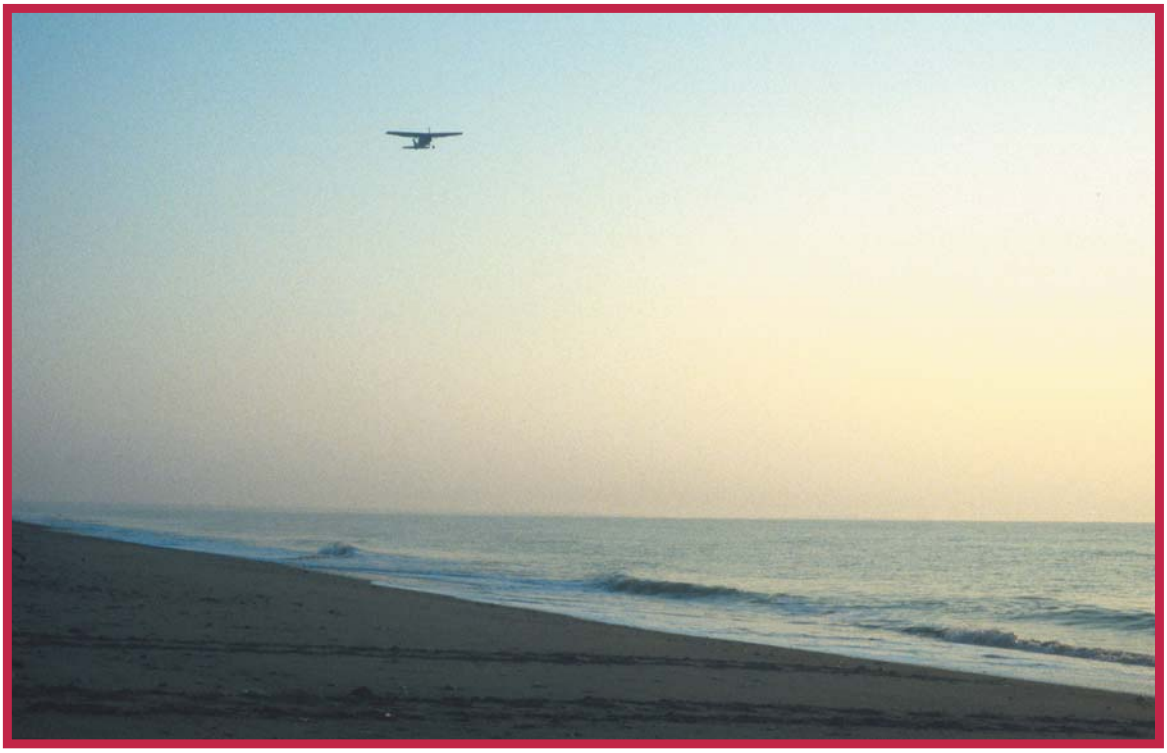
Population Trends and Nesting Distribution of the Loggerhead Turtle (*Caretta caretta*) in South Carolina 1980-1997



Final Report to the U.S. Fish and Wildlife Service

prepared by
S.R. Hopkins-Murphy, T.M. Murphy, C.P. Hope, J. W. Coker and M.E. Hoyle

South Carolina Department of Natural Resources
Division of Wildlife and Freshwater Fisheries
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ACKNOWLEDGEMENTS

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INTRODUCTION

Major rookeries for the loggerhead turtle (*Caretta caretta*) are located worldwide near the Tropics of Cancer and Capricorn. The most significant ones are in Oman (Ross and Barwani 1982), the southeastern United States (Hopkins and Richardson 1984) and Queensland, Australia (Limpus 1985). Smaller, but no less important rookeries are found in Japan (Kamezake 1986), Greece (Margaritoulis 1982), Brazil (Bacon *et al.* 1984) and Tongaland, Natal, South Africa (Hughes 1975). Nesting distribution for the loggerhead turtle in the southeastern U.S. occurs from North Carolina through Florida. Range-wide aerial surveys (Murphy and Hopkins 1984) indicated that 90% of the nesting effort occurred in Florida, with approximately six percent in South Carolina and two percent each in Georgia and North Carolina.

Genetic studies by Bowen *et al.* (1993) demonstrate that loggerhead females return to nest in the same region of coast where they were hatched. These nesting assemblages, now referred to as "sub-populations", are vulnerable to extirpation, and regional dispersal will not be sufficient to replenish the depleted ones within thousands of years (TEWG 1998). Alterations, both natural and anthropogenic, are constantly occurring which change the suitability of beaches for nesting. As the South Carolina coastline continues to undergo development and natural erosional cycles, the nesting population will be affected. Likewise, mortality to females can occur near the nesting beaches and in far off parts of the ocean.

Both the Recovery Plan for Marine Turtles (Hopkins and Richardson 1984) and the Recovery Plan for the U.S. Population of Loggerhead Turtle, *Caretta caretta* (NMFS & USFWS 1991) call for monitoring trends in nesting activity by means of standardized surveys. In 1980, the Department of Natural Resources began aerial beach surveys designed to provide a long-term index to the status and distribution of the loggerhead turtle in South Carolina. This paper contains the results of those surveys over the past 18 years.

METHODS

Description of the Survey Zones

The names and locations of aerial survey zones north of Charleston are shown in Figure 1 and the survey zones south of Charleston are shown in Figure 2. In addition to the description, each zone is categorized as "undeveloped", "developed", "mixed-use" or "non-nesting area". "Undeveloped" is when there is little or no human habitation in the entire zone. "Developed" is when the entire zone contains human habitation. "Mixed-use" is when the zone contains some of each or when there is a natural beach, but with high human use, such as a state park. "Non-nesting area" is when there is little or no nesting, and these were excluded from the analysis.

Huntington Beach State Park, under the authority of South Carolina Parks, Recreation and Tourism Department, (SC PRT) is an undeveloped beach with campsites located behind the dunes. The southern portion of the park has a relatively stable dune system, but the north end near the Murrells Inlet jetty is more erosional with few dunes. (Mixed-use**)**

Litchfield Beach is comprised of several separate developments. North Litchfield Beach is a public beach with single family homes set behind the secondary dunes. Litchfield-by-the-Sea is a gated community with several high-rise condominiums. The beach is stable. South Litchfield Beach has single family homes that are located behind the primary dunes, which tend to be more erosional. (Developed**)**

Pawleys Island is comprised of single-family homes and one condominium complex. The northern portion of the beach has stable dunes and adequate setbacks. The southern end has houses on the active beach. (Developed**)**

Debidue Beach consists of a gated community with single-family homes and condominiums. There is a seawall along the center of the beach where there is no dry beach at high tide. This area was re-nourished in 1998 with sand from an inland source, but most of it has been lost. The northern beach has dune fields and new, private homes are being constructed. The University of South Carolina owns the southern portion, called Hobcaw Barony, where there is no development. (Mixed-use**)**

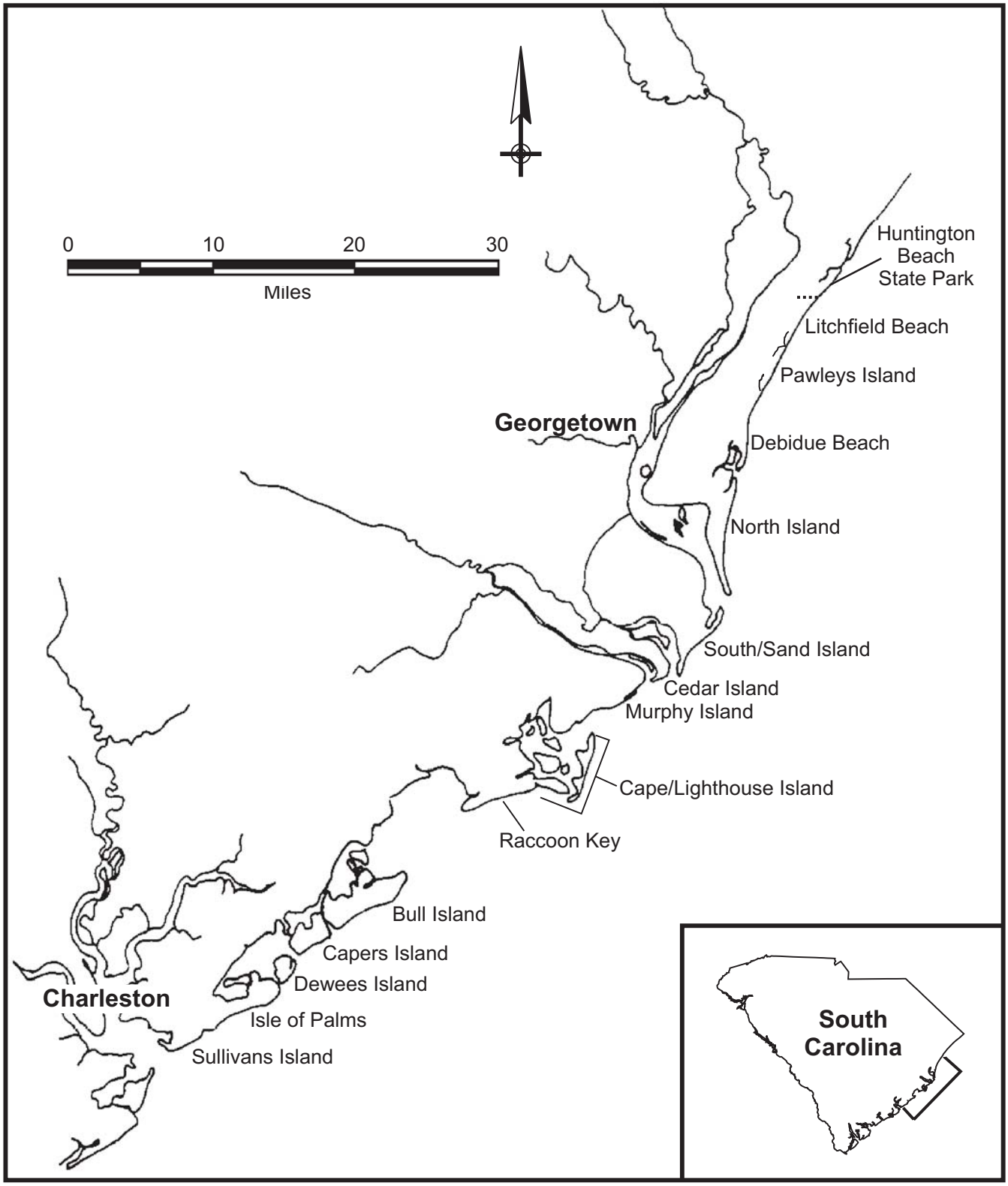

Figure 1. Aerial survey zones north of Charleston, South Carolina.

