stranding rates (Murphy, et al., unpub.). Of these, one carcass stranded after 3 days and one after 8 days. The remaining 7 turtles failed to strand. In an effort to determine the fate of carcasses at sea, four carcasses were anchored at sea. By the end of 5 days, only the marginal scutes where the attachment was made remained from two, and the other two carcasses were entirely gone. Scavenging by sharks was suspected, but not confirmed, although this has been observed at sea (Richardson, pers. comm.).

Thus of the 22 tagged free-floating loggerhead carcasses, only six were reported as strandings, suggesting that a significant percentage of the near-shore sea turtle mortality fails to be documented.

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Value and Use

A region-wide stranding network serves to document the geographic and seasonal distribution of sea turtle mortality. An example of how this can document a source of mortality is shown by the South Carolina data. Observations of turtle carcasses stranding early in the spring in an area around Winyah Bay was noted for a number of years (Wilkinson, pers. comm.). The season and area correlated to the set net fishery for sturgeon. Dead sea turtles were observed tangled in these nets, especially after a period of bad weather that prevented fishermen from checking their nets (Smith and Marchette, 1980). When the sturgeon season was shortened, strandings were reduced. When the sturgeon season was closed in 1986 to protect the reduced stocks of sturgeon, sea turtle strandings were essentially eliminated. When South Carolina sturgeon fishermen moved their activity to North Carolina, sea turtle strandings appeared in areas and at times where they had not previously been recorded. This shows the utility of using strandings to identify sources of mortality from natural and man-induced causes.

Strandings can also be used to obtain an annual index to mortality. This can test the relationship between factors suspected of contributing to mortality levels such as sea temperatures and fishing efforts.

Strandings are also an indication of the size distribution of turtles being killed. This can be used to correlate to the source of mortality, *i.e.*, size distribution shown in incidental catch versus size distribution from strandings. Another value is that the size distribution may be used to estimate the impact of mortality on the population. The reliability of these estimates will increase as our knowledge of sea turtle population ecology increases.

Shortcomings and Cautions

1. Network efficiency—The best coverage in the southeastern U.S. is probably found in Georgia due to the large number of turtle projects on the barrier islands there. South Carolina probably has majority coverage of the beaches, but remote islands receive only sporadic coverage. North Carolina has experienced several changes in the state stranding network coordinator, and lapses in coverage may have occurred. Florida has very high beach use and would be expected to have a high rate of reporting. However, in many cases beach cleaning crews remove and bury carcasses early in the morning and these carcasses go unreported. This is supported by the high frequency of strandings reported on weekends when crews are not working (Ehrhart, pers. comm.). Since a portion of stranded sea turtles go unreported in all states, stranding data from islands or beaches with consistent year-to-year coverage provide the best information to examine annual trends and perhaps network efficiency.
2. Distance from shore—It seems logical that the greater the distance from shore the mortality occurs, the less likely the carcasses are to strand. And if sharks are feeding on them, then the smaller size classes would strand less frequently. This may particularly affect the stranding rates for juvenile Kemp's ridleys and greens.
3. Identification—Strandings of Kemp's ridleys and green turtles may also be underrepresented on the Atlantic coast in that the

It seems logical that the greater the distance from shore the mortality occurs, the less likely the carcasses are to strand. And if sharks are feeding on them, then the smaller size classes would strand less frequently. This may particularly affect the stranding rates for juvenile Kemp's ridleys and greens.

majority of the strandings are loggerheads and the stranding network volunteer may fail to recognize species other than *Caretta*.

In conclusion, caution should be exercised in using stranding data *alone* to estimate the effects of incidental catch mortality on the population until the relationship between at-sea mortality, strandings and reported strandings can be made. It is clear, however, that strandings represent an absolute minimum mortality.

CRITIQUE OF RELEVANT PAPERS

The most relevant data concerning strandings are the annual reports from the Sea Turtle Stranding and Salvage Network. This represents the best information of the region-wide mortality, although the previous cautions should be noted. An attempt should be made to discern the causes of mortality for the carcasses recorded thus far by working with the individual stranding network coordinators, who are the most knowledgeable concerning mortality in their areas.

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Historic and Current Information

Capture of sea turtles incidental to other fishing operations has been known to exist basically since the introduction of fisheries statistics. Fixed and towed net fishermen used incidentally captured sea turtles as bycatch income or for personal consumption until legal protection was provided to all species of sea turtles.

Within the last decade, concern over the extent and impact of incidental catch mortality led to the quantification of capture levels. Bullis and Drummond (1978) quantified capture levels on exploratory fishing vessels. Ulrich (1978) and Hillestad et al. (1977) documented rates of captures and mortality aboard commercial shrimp trawlers using on-board observers. Hillestad et al. (1981) reported on the world-wide incidental capture of sea turtles and Crouse (1982) reported on incidental capture related to a variety of U.S. commercial fisheries. Henwood and Stuntz (1986) extrapolated all available data on sea turtle capture and mortality rates in shrimp trawls. They estimate the level of sea turtle mortality at as many as 11,000 turtles per year for the Gulf of Mexico and the south Atlantic.

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The distribution of sea turtle captures by statistical zone are presented in Figure 10 and Table 3. This is based on data presented in Henwood and Stuntz (1986). In addition to the percent captures by zone, the percent fishing effort by area is also depicted. Statistical zone 31, which is most of the coast of Georgia, recorded nearly half of the captures with about 60% of the effort. Zone 28, which contains

Figure 10. Percentage of incidental captures and fishing effort by statistical zones in the South Atlantic Region

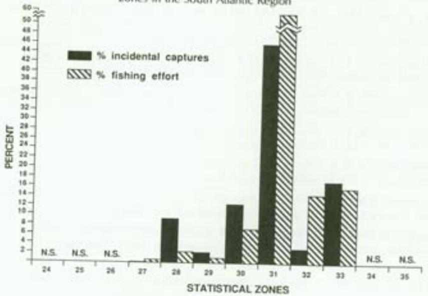

Table 3. Sea Turtle Capture and Mortality Rates for Statistical Zones 24–33.