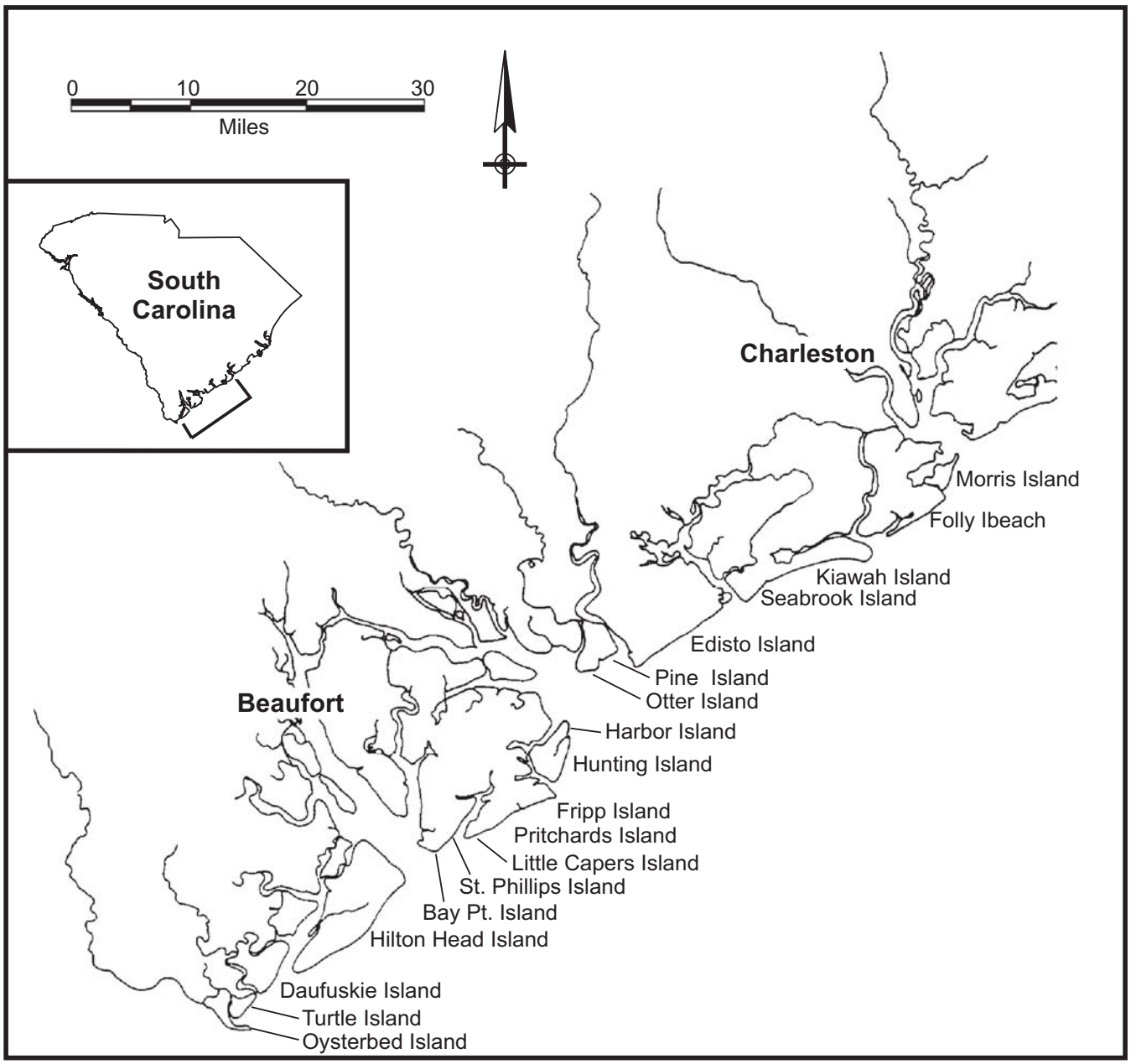

Figure 2. Aerial survey zones south of Charleston, South Carolina.

The next five islands are Wildlife Management Areas under the authority of South Carolina Department of Natural Resources (SC DNR).

North Island is a pristine wilderness area except for the historic lighthouse. The north jetty at the Winyah Bay entrance channel is located on the south end and the beach wraps around from the Atlantic Ocean to the Bay. The 15-km beach has a textbook profile with dune fields that are 100 m wide in some areas, merging into the salt-pruned thicket community. Some dunes are 3-8 m high and rise above the maritime forest. (Undeveloped)

Sand Island beach, intersected by the south jetty, also extends from the ocean around to Winyah Bay. There is no maritime forest and wax myrtles are the tallest vegetation. In 1989, Hurricane Hugo completely flattened Sand Island and recovery has been slow with a few low dunes at the south end.

South Island is mainly composed of former rice fields, now managed for waterfowl and other wetland species. The beach is wide with well-formed dunes that may become scarped during winter storms, but usually rebuild each spring. Because Hurricane Hugo moved the inlet between these two islands about a mile to the north, they are combined in the analysis as Sand/South Islands. (Undeveloped**)**

Cedar Island is situated between the North and South Santee rivers and has undergone some erosion on the south end. A very large sandbar has accrued offshore and may change this beach in the near future. (Undeveloped**)**

Murphy Island has many small tidal creeks intersecting the beach and there are areas of mud flats along some of the beachfront. There are low to moderate dunes. (Undeveloped**)**

The next four islands are part of the Cape Romain National Wildlife Refuge. Cape Island is 9 km long and forms a cuspate headland. The beach is steep with coarse sand and long sections consist of flat, washover terraces. Lighthouse Island is very similar in appearance to Cape Island, but it is oriented to the south instead of east and west. During the course of this study, the western arm of Cape Island beach accreted in front of Lighthouse Island, preventing turtles access to it. The sandy spit has since merged with Lighthouse Island and turtles can now nest there again. Because of this, these two islands are combined in the analysis as Cape/Lighthouse Islands. (Undeveloped**)**

Raccoon Key is divided into numerous, short, shelly beaches with no true dunes**.** (Undeveloped)

Bull Island has a highly erosional beach at the north end, but the remainder of the island is fairly stable with a well-formed dune field. (Undeveloped)

Capers Island is undeveloped and is managed by the SC DNR as a Heritage Preserve. It is highly erosional and the beach is littered with fallen trees. There are small dunes at the north end. (Non-nesting area)

Dewees Island is currently being developed at very low density and with very strict building covenants. The beach is wide with low dunes and there are extensive shoals offshore. (Non-nesting area**)**

The Isle of Palms has single family homes, but there are multi-story condominiums on the north end and a pier and commercial area in the center of the beach. Most of the beach has good dune habitat except for the north end where groins and sandbags have been installed to protect property. (Developed)

Sullivans Island consists of single family homes. The dune field is wide and the homes are well back from the beach**. (**Non-nesting area**)**

Morris Island is just south of the Charleston Harbor and the south jetty intersects the north end. The interior is a diked, spoil disposal area and the beach is narrow, erosional and with few dunes. (Non-nesting area)

Folly Beach is a residential community south of Charleston Harbor. After the completion of the Charleston jetties, the natural, erosional retreat of the island accelerated. Rock groins, perpendicular to the shore, are in place along the length of the beach which was re-nourished in 1993. (Developed**)**

Kiawah Island is a gated, residential resort. The beach is wide, flat and fairly stable. There are well-developed dune fields, and homes are required to be

located away from the beach. In other areas, there are multi-story condominiums and the Kiawah Inn. (Developed**)**

Seabrook Island is a gated residential resort community with single-family homes and duplexes. Seabrook is roughly circular in shape and extends from the ocean around to the shore of the North Edisto River. This section has an environmental education camp under the auspices of the Episcopal Church. The middle portion has a rock revetment while the northern section has a wide dune field between the homes and the nesting beach. (Developed**)**

Edisto Island is located between the North and South Edisto Rivers. The beach habitat is a combination of undeveloped, erosional, very shelly beaches, a state park campground and the Town of Edisto Beach, consisting of single family homes. All of these beaches are steep and narrow. (Mixed-use)

Pine Island is privately owned, undeveloped and consists of a few, very small pocket beaches that are fronted by *Spartina alternaflora* marsh. (Non-nesting area)

Otter Island is undeveloped and owned by the state of South Carolina under the authority of SC DNR. The beach is narrow with low dunes interspersed with erosional areas. It is a Heritage Preserve and also part of the National Estuarine Research Reserve (NERR). (Undeveloped)

Harbor Island is a small circular barrier island with very little maritime forest. The single family homes and condominiums are situated in the dune fields and thickets. A short portion of the beach has an erosional area with no dunes, but most of the southern portion is accreting. (Developed)

Hunting Island State Park beach is littered with fallen trees, the remnants of a highway, and exposed marsh peat and stumps. The island is owned by the SC PRT and has about 800,000 visitors a year. A few cottages at the south end are under life-long leases to individuals. This beach is scheduled for re-nourishment in the near future. (Mixed-use)

Fripp Island is developed with private homes and condominiums. There was suitable nesting habitat in the early 1970's, but construction of rock revetments has resulted in the entire beach being covered by water at high tide. However, a large sand bar has come ashore at the north end. (Developed)

Pritchards Island is undeveloped, rapidly eroding and the beach is littered with fallen trees and the remains of two homes that used to be located within the maritime forest. At high tide, the surf is at the tree line. There is only one short section of dry beach with low dunes. The island is owned by the University of South Carolina-Beaufort (USC-B) and a research facility was constructed for the Center for Coastal Ecology. (Undeveloped)

Little Capers Island consists of a narrow beach intersected by several inlets. There is only one house on about 10 acres of upland. Other houses, which were once on the beach, have been destroyed by erosion. (Undeveloped)

St. Phillips Island is a privately owned, undeveloped barrier island. There are fallen trees on some of the beach and a short rock revetment protects the two houses on the island. The ocean-facing beach is narrow with low dunes. This island is protected in perpetuity by a conservation easement with The Nature Conservancy. (Undeveloped)

Bay Point Island is a small, undeveloped barrier island on the north side of Port Royal Sound. The beach fronting the sound has a wide dune field, while the ocean-facing beach is littered with fallen trees. There are plans to develop this island and its future is uncertain. (Undeveloped)

Hilton Head Island is the largest barrier island on the South Carolina coast. It is comprised of large gated communities, private homes, condominiums, and multi-story, oceanfront hotels. There are small "pocket" beaches on the side of the island facing Port Royal Sound while the ocean-facing beach was renourished in 1991 and 1997. (Developed)

Daufuskie Island is currently under development. The beach was re-nourished in 1998, and there are only a few, low natural dunes at the south end of the island. (Non-nesting area)

Turtle Island is an undeveloped, state-owned island under the authority of the SC DNR. There are only small pocket beaches with no dunes. It is also a Heritage Preserve. (Non-nesting area)

Oyster Bed Island is a small, island at the base of the Savannah River north jetty. Ownership was disputed between Georgia and South Carolina. Since it was not included in the earlier surveys, it is excluded from the analysis.

Survey Methodology

This aerial survey methodology has appeared in several publications in the "gray" literature (Hopkins and Murphy 1983, Pritchard *et al.* 1983, Hopkins-Murphy and Murphy 1988, Hopkins-Murphy and Murphy 1994 and Schroeder and Murphy 1999). Since these sources may not be readily available, it is presented again here.

Aerial surveys

Beach surveys are initiated at dawn from Murrells Inlet south to the Savannah River during June and July. So little nesting occurs on the northern portion of the coast that surveys there would not be cost effective (Stancyk *et al.* 1979). A helicopter, which was used during 1980-82, had better visibility, adjustable speed and the capacity to hover, but was much more expensive. A single engine, wing-over-cockpit aircraft was used from 1985 to 1997. The aircraft is positioned over the surf zone at an altitude of 67 m and a speed of 80 to 100 kt, depending on the density of turtle tracks. Flights began at dawn (approximately 0600) and were completed by 0830. Tracks were recorded using a digital counter or a tape recorder. The tape recorder is used when flying over ground truth islands to sequence tracks relative to landmarks for mapped ground truth. Tracks are recorded as nests, non-nesting emergences (false crawls) or unknown. In order to monitor nesting females, it is crucial to this survey methodology to count only "fresh" tracks or those made the previous night. To do this with a high degree of reliability, surveys are scheduled around the twice-monthly spring tides of the full and new moon. These tides wash the widest area of the intertidal zone and remove the lower portion of old tracks. This makes it easier to discern the fresh tracks, which are seen in the intertidal zone the next morning, as the turtles are returning to the sea on an ebbing tide. Since loggerheads nest at night, flights are scheduled on the morning after the optimum tide, (one that peaks just at dark), the morning of that optimum tide and one day prior to this tide. Flying three consecutive days tends to smooth out daily variability in turtle activity. Three days of surveys at each twice monthly spring tide in June and July results in a total of 12 surveys during the most active portion of the nesting season for southeastern U.S. loggerheads and provides approximately a 17% sample of the nesting effort.

The surveys are conducted for three consecutive years. The differences in annual nesting effort are a consequence of a species that exhibits different remigration intervals. Thus there are high and low nesting years as the two or three-year cycles overlap. Therefore, the three survey years must either be averaged or summed to smooth out the inherent between-year variability in nesting. The result is one set of surveys. Sets are conducted on a five-year cycle, thus they are separated by two non-survey years. Richardson (1982) reported that 43% of Georgia loggerheads nest on a two-year cycle (remigration interval), 36% on a three-year cycle, and 4% nest annually. Thus, surveys flown for three consecutive years monitor approximately 83% of the nesting population.

Ground truth surveys

To calculate the accuracy of the aerial observations, ground-truth surveys were carried out on a subsample of the beaches. These included Sand/South, Cape and Kiawah Islands. Ground surveys were made at approximately the same time as the fly-over. Large numbers were drawn in the sand at 1,000-m intervals before the arrival of the plane to serve as landmarks in order to sequence the tracks and assess errors. All crawls with body pits were probed to determine the presence of eggs. Ground truth surveys record "fresh" nests and false crawls, i.e. only those that had a least some part of the track in the intertidal zone of the beach, in sequence relative to the landmarks.

Data analysis

Aerial nest counts were adjusted based on the ground truth sample. This required several steps.

Step 1. The aerial "unknowns" were distributed between the nests and false crawls in the same pro-

portions for each individual island where they were seen. This results in an **adjusted aerial nest count**. If there were any unknowns on the ground truth islands, they were distributed in the same way. There should be few, if any, unknowns in the ground truth, but some might occur where thrown sand was evident, but the ground observer could not locate an egg chamber.

Step 2. The air to ground correction constant (K) was calculated.

$$K = \frac{\text{Total nests on ground truth islands}}{\text{Total adjusted aerial nests } \textbf{on ground truth islands}}$$

Step 3. The total adjusted aerial nests for **all** beaches in 12 surveys are summed and multiplied by K.

Step 4. In order to extrapolate from the 12 survey flights to total nesting effort for the season, data on daily frequency of nesting was needed. Both published and unpublished data on daily nesting from seven different islands over a total of 27 seasons were obtained. They were: Sand Island, 1977-82; South Island, 1977-82; Kiawah Island, 1980-83; Edisto Island, 1982-86 and Little Cumberland Island, Georgia, 1977-82. These data were combined to form a composite frequency distribution. This composite curve represents a total of 4,669 nests. It was converted to a three-day running average (Appendix D). The distribution of nests by day in this composite curve is assumed to be the seasonal distribution of nesting loggerheads in the northern sub-population. Based on this composite curve, a simple proportion was used:

$$\frac{\text{expected \# of nests on 12 survey dates in composite distribution}}{\text{4,669 (total nests in composite distribution)}} = \frac{\text{adj. aerial counts from 12 surveys}}{\text{x (total nesting estimate}}$$

Step 5. The season nesting estimate for **each** beach is calculated by multiplying the percent that each beach represented in the 12-flight total by the total nesting estimate.

Step 6. The **relative importance index** is derived by dividing the percent of nesting by the percent of area. For example, if a beach had 3% of the nesting effort and also was 3% of the total survey area, then its relative importance index would be l.0. This would be considered an "average" beach. Any beach with a relative importance index less than 1.0 would be considered below average, and any with a value greater than 1.0 would be considered above average.

In analyzing this long-term data set, we first looked at the nesting estimates for the entire survey area, then northern and southern sections of the coast. We then looked at undeveloped versus developed beaches and beaches with mixed-use.

The second part of the analysis involved looking at the nesting trends on individual survey zones. Again they were grouped into "undeveloped," "developed," and "mixed-use." These data calculated for each survey zone include: the length of beach, the estimated number of nests, the density of nesting, the percent of nesting each survey zone represents, the percent of the linear coastlines each survey zones represents, and finally, the relative importance index.

These data for each zone are presented in the Appendices. Appendix A contains individual survey years. Appendix B shows the data averaged for each set of surveys. Appendix C presents a combination of both, and Appendix D is the composite frequency distribution data.

RESULTS AND DISCUSSION

Statewide Trends and Nesting Estimates

Statewide nesting estimates for the four sets of flights were 1980-82 = 5,412; 1985-87 = 3,983; 1990-92 = 4,031 and 1995-97 = 2,887 (Figure 3). During the interval between the first and second set of flights, the nesting effort declined by 26.4%. This represents a reduction of more than 1,400 nests or in excess of 5% per year.

An ANOVA was run to compare the two sets. The difference was highly significant with $P>0.005$ and an F value of 78.81. Thus we believe that this decline was a true change in the status of the population and not due to variability in the remigration intervals (Figure 4).

This trend was statewide and not localized on par-

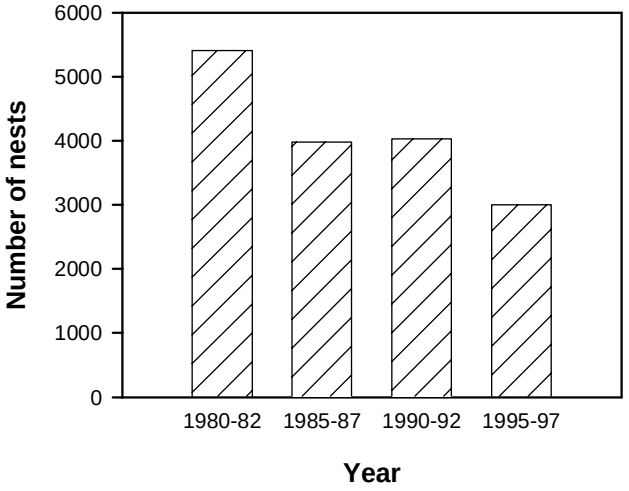

Figure 3. Nesting estimates for the South Carolina coast (Murrells Inlet to the Savannah River) averaged for each three-year survey interval, 1980-1997.

ticular beaches. We compared beaches north of Charleston with those south of Charleston (Figure 5). The decline in nesting effort was slightly higher in the northern portion of the coast, at 28.1% compared to 23.8% in the southern portion. Since a decline in nesting may be linked to development due to disturbance or alteration of habitat, we also looked at the nesting effort for undeveloped beaches (Figure 6). These include North, Sand/South, Cedar, Murphy, Raccoon Key, Bull, Otter, Pritchards, Little Capers, St. Phillips and Bay Point. Their decline is almost the same as that for developed beaches. The Cape/Lighthouse zone showed a 29.2% decline (Figure 7). The Cape/Lighthouse zone is analyzed separately because it represents between 21% and 31% of the annual nesting effort in South Carolina and can overwhelm data for other areas.

Although these beaches have been eroding during the past 40 years, some portions of them have accreted. They are isolated and are probably as undisturbed as any beaches within the range of the southeastern population. The declines noted here cannot, as far as we can determine, be attributed to anything related to the quality or quantity of the nesting habitat.

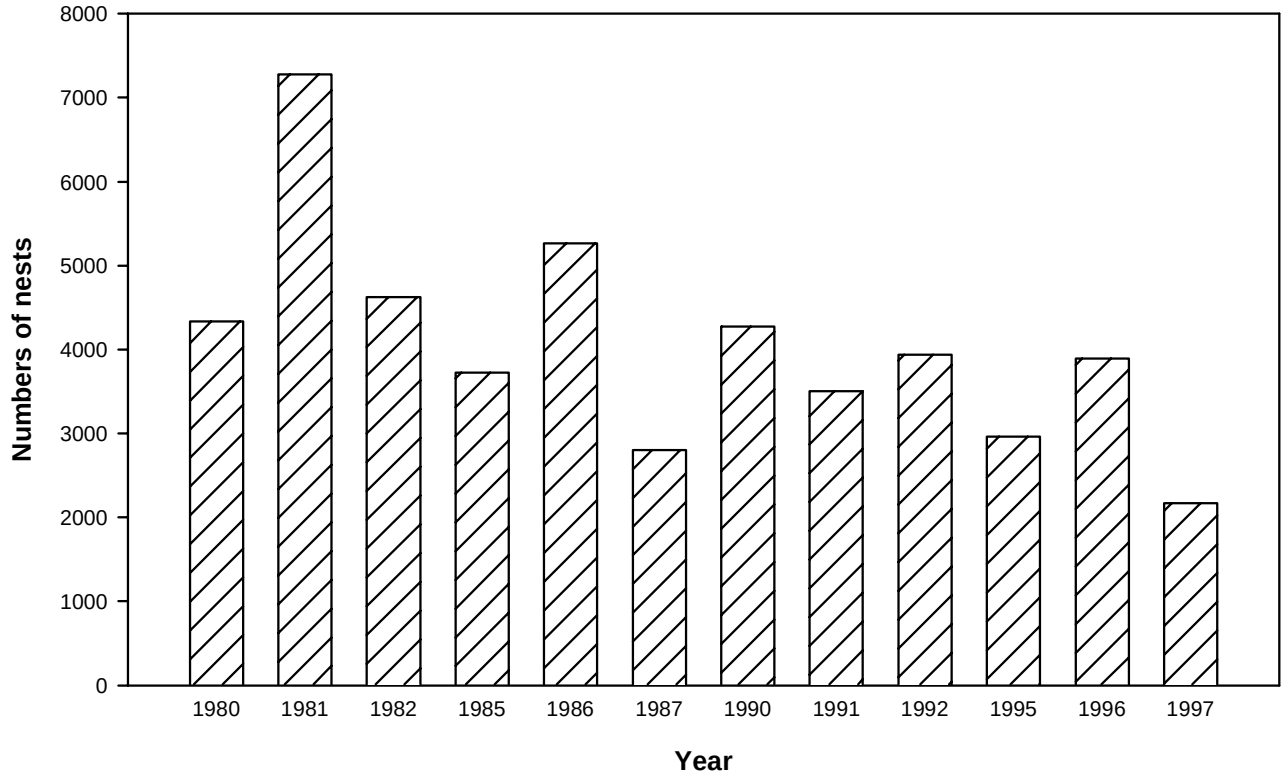

Figure 4. Annual nesting estimate for the South Carolina coast (Murrells Inlet to the Savannah River), 1980-1997.