Statistical Zone	Cap/ Mort Cc*	Cap/ Mort *Lk**	Cap/ Mort *Cm**	Cap/ Mort *Dc**	Cap/ Mort *Ei**	Std Net Hours	Totals Cap/ Mort	% Mort	Average Trawl Depth (m)	Average Tow Time (min)
24	0/0	0/0	0/0	0/0	0/0	0	NS	NS	NS	NS
25	0/0	0/0	0/0	0/0	0/0	0	NS	NS	NS	NS
26	0/0	0/0	0/0	0/0	0/0	0	NS	NS	NS	NS
27	0/0	0/0	0/0	0/0	0/0	29	0/0	0	31.9	160.0
28	44/1	2/0	3/0	0/0	0/0	218	49/1	2.04	17.8	143.4
29	10/4	0/0	0/0	0/0	0/0	86	10/4	40.0	14.0	136.6
30	61/21	0/0	0/0	3/1	0/0	691	64/22	34.38	8.0	146.0
31	225/73	13/3	3/2	0/0	0/0	5881	241/78	32.37	5.0	144.6
32	63/21	5/2	0/0	0/0	1/0	1451	69/23	33.33	5.7	143.9
33	87/18	0/0	3/0	0/0	0/0	1587	90/18	20.00	5.9	147.4
	490/138	20/5	9/2	3/1	1/0	9943	523/146	27.92	5.56	144.84
% Mort Total	94.5	3.4	1.4	0.7						

*Caretta caretta/loggerhead (Cc); *Lepidochelys kempi*/Kemp's ridley (Lk); *Chelonia mydas*/green (Cm); *Dermochelys coriacea*/leatherback (Dc); *Eretmochelys imbricata*/hawksbill (Ei)

Table 5. Seasonal rates of mortality of sea turtles incidentally captured by shrimp trawlers. (Henwood & Stuntz, 1986 draft)

	SEASON					
	Jan-Mar. Cap/Mort.	Apr.-June Cap/Mort.	July-Sept. Cap/Mort.	Oct.-Dec. Cap/Mort.	Totals Cap/Mort.	%
Gulf	11/1	9/4	13/2	19/8	52/15	28.9
Atlantic	25/0	101/30	325/108	72/8	523/146	27.9
Totals	36/1	110/34	338/110	91/16	575/160	27.8

(50°F) water temperatures are clearly not tolerated, in general sea turtles tend to avoid any temperature less than 20°C (68°F). Secondly, there appears to be a seasonal shift in the rate of mortality of incidentally captured turtles. It is reasonable to expect shorter drowning times at higher water temperatures when dealing with a poikilothermous animal. The relationship between seasonal captures and seasonal mortality are summarized in Table 5.

Value and Use

Catch-per-unit effort (CPUE) and rates of mortality of incidentally captured sea turtles provide a reasonable estimate of capture and fatalities when coupled with shrimping effort statistics. Incidental catch statistics certainly provide documentation of captures and mortality, and while the precision of extrapolations may be debated, the relative magnitude of the projections cannot be reasonably questioned. Catch-per-unit effort is probably directly related to turtle abundance, turtle activity (surface or bottom, diurnal or nocturnal), and net size. Mortality is a function of tow times, resuscitation technique, water temperature, and possibly multiple captures and the species being caught.

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Shortcomings and Cautions

CPUE varies with turtle density and therefore varies with area, water depth, season and gear type. These variables, combined with imprecise shrimping statistics, limit any extrapolations to estimates of relative magnitude. This is further complicated by the low-density species such as Kemp's ridley and green turtles. We have little or no ability to estimate annual mortality of these species on the Atlantic coast because of small sample sizes and high variance.

It should be remembered that mortality data from on-board observers represents the *best* case example given that all efforts are made to resuscitate comatose turtles and release them safely. This may bring about an underestimate of the degree of mortality. On the other hand, mortality may be overestimated by multiple captures of already dead turtles. Dead turtles are discarded and are certainly more prone to recapture than live turtles, at least until they decompose enough to float.

CRITIQUE OF RELEVANT PAPERS

H.O. Hillestad, J.I. Richardson, and G.K. Williamson. 1977. Incidental capture of sea turtles by shrimp trawlermen in Georgia. Report to NMFS, Contract No. 03-7-042-35129. 106 pp.

Summary: This report combines data on strandings and incidental captures obtained by interviews, on-board observers, aerial surveys, and ground surveys. Based on interviews of trawlermen, an estimate of 9,855 captures and 778 mortalities of turtles was obtained for Georgia during 1976. The shrimping effort of the 321 resident boats in Georgia was converted to total area trawled over by shrimp nets. It was estimated that 75,061 km^2 were covered per season. Given that the Georgia near-shore waters comprise less than 800 km^2, trawler nets could cover the entire area nearly 100 times. These figures clearly show the extensive physical coverage of a shrimping fleet. The drag path of a single vessel would be 23,383 hectares per day. This report represents the best and most extensive data on turtle/shrimper interactions available through interview.

Season of turtle strandings is closely correlated with shrimp seasons.

Conclusions

1. Although the rate of capture of sea turtles is low, the level of trawling activity produces a significant level of captures and mortality of sea turtles.
2. The frequency with which turtles are captured is directly related to the width of the net mouth.
3. Season of turtle strandings is closely correlated with shrimp seasons.
4. The vast majority of turtles captured are juveniles, and few tagged adult females have been recovered.

Cautions

1. Mortality rates reported through interviews estimate 7.9% of turtles captured died. On-board observers recorded 4 deaths of 18 captures (22%).

Ulrich. G.F. 1978. Incidental Catch of Loggerhead Turtles by South Carolina Commercial Fisheries. Report to NMFS, Contract No. 03-7-042-35151 and 03-7-042-35121. 48 pp.

Summary: A total of 1,343.1 hours of trawling by commercial fishermen resulted in 52 captures of marine turtles (CPUE = 0.03871). Ulrich estimated that 860 and 1,396 turtle mortalities would have occurred in South Carolina during 1976 and 1977, respectively. Selective fishing gear is recommended over restrictive fishing zones or seasons. Ulrich further states that the creation of closed trawling zones opposite major turtle nesting beaches would not afford significant protection to turtles. This is an excellent early study of the relationship between shrimping activity and turtles.

Mortality rates reported through interviews estimate 7.9% of turtles captured died. On-board observers recorded 4 deaths of 18 captures (22%).

Other Conclusions

1. The practice of allowing a recovery period for turtles on deck was judged to be important and had merit.
2. Seventeen of 52 turtles captured were dead, for a 32.69% mortality.
3. Only 4 of 13 tagged, dead turtles were recovered on the beach as strandings.
4. Presents data on recapture of turtles which were already dead.

Cautions

1. Estimates of turtle mortality are extrapolated from 1,342 hours of trawlings to 201,075 hours of estimated total hours of shrimp trawling in South Carolina (0.67% sample).
2. Report may represent an underestimate of capture and mortality rates because of a late season sampling bias. A third of the trawling effort was after the end of August because of late funding.

Bullis, H.R. and S.B. Drummond. 1978. Sea Turtle Captures off the Southeastern U.S. by Exploratory Fishing Vessels, 1950-1976.