We examined the nesting effort on nine developed beaches distributed along the coast. These include: Litchfield, Pawleys Island, Isle of Palms, Folly Beach, Kiawah, Seabrook, Harbor, Fripp and Hilton Head islands (Figure 8). The decline here may have been due to the loss of nesting habitat from construction of rock revetments.

After the third set of flights from 1990-92, we were cautiously optimistic about the results. It appeared that the statewide decline had slowed (Figure 3). But this may have been a result of when the surveys occurred relative to the yearly variability in nesting. The 1985-87 flights included two low years and one high one, while the 1990-92 surveys included two high years and one low one (Figure 4). The northern portion of the coast continued a very slight decline while the southern portion increased by nearly 8% (Figure 5). We think this may be a result of Hurricane Hugo in the fall of 1989. The eye of the storm came ashore at Charleston. With the counter-clockwise rotation, winds were onshore to the north of the city and from the landward side to the south. Therefore, all of the dunes north of Charleston were leveled, but south of there, beaches were not affected. The nest to false crawl ratio supports this. There were nearly three times

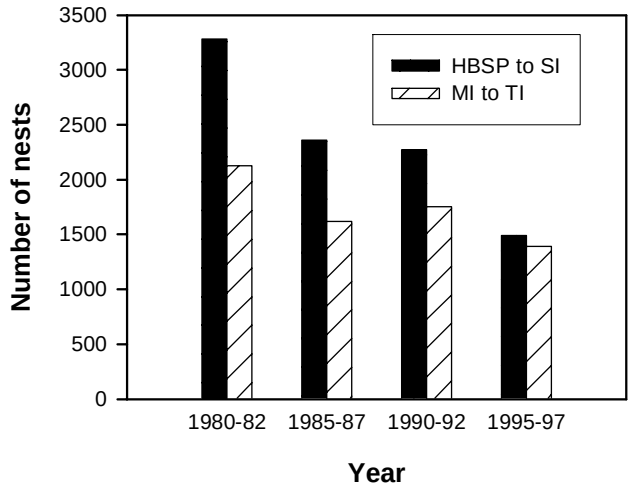

Figure 5. Mean number of nests estimated for each three-year interval for beaches north (Huntington Beach State Park to Sullivans Island) and south (Morris Island to Turtle Island) of Charleston.

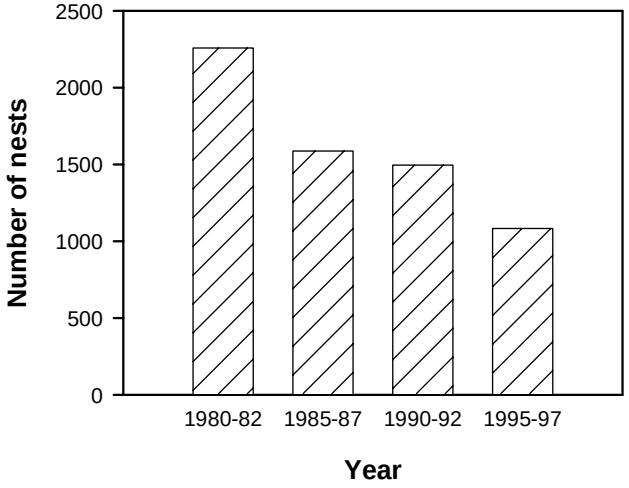

Figure 6. Mean number of nests estimated for undeveloped beaches in South Carolina (excluding Cape and Lighthouse Islands).

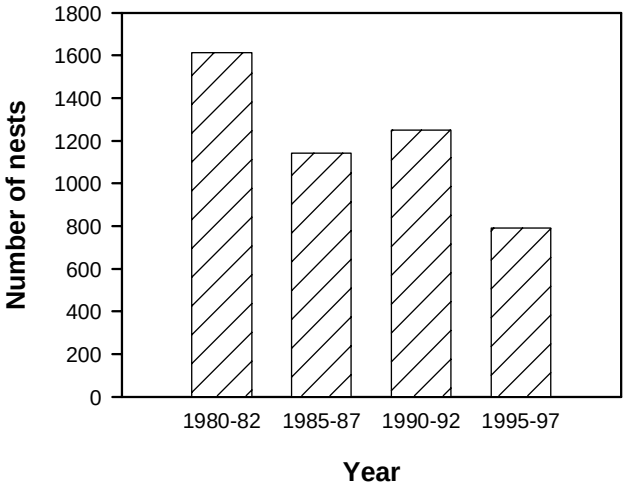

Figure 7. Mean number of nests estimated for Cape and Lighthouse Islands, Cape Romain National Wildlife Refuge.

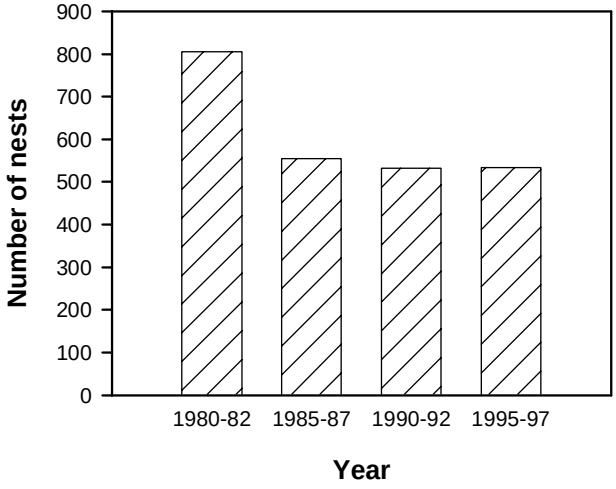

Figure 8. Mean number of nests estimated for developed beaches (Litchfield Beach, Pawleys Island, Isle of Palms, Folly Beach, Kiawah Island, Seabrook Island, Harbor Island, Fripp Island, Hilton Head Island).

as many false crawls on the beaches north of Charleston. Whether turtles shifted nesting to the south or if extensive false crawling extended their inter-nesting interval and resulted in fewer nests being laid is not known. There was a slight rise in nesting on Cape Island (Figure 7) and a decline on other beaches in this same area (Figure 6). There continued to be a slight decline on developed beaches (Figure 8).

Data from the fourth set indicate that the population had not stabilized. There was a decline of 28% between the third and fourth sets. This was a reduction of over 1,100 nests or again a decline in excess of 5% per year. Figure 4 shows the magnitude in yearly variability, but it also shows the steady decline in nesting effort. From 1980 to 1997, the high years are lower and the low years are lower. In the beginning of our surveys, the northern portion of the coast had more nesting than the southern portion. But by the fourth set of flights, the two were almost equal (Figure 5). Whether this is due to a true shift in nesting as southern beaches were re-nourished or the result of higher mortality of nesting females along the northern part of the coast is unknown. Certainly the northern undeveloped beaches have shown a sharp decline since 1980 from about 1,600 nests per season to less than 600 (Figure 6), even though nesting on Cape/Lighthouse islands was not as severe (Figure 7). The trend for the developed beaches since 1985 indicates a stable or very slight decline (Figure 8). As mentioned above, this may be due to the use of beach re-nourishment to maintain the quantity and quality of nesting habitat.

Trends and Nesting Estimates for Individual Survey Zones

Although the "site fixity" is documented for many species of marine turtles, we feel this may be influenced by the stability of the particular beach. South Carolina barrier islands are anything but stable. In fact, one of the islands only rose above sea level and became vegetated in the 1950's. We have a few examples that indicate turtles are redistributing themselves in response to the quality of nesting habitat. When the survey zones are analyzed separately, the spatial distribution over time becomes apparent (Figures 9, 10 and 11).

During the course of this study the nesting effort on the Cape/Lighthouse zone declined by over 50%.

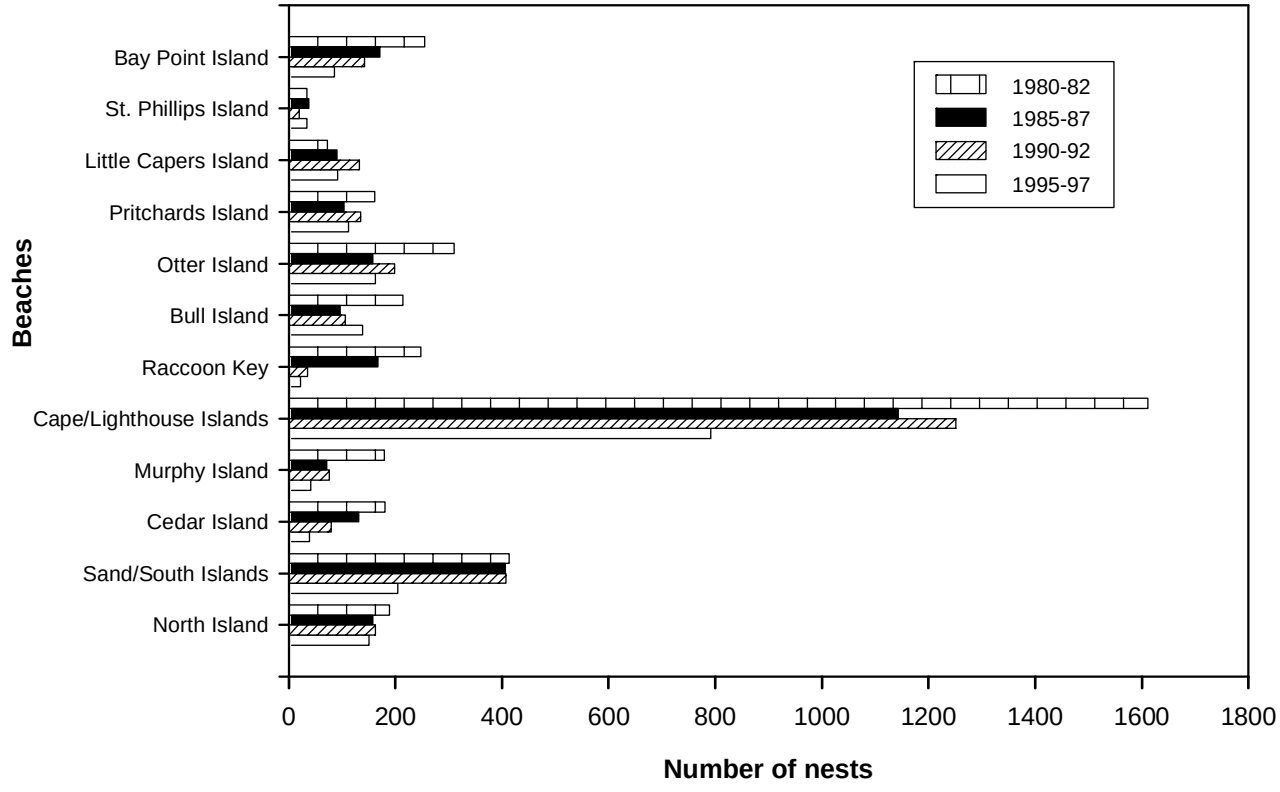

Figure 9. Mean number of nests estimated for each three-year interval for individual undeveloped beaches, 1980-1997.