Summary: A total of 53 turtle captures occurred during 7,625 hours of trawling. Turtle capture rates in large (18m) bottom-fish trawls were two times greater than in smaller shrimp trawls. Captures were positively correlated to the daylight hours and during the fall and winter seasons. The CPUE for bottom-fish trawls was 0.0098 captures per hour and for shrimp trawls was 0.0041 captures per hour.

The Atlantic sea turtle catch-per-unit effort is 8.5 times greater than the Gulf, but the Gulf shrimping effort is 5 times greater. An estimate of 12,615 mortalities of sea turtles is made, with 5,520 of these in the Atlantic.

The authors estimate that as many as 10,000 loggerheads, 800 ridleys, and 300 greens may be drowned annually as a result of trawling activities.

Hillestad, H.O., J.I. Richardson, C. McVen, J.M. Watson. 1981. Worldwide Incidental Capture of Sea Turtles. In: Biology and Conservation of Sea Turtles. K.A. Bjorndal, ed.

Summary: This paper presents a concise and complete summary of available information on incidental capture. It documents, through literature cited, the capture of all species of sea turtles in shrimp trawls.

D.T. Crouse. 1982. Incidental Capture of Sea Turtles by U.S. Commercial Fisheries. Report to the Center for Environmental Education.

Summary: Documents the incidental capture and/or mortality of marine turtles in gill nets, pound nets, crab pots, lobster pots, bottom-fish trawls, longlines, hook and line, purse seines, scallop. oyster and clam dredges, as well as maintenance dredges.

Wood, J.M.T. 1983. Environmental Assessment of a program to reduce the incidental take of sea turtles by the commercial shrimp fishery in the southeast U.S.

Summary: This report summarizes the information relating to incidental capture of marine turtles by shrimp trawls in order to evaluate the environmental impact of the TED implementation program. Reports the Atlantic shrimp fleet average 2.5 hours per tow compared to 4 hours for the Gulf. The Atlantic sea turtle catch-per-unit effort is 8.5 times greater than the Gulf, but the Gulf shrimping effort is 5 times greater. An estimate of 12,615 mortalities of sea turtles is made, with 5,520 of these in the Atlantic.

Of particular significance is his Table 1. This not only shows the relationship between tow time and mortality, but also tabulates the high percentage of comatose turtles. Many comatose turtles would die if not resuscitated; therefore, caution should be used when applying mortality rates from vessels with on-board observers.

A concluding statement states that majority use of TEDs by shrimpers should take from two to five years from 1983.

Henwood, T.A. and W.E. Stuntz. 1986. Analysis of Sea Turtle Capture and Mortalities Aboard Commercial Shrimp Trawling Vessels (Draft) Southeast Fisheries Center, Mississippi Laboratories, Pascagoula Facility.

Summary: This is a landmark report which used all the currently available data to calculate annual rates of capture and mortality of marine turtles by the shrimp fleet. While the specifics of the statistics could be debated, the magnitude of the estimates are indisputable. Based on 26,728 standard hours of trawling, 575 turtle captures, and 161 turtle deaths, the total annual mortality of marine turtles resulting from shrimp trawling was estimated at 11,000. Capture rates in the south Atlantic were 17 times greater than in the Gulf; thus 7.36% of the shrimping effort resulted in 53.89% of the estimated turtle mortality.

Major Conclusion: The authors estimate that as many as 10,000 loggerheads, 800 ridleys, and 300 greens may be drowned annually as a result of trawling activities.

Other Conclusions

Levels of accidental mortality are unacceptably high and represent a major barrier to the recovery of the species.

1. Levels of accidental mortality are unacceptably high and represent a major barrier to the recovery of the species.
2. CPUE

   Atlantic = 0.0526 ± 0.0043

   Gulf of Mexico = 0.0031 ± 0.0008 turtles per 30.5 m net hour
3. Mortality rates:

   Gulf: 29%

   Atlantic: 21%

   These are calculated values, not actual.

Sources of Data

a. On-board observers 1979-1981, 10,905 hours and 318 captures (CPUE = 0.02916).

b. Excluder Testing 1977-1984 with on-board observers using only the control net. 14,056 hours with 563 captures (CPUE = 0.04005).

c. By-catch study 2,617 hours with 3 captures in the Gulf 1973-1978 (CPUE = 0.0012).

Totals:

884 captures during 27,578 hours

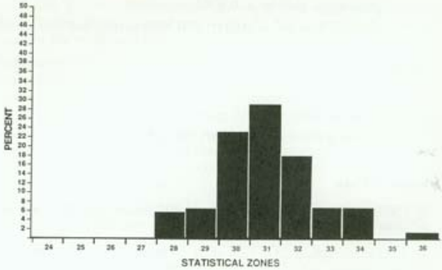
CPUE = 0.03206

161 dead turtles, thus a 28.0% actual overall mortality based on 575 captures

Cautions

1. Mortality rates were calculated from tow time regressions and extrapolated by effort based on available shrimping statistics. The most recent shrimping statistics were not available.
2. The assumption is made that data from boats with on-board observers reflect those of the fleet as a whole. It is more likely that the mortality percentage is conservative in that the observers made maximum efforts to revive turtles. This is not likely to be true of the fleet as a whole.
3. There are inconsistencies between their Figures 3-12 and their Tables 4-8. The numbers on the maps are different than those recorded in the Tables by species.

Figure 12. Percentage of the 1985 fishing effort for each statistical zone in the South Atlantic region



4. Data from their Figure 13 are pooled into ten 30-minute intervals, probably because the data were taken as such. However, this would tend to give an inflated value. The sample size for each time increment is needed to evaluate the effects of unequal sample size.
5. The effect of recapturing already dead turtles is not addressed in mortality rates.
6. The effects of water temperature on mortality rates could not be addressed.

7. The seasonal effect on mortality rate is minimized by the use of calendar quarters. Months grouped according to mean temperatures would probably further accent seasonal effects.
8. Current, updated data on shrimping effort were not available at the time this draft was written. Considerable differences in the estimates of captures and mortalities could result from calculations using different fishing statistics. There is nothing wrong with this, but it may become confusing if multiple sets of numbers are available.
9. Why the authors used the regression equation of mortality versus tow time to estimate mortality instead of observed rates of mortality is unclear.
10. Estimates of mortality for any species other than the loggerhead are very weak due to the limited sample sizes. This problem is not likely to be resolved due to the low densities of these species.

Ogren, L.H., J.W. Watson and D.A. Wickham. 1977. Loggerhead Sea Turtles, *Caretta caretta*, encountering shrimp trawls. Marine Fisheries Review, Vol. 39, No. 11, Nov. 1977. pp. 15-17.

Summary: The authors describe the swimming behavior of 3 loggerheads when approached by a shrimp trawl. Two of the three turtles observed were captured. The turtles swam 1 meter off the bottom just ahead of the net until tiring. They then became entangled in the net. The doors of the net had a lateral corraling effect and no vertical escape was attempted.