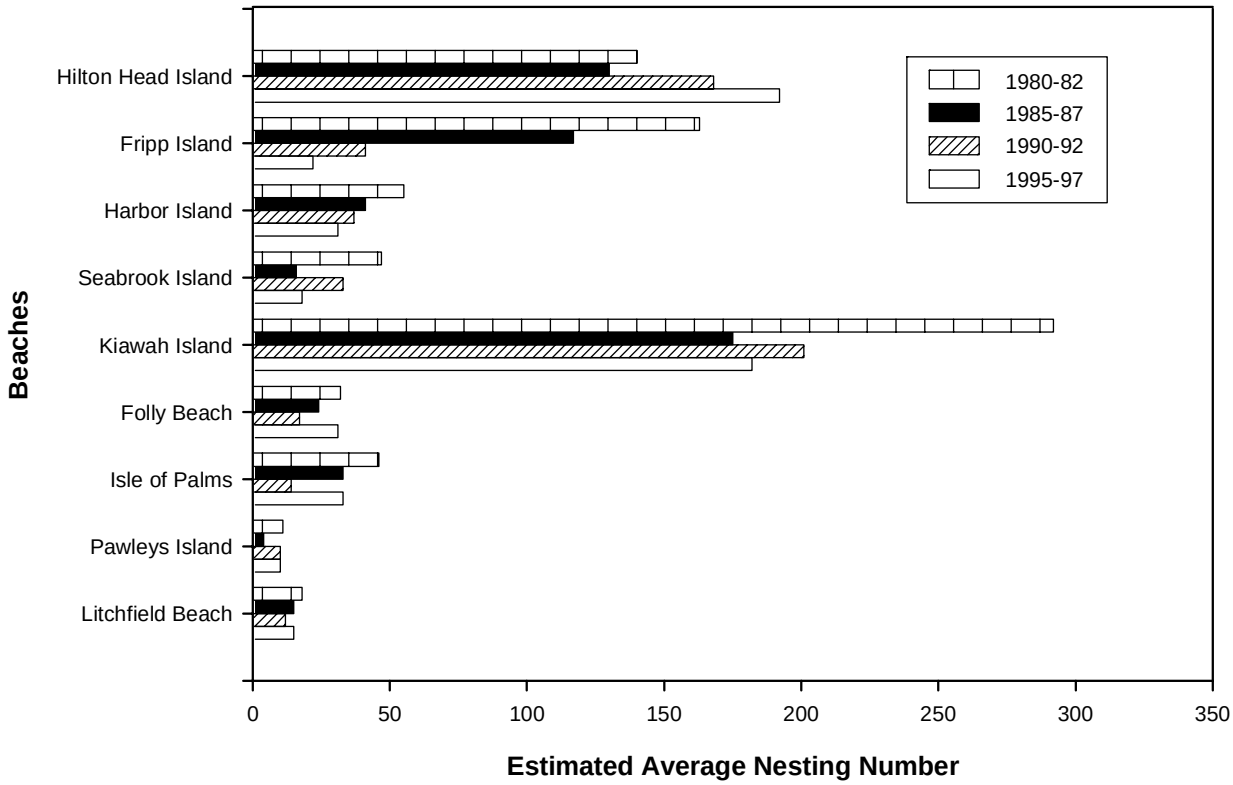

Figure 10. Mean number of nests estimated for each three-year interval for individual developed beaches, 1980-1997.

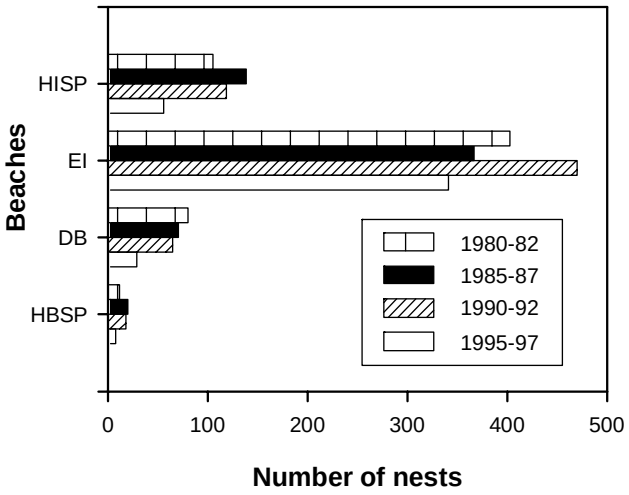

Figure 11. Mean number of nests estimated for each three-year interval for individual beaches with mixed use, 1980-1997 (HISP = Hunting Island State Park, EI = Edisto Island, DB = Debidue Beach, HBSP = Huntington Beach State Park).

Figure 9 shows how the number of estimated nests in the Cape/Lighthouse zone dwarfs all the other zones. That is why the data for undeveloped beaches are presented without this zone included. It also shows how important the Cape/Lighthouse zone is to the nesting effort in South Carolina as well as to the northern subpopulation. Why nesting females come to this specific section of coast when there seems to be equally suitable nesting habitat nearby is not fully understood. We compared several of the islands within the Cape Romain National Wildlife Refuge. Raccoon Key is an island south of the Cape/Lighthouse Islands zone. Raccoon Key once contained low dunes and about 250 nests per season. Now because of severe erosion, it is just a shelly washover terrace with only about three dozen nests per season. Thus the 12.3% rise in nesting at Cape/Lighthouse during the third set of flights may be turtles that previously nested on Raccoon Key. A large sandbar just offshore and moving slowly towards the island may restore the beach's dunes.

Results of sonic and radio telemetry indicated that nesting females instrumented on South Island also used Sand, Cedar and North Islands for nesting (Murphy and Hopkins 1981). The stability seen during the first

three survey sets on Sand/South may have been the result of turtles shifting from Cedar, or maybe even Murphy Islands. The sudden drop in nesting effort on the Sand/South zone, after years of stability, is also not understood. The beaches just to the north and south of this zone, North and Cedar islands, respectively, showed a more "stepwise" decline. Cedar Island's decline was more severe than the decline seen on North Island. The pattern appears similar for Bull and Otter islands, i.e., an initial decline in the mid-1980's and then fairly stable since then.

Almost all of the undeveloped islands have shown declines over the course of this study except Little Capers and Pritchards (Figure 9). The pattern seen for Pritchards and Little Capers is probably related to the events on Fripp Island. Fripp Island once had over 150 nests per season. Over the last decade the property owners have placed rock revetments along the shoreline until now the entire island is armored. There is only a small sandbar at the north end, and nesting has declined to less than 40 nests per season during 1990-92 and to only 4 nests in 1993. Meanwhile, just to the south, Pritchards and Little Capers islands have shown increases in nesting. Bay Point and St. Phillips' patterns may also be inter-related since only a small inlet separates them. At the beginning of these surveys, five of the eleven undeveloped beaches (excluding Cape/Lighthouse) had over 200 nests per year. Now only one of them does. Since development is not a factor, these results could be due to shifts in nesting and/or mortality of nesting females.

Figure 10 shows the estimated nesting effort for developed beaches. Only Kiawah Island has exceeded 200 nests per season during the course of this study. At Hilton Head, nesting increased by 38% following beach re-nourishment in 1991. Folly Beach likewise showed an increase in nesting after re-nourishment. The results seen at Fripp Island are just the opposite. The increases in nesting noted above for Pritchards and Little Capers islands we believe is due to turtles deserting Fripp Island (Figure 10). Turtles would need to shift to other beaches as rock revetments eliminated the nesting habitat. The adjacent island to the north, Hunting Island State Park, also showed increases until erosion also eliminated its dunes. Harbor, Seabrook, Isle of Palms, Pawleys Island and Litchfield Beach showed no pattern. The low number of nests results in a small sample size for the 12 aerial surveys and were probably inadequate.

Figure 11 shows nesting estimates for islands with "mixed use." The pattern for Edisto Island is the reverse of that shown for Kiawah and Seabrook Islands. Since these three zones are adjacent, this could reflect a shift in nesting across the North Edisto River. As with the above example, the slight rise in nesting at Debidue Beach corresponds to the slight decline at North Island, which is the next island to the south. The results seen at Hunting Island and Huntington Beach State Park are similar to the other low nesting beaches mentioned above.

Density of Nesting

When density of nesting is examined (Figures 12, 13 and 14), a slightly different picture emerges. Where the Cape/Lighthouse zone had four times as many estimated nests per season than the other undeveloped beaches, the Cape/Lighthouse zone was only about twice the density of nests. The smaller islands, such as Bay Point, Otter, Sand/South and Cedar, emerge as high-density beaches. This is important to management decisions, since it would be more efficient to implement nest protection measures on these beaches. Pritchards and Little Capers also approach these densities.

On the developed beaches (Figure 13), Fripp was once at a density similar to the undeveloped islands. Now, only Harbor and Kiawah beaches have more than ten nests per kilometer per season. Three of the four mixed-use beaches exceeded this density in two of the four sets since some of their beach areas are not developed.

Percent of Nesting

The percent of nesting data, (Figures 15, 16 and 17), gives an even different picture than estimated nests and density. Once again the Cape/Lighthouse zone has the largest percentage of the total nesting effort. Second is Edisto Island, with between 7.5% in the first set to nearly 12% in the last two sets. The Sand/South zone is third with between 7.5% to slightly over 10%. Kiawah Island averaged above 5% during the course of this study. Although we did not know the exact percentages for Cape/Lighthouse, Sand/South and Kiawah, we knew from previous research that they had significant nesting. That is why they were chosen as ground truth islands. Together they comprised

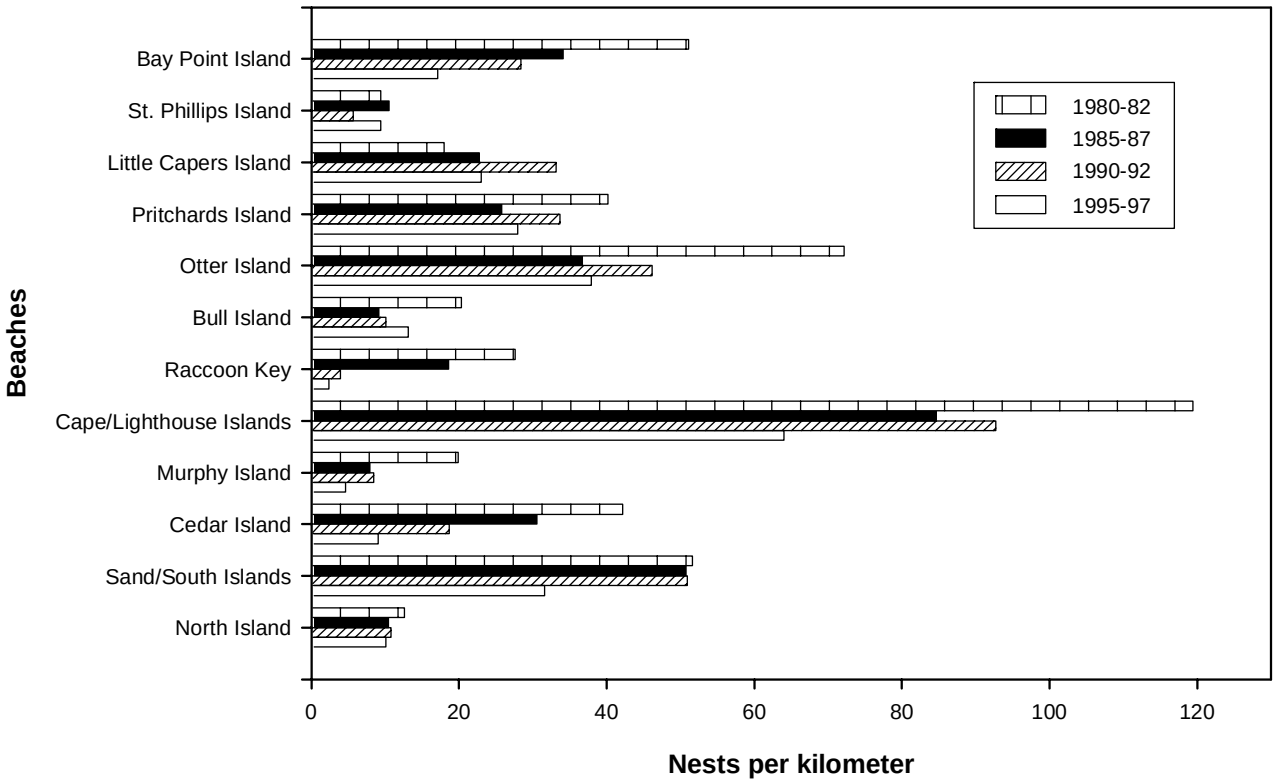

Figure 12. Mean nesting density for each three-year interval for individual undeveloped beaches, 1980-1997.