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SHRIMPING EFFORT

This section on shrimping effort, including the tables, is taken almost entirely from "Profile of the Penaeid Shrimp Fishery in the South Atlantic," 1982, M.D. McKenzie (ed.).

Shrimp represent an annual crop, and their abundance is subject to considerable variations from year to year, depending largely upon changes in environmental conditions such as salinity, water temperature, rainfall, river discharge and ocean currents.

Natural History of Shrimp in the South Atlantic Region

Shrimp represent an annual crop, and their abundance is subject to considerable variations from year to year, depending largely upon changes in environmental conditions such as salinity, water temperature, rainfall, river discharge and ocean currents. These conditions have a direct effect on shrimp populations by influencing spawning periods, growth rate, movement and migration. All of these factors, in turn, influence season opening dates and the areas in which fishing will be permitted.

Three shallow-water species of Penaeid shrimp support almost entirely the commercial shrimp fishery of the South Atlantic. These include the brown shrimp, *Penaeus aztecus aztecus*, the white shrimp, *Penaeus setiferus*, and the pink shrimp, *Penaeus duorarum duorarum*. Brown and white shrimp are by far the most important, while pink shrimp represent only a small percentage of the total shrimp catch annually.

All three shrimp species have very similar life cycles. Each species passes through essentially the same developmental stages, but the times of year during which a particular stage occurs (as well as spawning locations) differ considerably. Brown shrimp spawn primarily during the winter (probably from November through February), with their young first reaching marketable size in early summer. In contrast, white shrimp spawn during the spring and summer from April through July, with their young reaching marketable size in late August and September. Pink shrimp, though not commercially abundant except in North Carolina, spawn at about the same time as do white shrimp.

White shrimp spawn close to beaches along the coast. This normally occurs within one to five miles from shore, in waters ranging from ten to thirty feet in depth. In comparison, brown shrimp are thought to spawn much farther offshore, although the exact spawning locations are still not known. In the past, a few large brown shrimp in spawning condition have been found off the South Carolina coast during November and December, and concentrations of large brown shrimp have been located off the northeast coast of Florida during the winter months in depths of about 30 fathoms.

During the spawning season, sexually mature or "roe" females of each species release their eggs offshore and the young shrimp, after hatching, pass rapidly through various and complex larval developmental stages. Following this development they move through the mouths of sounds, bays, inlets and rivers into salt marsh creeks along the entire coast. Within the tidal creeks of the shallow estuarine nursery grounds, these shrimp reach a juvenile and then sub-adult stage a few months later. Here, within this extremely productive zone, food is plentiful and growth is rapid. As growth continues, a gradual seaward migration takes place.

Environmental factors probably play the most important role in determining the success or failure of the commercial shrimp harvest.

Environmental factors probably play the most important role in determining the success or failure of the commercial shrimp harvest. Water temperature, salinity, rainfall, river discharge and water currents all have significant effects upon shrimp populations during any given year. Temperature is the most significant factor, influencing growth and survival rates as well as migration. During the warmer months, growth is rapid but diminishes or even stops during the winter.

During some winters, extremely low water temperatures have resulted in mass mortalities of white shrimp. Decreasing water temperatures in the fall and winter also stimulate the seasonal and local migration of shrimp. As cold weather approaches, larger adult white shrimp move offshore and southward along the coast and small white shrimp move into deeper waters in protective estuaries or offshore. Brown and pink shrimp, however, often burrow into the bottom during cold periods.

Along the Atlantic coast of the U.S., the white shrimp has centers of abundance in South Carolina, Georgia and northeast Florida and is always found at depths less than 9 fathoms. The brown shrimp occur seasonally along the middle Atlantic states, but breeding populations apparently do not range north of North Carolina. Although brown shrimp occur in commercially exploitable quantities to 60 fathoms, the species is most abundant in waters of less than 30 fathoms. Along the South Atlantic coast, pink shrimp occur in sufficient abundance in waters of six to twenty fathoms.

Shrimp abundance in the South Atlantic appears to be directly related to distance from shore or depth. Along the Georgia coast, shallow water extends further offshore relative to other areas in South Carolina and Florida.

This short, natural history of the three species of shrimp is presented in order to better understanding landings and vessel information, since the temporal and spatial distribution of the fleet generally mirrors that of the resident shrimp crop (Tables 6, 7 and 8).

Table 6. Percentages of shrimp landings of each Southern Atlantic state made during each month averaged from designated seasons. (Source: From Anderson et. al., 1949b.)

Month	North Carolina (1941-1945)	South Carolina (1941-1944)	Georgia (1931-1935)	Florida (1933-1934)
January	3.3	0.0	2.2	18.8
February	0.0	0.0	2.5	11.2
March	0.3	0.0	2.8	10.4
April	0.5	0.1	3.6	8.2
May	1.2	1.9	6.1	4.7
June	0.7	2.9	8.0	6.2
July	7.9	9.5	5.5	2.5
August	19.2	16.8	16.8	5.8
September	19.9	24.9	19.7	5.9
October	29.5	28.5	17.2	5.0
November	15.8	14.1	12.2	6.7
December	1.7	1.3	3.4	14.6

* Both coasts of Florida combined.

Table 7. Percent of the South Atlantic shrimp catch (heads-on) by state from the FCZ versus territorial seas, 1980. (Source: McCoy, pers. comm.)

	% of 0 to 3 miles (lb)	% of Year's Catch	3 miles Seaward	Year's Catch	Total Landings
Florida (E. Coast)	3,494,000	47.0	4,009,000*	53.0	7,503,000
Georgia	3,476,128	41.0	4,998,804	59.0	8,474,932
South Carolina	6,999,992	97.0	194,367**	3.0	7,194,359
North Carolina	9,741,322	99.2	82,168	0.8	9,823,490

* Figures include Rock Shrimp; Florida officials estimate that 12-15% of the non-rock shrimp catch was made in the FCZ (F. Kennedy, FL DNR, St. Pete., FL; pers. comm.).

** These figures are believed to underestimate the actual percent of the catch which originated in the FCZ for S.C. According to Theiling (S.C. Marine Res. Center, Chas., S.C.), about 5 to 10% of the catch in 1980 occurred in the FCZ.

Table 8. Percentage of the South Atlantic shrimp catch from the FCZ versus territorial seas, 1973-1980* (Source: *Fishery Statistics of the U.S.*, NOAA/NMFS, various years; *Fisheries of the U.S.*, NOAA/NMFS, various years).

	0 to 3 Miles (lb)	% of Year's Catch	3 Miles Seaward	% of Year's Catch
1973	22,141,000	88.0	2,921,000	12.0
1974	23,256,000	87.0	3,628,000	13.0
1975	22,192,000	89.0	2,724,000	11.0
1976	23,125,000	89.0	2,996,000	11.0
1977	15,092,000	84.0	2,905,000	16.0
1978	13,675,000	68.0	6,463,000	32.0
1979	15,640,000	48.0	16,655,000	52.0
1980	23,712,000	72.0	9,284,000	28.0

* Management personnel from state agencies in the Region question the accuracy of these figures due to differences in collection techniques and the inclusion of rock shrimp data.

Historical and Current Information

Fishermen have harvested shrimp since at least 1816, although commercial catch statistics were not collected and published until 1880. Dip nets, haul seines and cast nets were the principal gears used initially, but between 1912 and 1915 fishermen began to use otter trawls. The otter trawl became standard gear by 1917 and by the 1930s accounted for approximately 90 percent of the catch, with the remainder being taken by cast nets and seines.

Early fishing craft were small, open skiffs powered with gasoline engines. During the 1920s and 1930s vessels were decked over, engines placed forward with a pilot house added and the diesel engine introduced. Since then shrimp trawlers in the South Atlantic have been strongly influenced by vessels designed to fish along the Florida coast and in the Gulf of Mexico. Presently, most trawlers are double-rigged for towing two nets at once.

Shrimp catches increased dramatically after introduction of the trawl around 1917 (Table 9). During the Depression, low prices caused a general decrease in landings of shrimp. World War II had a negative effect on fisheries in general since many personnel and materials were diverted to the war effort. However, the shrimp fisheries emerged from World War II over five times as valuable as they were at the war's beginning, from $754,000 in 1940 to $4 million in 1945.

Table 9. Recorded commercial production of shrimp (thousands of pounds, heads-on) landed in each South Atlantic state, during 1880 through 1980. (Sources: 1880-1976 - *Fishery Statistics of the U.S.*, 1965-1976; 1977-1978 *Shrimp Landings, Annual Summary* 1977, 1978; 1979-1980 South Atlantic State/Federal Statistics Program.)

	North Carolina	South Carolina	Georgia	Florida E. Coast	Total
1880	63	630	56	72	821
1887	120	338	185	1	1
1888	124	359	191	2	1
1889	135	380	150	78	743
1890	144	372	162	66	744
1897	146	374	68	39	627
1902	84	370	344	3,013	3,811
1908	371	452	528	4,346	5,697
1918	940	55	5,793	8,868	15,656
1923	1,658	355	10,668	11,024	23,705
1927	1,276	1,657	12,280	14,779	29,992
1928	845	431	9,526	22,507	33,309
1929	897	288	12,378	17,266	30,829
1930	1,299	793	8,853	15,260	26,205
1931	338	2,635	5,471	17,050	25,494
1932	292	1,501	3,602	17,068	22,463

(Continued on next page)

	North Carolina	South Carolina	Georgia	Florida E. Coast	Total
1934	2,564	1,801	6,843	14,753	25,961
1936	3,815	1,101	9,715	18,946	33,567
1937	4,184	1,201	9,504	12,547	27,436
1938	4,569	3,723	10,426	8,847	27,565
1939	4,811	4,090	10,802	7,982	27,685
1940	4,156	1,784	9,336	7,426	22,702
1945	10,614	4,696	16,392	11,879	43,581
1950	8,311	7,746	11,157	9,267	36,481
1951	8,200	3,730	7,608	8,233	27,771
1952	8,713	4,072	5,991	6,895	25,671
1953	14,645	5,086	7,535	5,667	32,933
1954	9,182	6,644	7,742	5,078	28,646
1955	10,324	6,918	7,161	4,136	28,539
1956	6,243	5,589	7,991	5,695	25,518
1957	7,933	6,690	8,788	5,179	28,590
1958	2,519	5,815	8,746	5,504	22,584
1959	6,378	7,515	7,602	4,511	26,006
1960	5,988	8,030	10,403	6,793	31,214
1961	3,016	3,907	6,810	6,016	19,749
1962	5,805	6,474	8,610	5,189	26,078
1963	3,374	2,201	5,448	4,506	15,529
1964	4,279	2,632	5,939	4,491	17,341
1965	5,416	6,795	8,585	5,395	26,191
1966	5,697	4,263	6,476	5,039	21,475
1967	4,919	4,088	6,657	4,933	20,597
1968*	4,616	6,333	8,536	4,800(4,793)	24,285
1969	7,854	5,817	8,447	5,188	27,306
1970	5,054	4,951	5,996	4,606	20,607
1971	7,615	0,753	8,862	3,970	31,200
1972	5,563	8,085	7,258	4,341	25,247
1973	5,003	8,256	8,248	3,061	24,568
1974	8,440	7,429	7,230	3,992	27,091
1975	5,164	8,866	8,090	2,806	24,926
1976	6,643	8,653	7,772	3,040	26,108
1977*	5,600	4,338(4,283)	4,595	3,546	18,079(18,024)
1978*	2,961	5,083	5,517(5,671)	4,206	17,767(17,921)
1979	4,941	8,240	9,713	6,724	29,618
1980	9,823	7,214	8,394	7,638	33,069

Rock shrimp and royal red shrimp poundages are included.

* Disparity exists in *Shrimp Landings* data.

In analyzing shrimp landing values and the number of licensed trawlers (Table 10), several interesting trends are apparent. Although landings have fluctuated considerably, there has been no dramatic increase in the annual shrimp catch since the late 1950s. The number

In the winter months, boats move south to Florida or farther offshore in Georgia and Florida. During the spring and summer, landings increase in Georgia, and South and North Carolina. The fall months are the most productive and most fishing is conducted near-shore (0-3 mi) or in the sounds and bays, if and when they are opened.

Table 10. Number of commercial fishermen employing shrimp otter trawls in each South Atlantic state during each year, 1950 through 1978, with totals exclusive of duplication. (Source: 1950-1976 Fishery Statistics of the United States and 1977, 1978 - NMFS, Wash., D.C.)