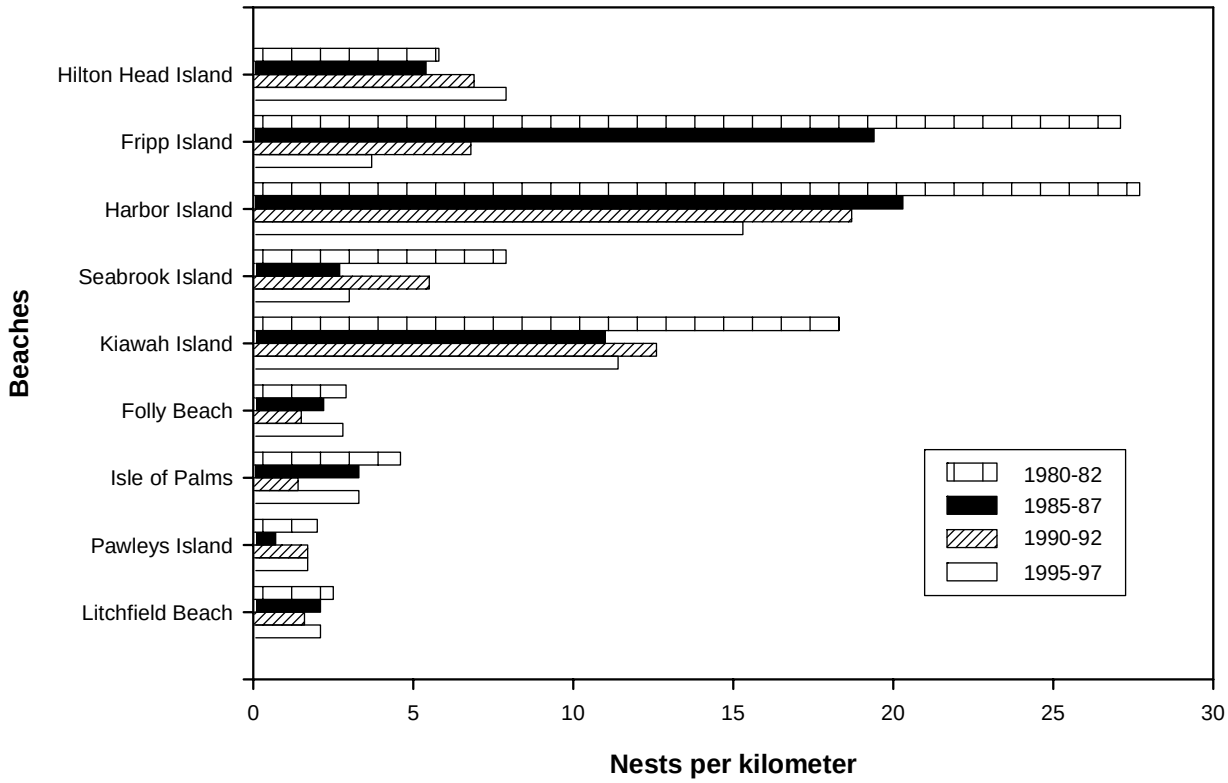

Figure 13. Mean nesting density for each three-year interval for individual developed beaches, 1980-1997.

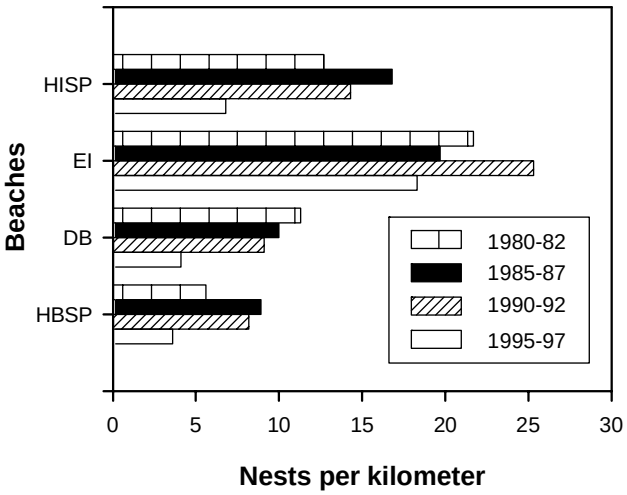

Figure 14. Mean nesting density for each three-year interval for beaches with mixed use, 1980-1997 (HISP = Hunting Island State Park, EI = Edisto Island, DB = Debidue Island, HBSP = Huntington Beach State Park).

in excess of 40% of the nesting effort, thus we feel very confident in the K values derived from these ground truth islands. Edisto and Hilton Head may appear to be good candidates for ground truth, however, they are surveyed too late in the flight to require beach patrol to wait until the fly-over before probing or moving nests.

All of the other undeveloped islands, except St. Phillips, accounted for between 3% and 6% of the nesting effort. And except for Fripp in the early years, the remainder of the developed islands were at or below 1%. Hunting Island State Park and Debidue Beach were the only "mixed-use" beaches that exceeded 1% of the nesting effort.

Percent of Area

Undeveloped zones represent 36.0% of the survey area. Developed zones represent 35.3%, mixed use 14.4% and areas with little or no nesting 14.3%. All but two of the undeveloped islands, Bay Point and Little Capers, are protected in perpetuity. If the state parks are included, along with sections of Edisto Island, the percent of habitat protected from development is also 36%.

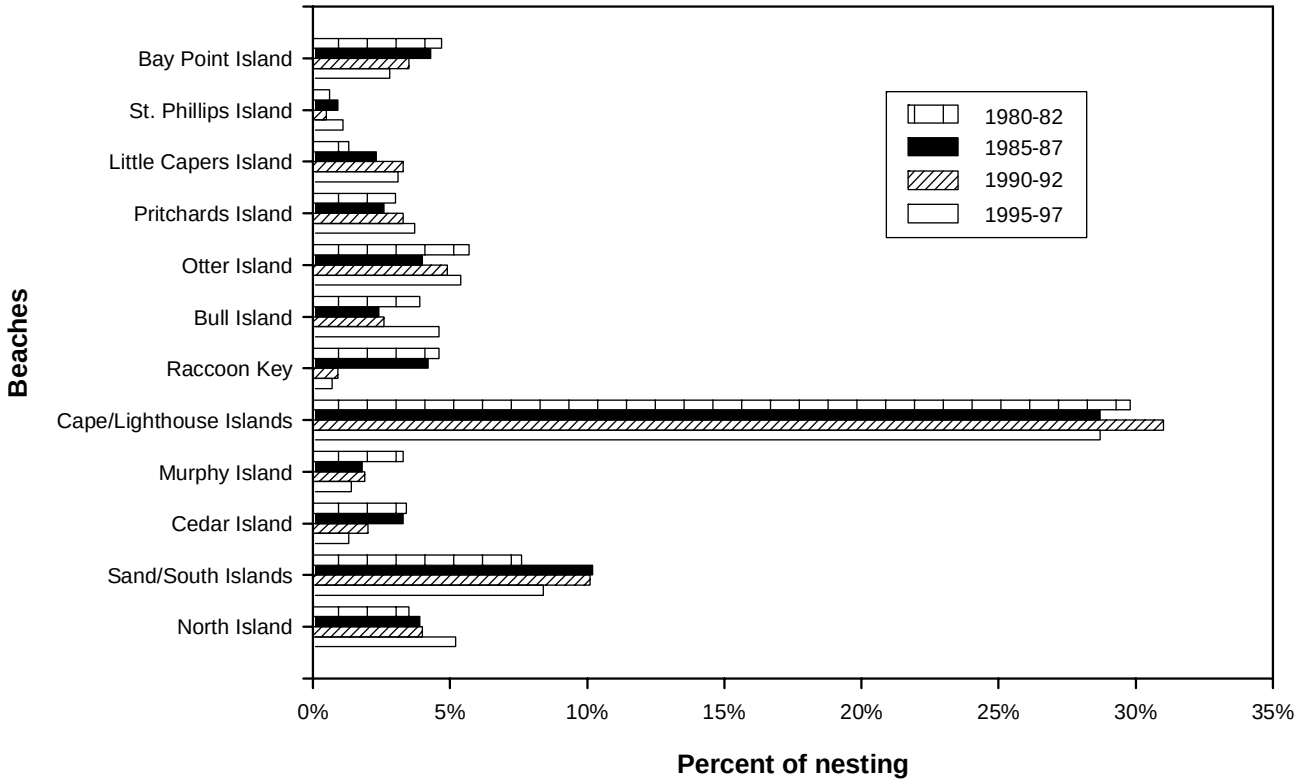

Figure 15. Percent of nesting averaged for each three-year interval for individual undeveloped beaches, 1980-1997.