	North Carolina	South Carolina	Georgia	Florida E. Coast	South Atlantic
1950	2,201	453	613	516	NP
1951	1,942	977	660	418	NP
1952	1,938	694	563	573	NP
1953	2,136	718	502	744	NP
1954	1,963	575	506	587	NP
1955	1,766	730	587	508	NP
1956	1,824	826	713	783	NP
1957	1,817	989	793	907	3,807
1958	1,380	951	1,096	1,080	3,723
1959	1,509	812	1,106	1,034	3,821
1960	1,575	819	953	982	3,667
1961	1,407	702	1,092	1,000	3,534
1962	1,410	740	1,177	889	3,569
1963	1,349	665	1,156	813	3,368
1964	1,361	503	1,104	676	3,119
1965	1,314	489	1,095	661	3,075
1966	1,313	442	1,079	697	3,099
1967	1,241	476	1,076	633	2,904
1968	1,126	633	1,139	612	2,957
1969	1,171	718	1,219	543	3,048
1970	1,326	642	1,003	527	3,004
1971	1,500	874	1,277	559	3,731
1972	1,638	938	1,231	491	2,988
1973	1,856	993	1,218	465	3,811
1974	1,878	1,164	1,406	392	3,283
1975	2,032	1,218	1,530	349	4,340
1976	2,011	1,162	1,562	429	4,456
1977	1,649	921	896	454	3,549
1978	1,345	1,221	1,005	549*	3,389*

* Florida and therefore South Atlantic figures are estimated.
NP = not published

of licensed shrimp trawlers has changed significantly in South Carolina and Florida, but the overall number in the South Atlantic Region has remained fairly stable. The trend appears to be toward larger double or twin-rigged trawlers in recent years.

The number of licensed trawlers for each state is not reflective of the number of boats fishing in a given area at a given time. This is because many captains will hold licenses in more than one state and the shrimp fleet is very mobile.

Tables 6 and 7 characterize the efforts of the fleet along the South Atlantic Region. In the winter months, boats move south to Florida or farther offshore in Georgia and Florida. During the spring and summer, landings increase in Georgia, and South and North Carolina. The fall months are the most productive and most fishing is conducted near-shore (0-3 mi) or in the sounds and bays, if and when they are opened.

Both the flounder fishery and the sound shrimp fishery should be investigated to determine if there are turtle captures and any resultant mortality.

The inshore fisheries are more significant in Georgia and South Carolina where there are large sounds. Additional strandings have been recorded in Georgia soon after the sounds were open (S. Shipman, pers. comm.).

The large sounds in North Carolina do not appear to be an area where the interaction between the shrimping fleet and sea turtles bring about mortality. Although there is high fishing effort, most of the boats are small and pull short tows because of their relatively small nets. The abundance of grasses in these shallow waters may also reduce the tow times (R. Carpenter, pers. comm.). The shoreline of these sounds is mostly marsh and could obscure any carcasses should they occur. However, no carcasses have been seen here (O. Florschutz, pers. comm.). The North Carolina strandings which occur on the beach during the winter months may be related to the flounder fishery. Most of these strand north of Cape Hatteras, which may relate to the influence of the Gulf Stream currents or turtle abundance since the fishery extends south of Cape Hatteras as well. Both the flounder fishery and the sound shrimp fishery should be investigated to determine if there are turtle captures and any resultant mortality.

Value and Use

Shrimping statistics provide information on the seasonal and geographic distribution of the fleet. The location and magnitude of the effort relative to the statistical zones and distance from shore is needed to evaluate management decisions.

Shortcomings and Cautions

"Effort" data should be used rather than "landings" data. While effort and landings generally mirror each other, the ratio between catch and effort varies, and it is effort that causes mortality, not catch success. Also, because of better refrigeration and the mobility of the fleet, landings data does not necessarily reflect where the shrimp were caught.

AERIAL PELAGIC OBSERVATIONS OF MARINE TURTLES

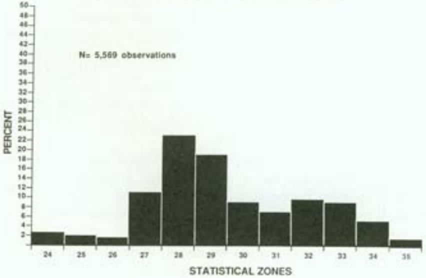
Historic and Current Information

Information on the at-sea distribution of sea turtles has until recently been limited to casual observations. Fishermen frequently reported turtles around reefs. Breeding turtles were reported during the spring months adjacent to nesting beaches. These reports probably reflect the distribution of observers rather than turtles and are anecdotal in nature.

Since 1978, four over-the-water aerial surveys have been completed where marine turtles were counted. The cetacean and turtle assessment program (Ce TAP) surveys were conducted over northeastern U.S. waters during 1978-1979 under a Bureau of Land Management contract. During 1979-1981, four sub-areas (three in the Gulf of Mexico and one on the Florida east coast) were surveyed by the U.S. Fish and Wildlife Service. Extensive flights were conducted under the southeast turtle survey program (SETS). These surveys were flown over the waters off the southeastern U.S. coast from 1982-1984 for the National Marine Fisheries Service.

The percentage distribution of the SETS pelagic observations by statistical zones is presented in Figure 13 as compiled by Schroeder (1986). This distribution of sightings is uncorrected for effort and flight conditions. Most recently (1983-1986) flights have been flown over areas of the Gulf of Mexico by National Marine Fisheries Service. These flights have provided interesting information on the geographic and seasonal distribution of sea turtles and provide an index to relative abundance.

Figure 13. Percentage distribution of pelagic aerial observations of marine turtles by statistical zone of the South Atlantic region



Pelagic survey data show the following trends:

1. Turtles are generally seen in waters less than 150 feet in depth.
2. They are rarely seen beyond the Continental Shelf.
3. Along the North Carolina, South Carolina and Georgia coasts, observations are farther offshore during the fall and winter.
4. Observations are near-shore during the fall and winter at or south of Cape Canaveral.
5. The total rate of observations is lower in the fall and winter for all areas combined.

These data suggest several things concerning the seasonal distribution and relative abundance of sea turtles. There appears to be a constriction of the winter range as turtles move south and offshore in response to dropping coastal sea water temperatures. Despite the apparent constriction in the range, the rate of observations of turtles declines during the fall and winter. This suggests either reduced surface activity or movement to areas outside the survey area.

Value and Utility

Aerial pelagic surveys provide a good indication of the geographic distribution of marine turtles. Surveys also provide an index of relative abundance. The seasonal shifts in the distribution of observations probably reflect seasonal movement patterns of turtles and provide information on habitat use.

Shortcomings and Cautions

At-sea aerial observations of turtles should not be considered synonymous with total numbers of turtles. Sightings represent only those turtles near the surface, which is generally a very small portion of the total present. Flight conditions influence visibility of the turtles which are at or just below the surface. Some conditions are: sea state, glare, observer efficiency, water clarity, altitude, aircraft speed, ocean debris, and air turbulence. Also affecting the visibility of turtles are turtle size, color and distance from the aircraft.

The one piece of information needed to make the extrapolation from turtles seen at the surface and the number of turtles in the total water column is percent surface time.

The relationship between the rate of observations and the number of turtles present in the survey area has been demonstrated to be influenced by water temperature, time of day, and individual turtle behavior. It may also be related to behavioral thermoregulation, migration, courting or feeding behaviors.