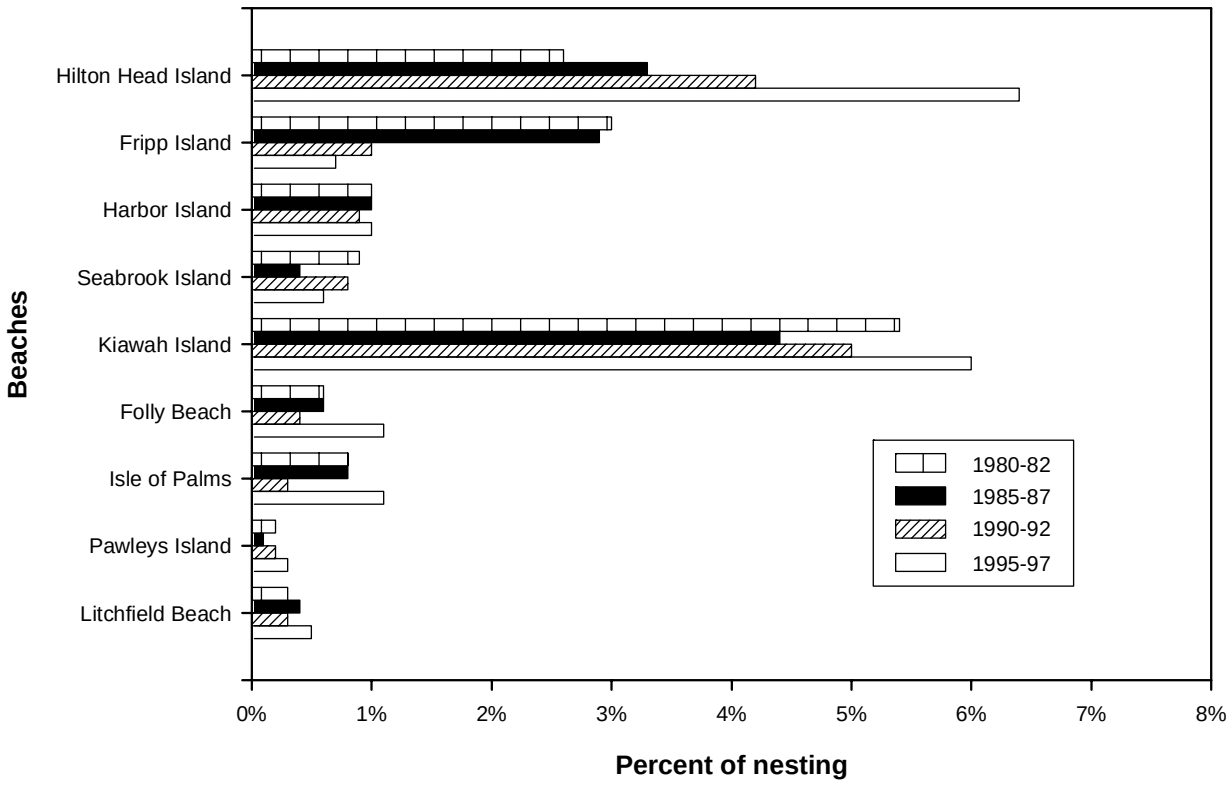

Figure 16. Percent of nesting averaged for each three-year interval for individual developed beaches, 1980-1997.

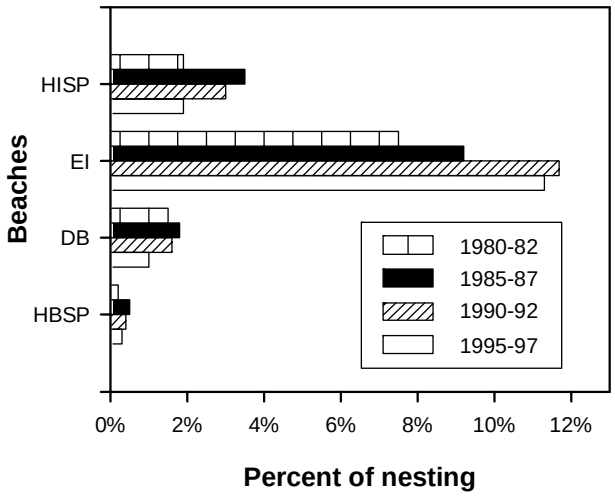

Figure 17. Percent of nesting averaged for each three-year interval for individual beaches with mixed use, 1980-1997 (HISP = Hunting Island State Park, EI = Edisto Island, DB = Debidue Beach, HBSP = Huntington

The popular press, including some conservation magazines, blame development (loss of habitat) for declining populations of sea turtles. These data show that this is not the case in South Carolina. While loss of habitat may ultimately limit recovery, currently there is adequate nesting habitat which is being used at less than carrying capacity.

Relative Importance Index

As mentioned earlier, the relative importance index is the relationship between the percent of nesting and the percent of the survey area (Figures 18, 19 and 20). In all four sets of the survey, the Cape/Lighthouse zone scored above 5.0, or its nesting effort was five times greater than an average beach. Put another way, this zone had five times more nests than would be expected if the distribution of nesting was equally distributed along the coast. Six of the other undeveloped zones (Bay Point, Little Capers, Pritchards, Otter, Cedar and Sand/South islands) scored above 1.0. And the Otter and Sand/South zones consistently scored greater than 2.0. Only one of the developed zones, Harbor Island, scored slightly above the 1.0 level with Kiawah slightly below it. Most of the developed and mixed-use zones were well below the 1.0

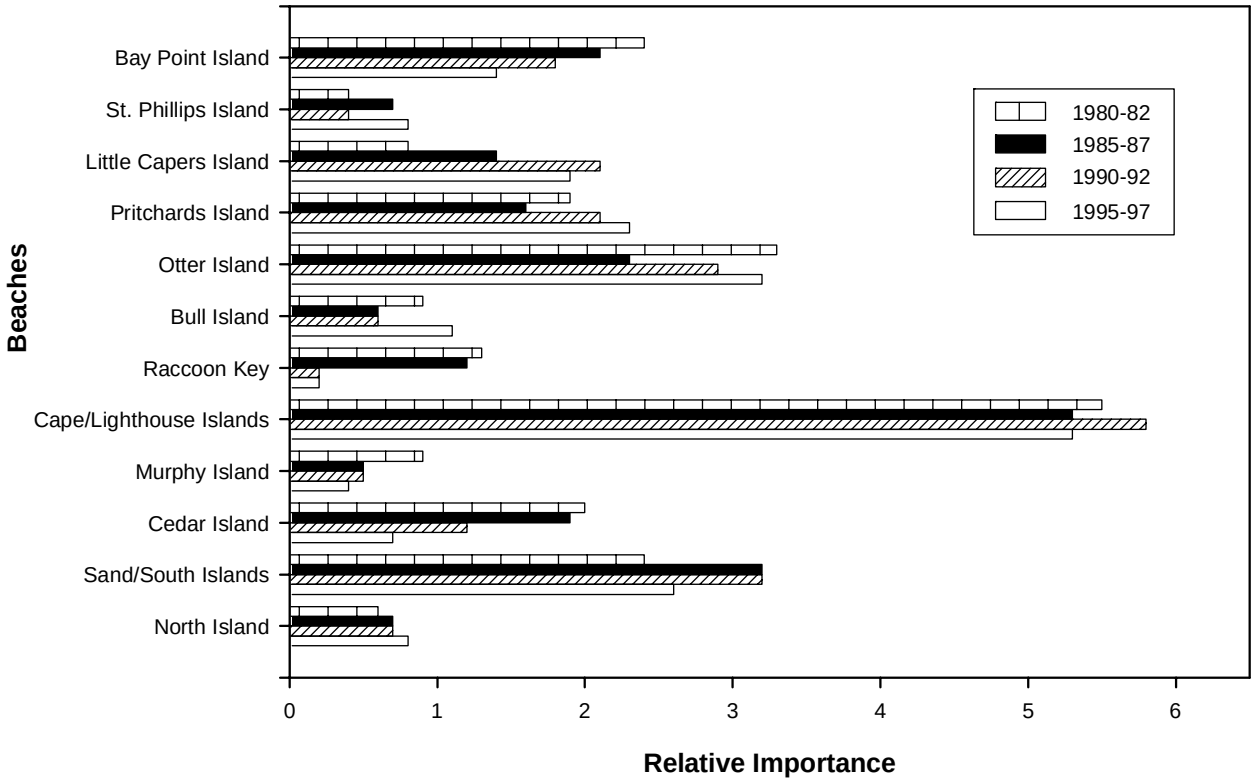

Figure 18. Relative importance averaged for each three-year interval for individual undeveloped beaches, 1980-1997.

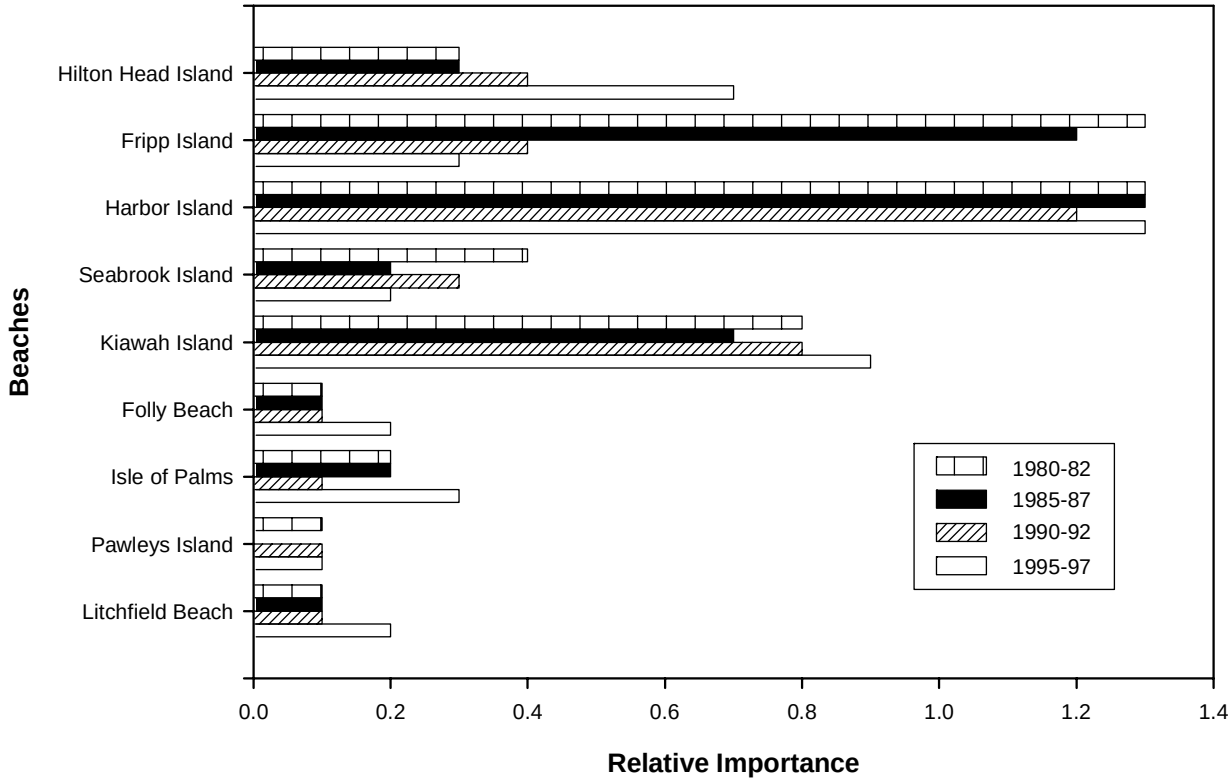

Figure 19. Relative importance averaged for each three-year interval for individual developed beaches, 1980-1997

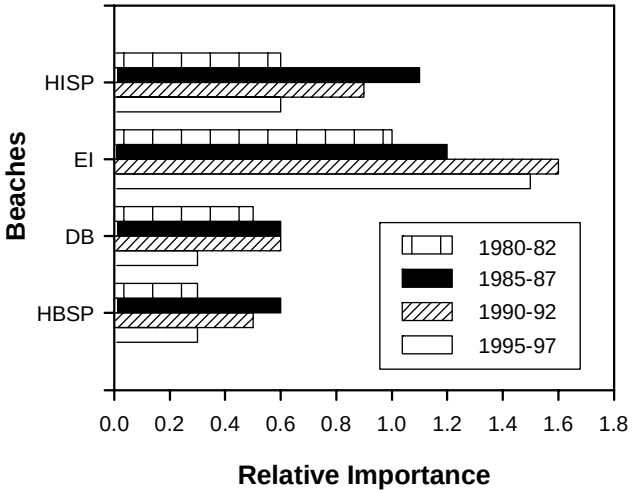

Figure 20. Relative importance averaged for each three-year interval for individual beaches with mixed use, 1980-1997 (HISP = Hunting Island State Park, EI = Edisto Island, DB = Debidue Beach, HBSP = Huntington Beach State Park)

relative importance index. Only Edisto Island scored at or slightly above 1.0 during all four sets of surveys.