The one piece of information needed to make the extrapolation from turtles seen at the surface and the number of turtles in the total water column is percent surface time. The surface time data used to make the conversions to population estimates came from a study by Kemmerer et. al. (1982). Of the 20 turtles monitored by radio telemetry in the Canaveral Ship Channel, only four contributed significantly to the data base. They also found that time of day significantly influenced surfacing time, with the longest times around 0700. However, radio interference from the Cape Canaveral area during daylight hours resulted in the majority of the data being collected at night.

Using the mean surface time conversion factor of 3.8% from Kimmer et. al. (1982), a total population estimate for loggerheads greater than 60 cm of 387,594 (Thompson et. al., 1986) was derived. If, however, the mean surface time factor of 5.2% from a study by Musick et. al. (1983) had been used, the population estimate would have become 283,230, or a difference of 104,363 turtles. To extrapolate from turtles seen at the surface to a total population estimate is inappropriate at this time because of the lack of representative data on percent surface time.

Apparently a low percentage of the turtles present are sighted and only a small percentage of the habitat can be surveyed. Thus extensive extrapolations are required. Even where extensive surveys are flown, each observation may represent over 200 turtles in a derived population estimate. This results when surveys represent generally less than a 10% sample of the habitat occupied by turtles and when reported time at the surface is less than 5%.

Many of the variables influencing observation frequency can be standardized by standardizing flight conditions as much as possible. Variables which cannot be standardized are statistically compensated for and are subject to a level of inaccuracy. As multiple factors are "corrected for," variances accumulate, making the reliability of the estimates difficult to assess.

The usefulness of aerial at-sea surveys in assessing species of marine turtles other than loggerhead appears minimal at this time.

The usefulness of aerial at-sea surveys in assessing species of marine turtles other than loggerhead appears minimal at this time. This is because of the low density of these other species in the area of concern and the frequent inability to correctly identify species seen from an aircraft. Observations of Kemp's ridley are further reduced by the smaller size of the species.

While pelagic aerial surveys may provide an index of relative abundance of seasonal and geographic distribution for loggerheads, any population estimates derived from them should be reviewed with caution because of the reasons given above.

A.J. Kemmerer, R.E. Timko and S.B. Burkett, 1981. Movement and surfacing behavior patterns of loggerhead sea turtles in and near Canaveral channel, Florida. (Sept. and Oct. 1981.) Stock Assessment Workshop, SEFC MS MMT/8, August, 1981. 50 pp.

Summary: Twenty loggerhead turtles were equipped with radio and sonic transmitters. Ten of the turtles were translocated 8 kms. Eight of the ten were known to return to the area of capture. This demonstrates the futility of translocating loggerhead turtles short distances to avoid local impacts such as dredge operations.

Useful data from 4 turtles were used to calculate surface activity based on 732 surfacings. A mean of 3.78 percent of the turtles' activity was calculated to occur at the surface. This is a thoughtful, well analyzed project which suffered from difficult-to-predict interference which greatly limits its utility.

Cautions

1. The 95% confidence limits reported for statistics of surface time are ± 2 standard errors. This suggests, for example, that 95% of the time a turtle will be on the surface between 3.51 and 4.05 percent of the time. This is clearly not the case (their Figs. 21 and 27). A large portion of the observations appear to fall outside of this reported confidence interval. The use of ± 2 standard deviations would appear to better represent the variance around the mean. The standard deviation is not completely useful, as it exceeds the lower limit of zero.
2. The use of the surface data presented here in extrapolating pelagic aerial observation data to population estimates should be considered limited. This is a result of the low percentage of the time a turtle is at the surface and the non-representative nature of the data. The low percent surface time results in a large multiplying constant. Put another way, the surface time calculated from the telemetric monitoring of 4 turtles represents 96% of the population estimate.

T.H. Fritts and A.B. Irvine, R.D. Jennings, L.A. Callum, W. Hoffman, and M.A. McGehee. 1983. Turtles, Birds, and Mammals in the Nearby Atlantic Waters. U.S. Fish and Wildlife Service, Division of Biological Services, Washington, D.C. FWS/OBS-82/65. 455 pp.

Summary: This is an excellent reference and report. Included is a clear statement of statistical procedures used, assumptions made, and appropriate cautions for the use of density estimates.

A total of 1,730 loggerheads, 11 greens, 12 Kemp's and 47 leatherbacks were seen in the four subunits sampled during this study. The subunits off the east and west coasts of Florida supported large numbers of turtles, while the subunits off of Louisiana and Texas had very few turtles observed. Turtle densities were estimated in turtles per km^2 and were based on turtles at the surface only. As with other pelagic surveys, turtles were generally observed in shallow water over the continental shelf. Greater than 93% of the loggerheads observed were in water less than 50 meters.

As with other pelagic surveys, turtles were generally observed in shallow water over the continental shelf. Greater than 93% of the loggerheads observed were in water less than 50 meters.

Of significance is the observation that many loggerheads that were observed were thought to be basking on the surface. Basking behavior has also been cited in the literature (Carr, 1952; Sapsford and Van der Riet, 1979) and would preclude extrapolation of aerial observations to population estimates based on surface times associated only with nearshore activity.

Density estimates were not calculated for turtle species other than loggerhead.

Thompson, N.B., T. Henwood, and W.E. Stuntz. 1986. A summary of information on three species of marine turtles in U.S. waters. NMFS Report, Miami, Florida. 43 pp.

Part II. Pelagic survey only.

A second estimate of loggerhead numbers in the report is an estimate of adult and subadult loggerheads based on pelagic aerial counts. Once again, the 95% CI suggest extreme accuracy. The CI indicate that the estimate is within 5% of the true population size at P = .05 (20,154 is approximately 5% of 387,594). The three years of pelagic aerial surveys averaged 1,682 observations. Thus we are led to believe that if we observe 0.43% of the turtles in the study area, we can estimate the total population to within a 5% accuracy. In other words, each observation represents 230 turtles in the annual estimate. This would appear extremely unlikely unless sources of errors are assumed not to occur or are ignored. For example, it is assumed that all turtles over 60 cm carapace length are seen and none under 60 cm are seen. It is also assumed that all loggerheads in all depths of water engaged in all of their various activities occur at the surface 3.8% of the time. This percentage, which is used to increase the estimate by 26 times, is based on useful data from only four turtles and is heavily biased toward nocturnal surface behavior.

It is recognized that this technique of pelagic aerial survey is being refined and developed and may eventually represent a useful index to the population of loggerheads. It is less clear if this methodology will ever provide population estimates accurate enough to detect any but the most gross changes in the population.

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SUMMARY FOR STATISTICAL ZONES 24–35

Refer to Figures 14 and 15 and Table 11 for zones 24-35:

Zone 24

Andros Island in the Bahamas to Key Largo, FL. Beaches within this zone have little or no nesting. Strandings are low and are probably related to causes other than shrimping since none occurs here. This zone was not sampled for incidental catch mortality. Pelagic observations show low numbers of turtles relative to other areas.

Zone 25

Key Largo, FL, to Ft. Lauderdale, FL. Beaches within this zone contain numerous high-rise hotels and condominiums. Low levels of nesting do occur here despite the high disturbance at night on the beaches from lights and people. There are low levels of strandings which may be related to high boat traffic. There is no shrimping and this zone was not sampled for incidental catch mortality. There are also low numbers of turtles seen by pelagic aerial survey.

Zone 26

Ft. Lauderdale, FL, to Hobe Sound National Wildlife Refuge, FL. Although development within this zone is high to moderate, portions of the beach here receive extremely high use for nesting. Because of this the percent interaction (Figure 14) is much higher than the two preceding zones. There are slightly more strandings, but no shrimping. Few turtles are seen offshore despite the high nesting. This may relate to feeding areas.

Zone 27

Hobe Sound National Wildlife Refuge, FL, to Indiatlantic Beach, FL. Beaches within this zone are moderately developed with mostly single-family homes. However, more multi-family condos are scheduled for construction. Melbourne Beach, at the northern portion of the zone, has the highest nesting density in the southeast U.S. Strandings are slightly high here and many more turtles are seen during pelagic aerial survey. There is no shrimping conducted here and the sampling for incidental capture was very low.

Zone 28

Indiatlantic Beach, FL, to New Smyrna Beach, FL. Most of this zone consists of the Canaveral National Seashore and it also contains a winter hibernaculum for sea turtles in the Port Canaveral ship channel. This is the third highest zone for nesting and the highest zone for pelagic aerial observation. Because of this, it has the highest interaction percentage and adjusted incidental capture rate. Fortunately, the fishing effort is low. The potential for mortality in this zone is extremely high should a higher level of shrimping occur here.

Zone 29

New Smyrna Beach, FL, to South Ponte Vedra Beach, FL. Most of the beaches within this zone have high to moderate development. Many of these beaches have vehicle traffic. This is probably why the level of nesting drops so dramatically from the zones to the south. There are high numbers of turtles seen offshore and there is moderate fishing effort. Although strandings are low, this may be a function of network efficiency. The adjusted incidental catch percentage shows that if shrimping effort were higher, there is a high potential for mortality.

Zone 30

South Ponte Vedra Beach, FL, to St. Andrews Sound, GA. Beaches within the Florida portion of this zone have moderate to low development with fairly good dune systems. The Georgia portion consists of Cumberland National Seashore and Little Cumberland Island. Both are excellent nesting beaches. Although nesting density is low here, stranding percentage is the highest and fishing effort percentage is the second highest. Turtles seen in offshore waters and the adjusted incidental catch percentage are moderate. Because of the high fishing effort and recorded strandings, this zone has the second highest index to interaction in the south Atlantic Region.

Zone 31

St. Andrews Sound, GA, to Tybee Island, GA. This zone encompasses the remainder of the Georgia coast. Of the dozen or so barrier islands, only four are developed. Large sounds separate most of the islands and they are backed by extensive salt marsh on the inland side. This zone is very similar to Zone 30 in that it has the highest percentage of fishing effort and the second highest percentage of strandings. There is low-density nesting but moderate numbers of turtles are seen offshore. The index to interaction is also very high.

Zone 32

Tybee Island, GA, to Lighthouse Island, SC. This zone is made up of barrier islands, large sounds and extensive salt marshes. Of the 24 islands in this zone, eight are developed. Nesting is higher than in the Georgia and north Florida zones. The fishing effort percentage is the third highest in the region and the stranding percentage is fourth. About one-third of these barrier islands are remote and strandings here do not receive complete coverage. A greater density of turtles are offshore during pelagic aerial surveys than are reported for the zone to the south.

Zone 33

Lighthouse Island, SC, to Kure Beach, NC. The southern half of this zone consists of undeveloped barrier islands under federal or state ownership. They receive the highest nesting effort north of Zone 28. The northern half of this zone has high to moderate development and little nesting. The stranding percentage is third highest in the region and most are recorded in the southern part of the zone. Most of the fishing effort is likewise found in the southern part of this zone. Pelagic observations are about the same as Zone 32.

Zone 34

Kure Beach, NC, to Portsmouth Island, NC. Beaches in the southern portion of this zone have a low level of development. The northern part is included in the National Seashores of the Outer Banks. Despite the excellent beaches and dunes, nesting is very low. This is the northern extent of the nesting range. Fishing effort, strandings and pelagic observation percentages all decline here.

Zone 35

Portsmouth Island, NC, to Kill Devils Hill, NC. This zone is a continuation of the Outer Banks. There are low nesting, low strandings and low fishing percentages.

Figure 14. Index to percentage interaction by statistical zone in the South Atlantic region

(PERCENT STRANDINGS + % LISTING EFFORT + % NESTING + % ADJUSTED INCIDENTAL CAPTURE = INTERACTION.)

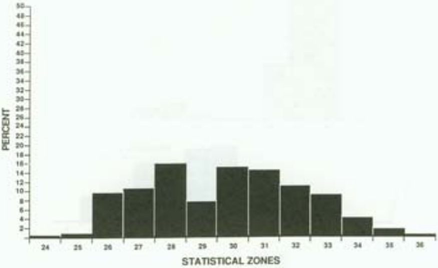

Table 11. Percent distribution of four aspects related to the interaction of sea turtles and shrimping.

Zone	% Strandings	% Fishing Effort	% Incidental Catch	% Nesting	Cumulative Total	% Involvement Total ÷ 4
24	0.71	0.00	NS	NS	0.71	0
25	0.74	0.00	NS	0.28	1.02	0
26	2.38	0.00	NS	36.66	39.04	10
27	5.08	0.00	0.00	37.28	42.36	11
28	4.75	5.80	38.83	14.64	64.02	16
29	4.34	6.52	20.09	0.60	31.55	8
30	20.45	23.19	15.99	0.38	60.01	15
31	19.74	28.99	7.08	1.47	57.28	14
32	13.02	18.12	8.22	4.55	43.91	11
33	16.13	6.52	9.79	3.16	35.60	9
34	5.23	9.42	NS	0.76	15.41	4
35	6.76	0.00	NS	0.19	6.95	2
36	0.68	1.45	NS	0.00	2.13	1
Total	100.00	100.01	100.00	100.00	399.99	101

Figure 15. Standardized distributions expressed in percentage for each statistical zone for comparison of five attributes