Table 1 ranks the 25 survey zones based on their relative importance for the four survey sets. (The eight zones with little or no nesting are excluded.) If the rankings are divided into thirds, the zones within each sub-group remain about the same throughout the duration of the study. Rankings may shift within a sub-group, but shifting between sub-groups is rare. Exceptions are where zones are at the lower end of the higher sub-group and the higher end of the next lower sub-group. Special circumstances, such as the loss of dunes on Fripp Island and Raccoon Key and the enhancement of the beach at Hilton Head Island, can cause larger changes in the rankings. We feel that these results show that loggerheads shift their nesting sites in response to changes in the quality of the nesting habitat.

But in general over the past two decades, the spatial distribution of nesting effort has remained fairly constant. This is interesting in that not all of the undeveloped areas, such as Raccoon Key, have suitable nesting habitat. Some developed areas, such as the Isle of Palms, have good nesting habitat but low nesting. Even zones not included in the analysis for lack of nesting, such as Dewees Island, have good nesting habitat. Clearly there is more to why nesting females do not nest on certain beaches than just houses, lights and human disturbance.

This is also interesting, given that the same turtles are not nesting every year since the vast majority of nesting females are on multiple-year remigration intervals. Also, over the course of this study, some nesting females have died and neophyte nesters have been added to the population. Yet even with a declining population, the relative spatial distribution of nesting, and the other attributes analyzed here, remains remarkably the same.

When (or if) the species recovers, adequate nesting habitat must be available. Current protected and undeveloped beaches may be inadequate for increasing numbers of nesting females. It is therefore imperative that human disturbance on developed beaches be properly managed because they will be important nesting areas too.

CONCLUSIONS

The loggerhead was listed as a threatened species on 28 July 1978, under the endangered Species Act of 1973 and the State Nongame Act. The south Florida sub-population appears stable or slightly increasing (TEWG 1998). But the northern sub-population has declined since the early 1980's, especially the South Carolina portion of that sub-population. The nesting effort in South Carolina comprised 56% of the total nesting for the northern sub-population. Thus, what is happening here is significant to the future of this genetically distinct segment of the population.

The most recent Recovery Plan for the loggerhead turtle lists tasks and actions that are needed to recover the species. It also lists recovery criteria that should be met before de-listing can be considered. South Carolina began many of these actions before the plan was written and continues to implement them now.

One task was, "provide long-term protection to important nesting beaches". The state of South Carolina passed the Beachfront Management Act in 1988 which prohibits any new, hard structures to be erected on the beaches. Another task was to ensure that "at least 25 percent of all available nesting beaches is in public ownership." Thirty-six percent of the available nesting areas in South Carolina are protected in perpetuity through state, federal or private ownership.

Another recovery criterion was, "ensure at least 60 percent hatch success on major nesting beaches."

Table 1. Relative importance index rankings for survey zones, 1980-1997

1980-1982		1985-1987		1990-1992		1995-1997	
HIGH							
Zone Name	**Relative Importance**	**Zone Name**	**Relative Importance**	**Zone Name**	**Relative Importance**	**Zone Name**	**Relative Importance**
Cape/ Lighthouse Is.	5.5	Cape/ Lighthouse Is.	5.3	Cape/ Lighthouse Is.	5.8	Cape/ Lighthouse Is.	5.1
Otter Island	3.3	Sand/South Islands	3.2	Sand/South Islands	3.2	Otter Island	3.3
Sand/South Islands	2.4	Otter Island	2.3	Otter Island	2.9	Pritchards Island	2.4
Bay Point Island	2.4	Bay Point Island	2.1	Pritchards Island	2.1	Sand/South Islands	2.2
Cedar Island	2.0	Cedar Island	1.9	Little Capers Island	2.1	Little Capers Island	2.0
Pritchards Island	1.9	Pritchards Island	1.6	Bay Point Island	1.8	Edisto Island	1.6
Raccoon Key	1.3	Little Capers Island	1.4	Edisto Island	1.6	Bay Point Island	1.5
Harbor Island	1.3	Harbor Island	1.3	Cedar Island	1.2	Harbor Island	1.3
Fripp Island	1.3	Raccoon Key	1.2	Harbor Island	1.2	Bull Island	1.1
MODERATE							
Edisto Island	1.0	Edisto Island	1.2	Hunting Island SP	0.9	Kiawah Island	1.0
Murphy Island	0.9	Fripp Island	1.2	Kiawah Island	0.8	North Island	0.9
Bull Island	0.9	Hunting Island SP	1.1	North Island	0.7	Cedar Island	0.8
Kiawah Island	0.8	North Island	0.7	Debidue Beach	0.6	St. Phillips Island	0.8
Little Capers Island	0.8	Kiawah Island	0.7	Bull Island	0.6	Hilton Head Island	0.7
North Island	0.6	St. Phillips Island	0.7	Huntington Beach SP	0.5	Hunting Island SP	0.6
Hunting Island SP	0.6	Huntington Beach SP	0.6	Murphy Island	0.5	Debidue Beach	0.4
Debidue Beach	0.5	Debidue Beach	0.6	Fripp Island	0.4	Murphy Island	0.4
LOW							
Seabrook Island	0.4	Bull Island	0.6	St. Phillips Island	0.4	Huntington Beach SP	0.3
St. Phillips Island	0.4	Murphy Island	0.5	Hilton Head Island	0.4	Isle of Palms	0.3
Huntington Beach SP	0.3	Hilton Head Island	0.3	Seabrook Island	0.3	Seabrook Island	0.3
Hilton Head Island	0.3	Isle of Palms	0.2	Raccoon Key	0.2	Fripp Island	0.3
Isle of Palms	0.2	Seabrook Island	0.2	Litchfield Beach	0.1	Litchfield Beach	0.2
Litchfield Beach	0.1	Litchfield Beach	0.1	Pawleys Island	0.1	Pawleys Island	0.2
Pawleys Island	0.1	Folly Beach	0.1	Isle of Palms	0.1	Raccoon Key	0.2
Folly Beach	0.1	Pawleys Island	0.0	Folly Beach	0.1	Folly Beach	0.2

In South Carolina, 70% of the entire nesting effort is included in nest protection projects encompassing almost half of the coastline. In 1997, the hatching success ranged from 46.0% to 87% for all nests on project beaches (Hopkins-Murphy *et al.* 1999).

In addition, our agency has worked with the Office of Ocean and Coastal Resources Management (OCRM) to design sand fences that will improve the dunes while not impeding or trapping nesting turtles. We also work with other federal and state agencies to ensure that the timing of beach re-nourishment projects avoids the nesting and hatching season. So, from a Recovery Plan aspect, we have been, and are now doing more than is required on the beaches to recover the species. The difficulty with species that have deferred maturity, such as sea turtles, is that we are already 20-25 years behind if we begin solving the problems with beach management. Crouse *et al.* (l987) have shown by modeling that beach management alone will not recover sea turtle populations.

Since the declines we documented were coastwide and involved both developed and undeveloped beaches, apparently the mortality was occurring in the sea. The need for turtle excluder devices (TEDs) in shrimp trawls to protect large juvenile, sub-adult and adult turtles was obvious from our aerial survey data and from the Crouse *et al.* model. We thought the required use of TEDs should reverse the downward trend sooner than nest protection alone. South Carolina was the first state to enact regulations requiring TED use in l988. This was largely based on the first two sets of flights showing a 26.4% decline. Although both the state and federal regulations were held up in lawsuits for two seasons, there was at least partial TED use during l988 and l989. And there has been good compliance in South Carolina since TED regulations went into full force in l991.

After the third set of flights, where it appeared the decline had stabilized, we wondered if there was a relationship between the change in the nesting population and the use of TEDs. The mean number of strandings per season for juvenile and sub-adult loggerheads dropped from 146.6 to 50.3 and from 38.3 to 8.5, respectively, before and after TED implementation. During this same time, the number of adult females stranding per season went from 27.1 to 13.8. We did not include any April strandings that were caused by a set net fishery for Atlantic sturgeon or any male turtles. Juveniles comprised approximately 69% of the total strandings for both periods. However, while the percent composition of sub-adults declined from 18.1% to 11.7% after TED implementation, the percent of adult females rose from 12.8% to 18.9% of the total strandings. This shift toward adult females indicated that TEDs may not exclude all size turtles equally. This information was presented at the 14th Annual Symposium on Sea Turtle Biology and Conservation in 1994.

The fourth set of statewide aerial surveys and individual beach monitoring showed that the decline had continued despite the use of TEDs. Based on discussions at the Turtle Expert Working Group meetings, Epperly and Teas (1999) performed an analysis where they looked at carapace width and body depth of loggerhead turtles in the strandings database. They found that, "strandings of loggerhead turtles with body depths greater than the currently required minimum TED height openings has ranged between 33% and 47% of the total measured strandings since 1986. And in the last 3 years nearly 1300 stranded loggerhead turtles were deeper bodied than the currently required minimum TED height opening." Until TED openings are adjusted to exclude larger loggerhead turtles, the decline will continue and our northern sub-population will be in the same, critical state as the Kemp's ridley.

We can no longer be complacent about loggerhead turtle populations, especially those in South Carolina, Georgia and North Carolina. If Bowen *et al.* (1993) are correct, the large number of turtles nesting in Florida will not augment our stocks. Aerial beach surveys should be continued to monitor the long-term status and trends of the South Carolina loggerhead turtle population until an upward trend is documented and/or until the recovery goal of 10,000 nests per season is reached.

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Appendix A

1980

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	12	5.5	0.3%	0.9%	0.3
Litchfield Beach	7.2	12	1.7	0.3%	2.9%	0.1
Pawleys Island	5.8	0	0.0	0.0%	2.3%	0.0
Debidue Beach	7.1	81	11.4	1.9%	2.8%	0.7
North Island	15.0	148	9.9	3.4%	6.0%	0.6
Sand/South Islands	8.0	324	40.5	7.5%	3.2%	2.3
Cedar Island	4.3	138	32.1	3.2%	1.7%	1.9
Murphy Island	9.0	148	16.4	3.4%	3.6%	1.0
Cape/Lighthouse Islands	13.5	1525	113.0	35.2%	5.4%	6.5
Raccoon Key	9.0	178	19.8	4.1%	3.6%	1.1
Bull Island	10.5	79	7.5	1.8%	4.2%	0.4
Capers Island	5.2	69	13.3	1.6%	2.1%	0.8
Dewees Island	4.0	12	3.0	0.3%	1.6%	0.2
Isle of Palms	10.0	18	1.8	0.4%	4.0%	0.1
Sullivans Island	5.0	12	2.4	0.3%	2.0%	0.1
Morris Island	5.4	0	0.0	0.0%	2.2%	0.0
Folly Beach	11.0	46	4.2	1.1%	4.4%	0.2
Kiawah Island	16.0	210	13.1	4.8%	6.4%	0.8
Seabrook Island	6.0	37	6.2	0.9%	2.4%	0.4
Edisto Island	18.6	295	15.9	6.8%	7.4%	0.9
Pine Island	4.0	12	3.0	0.3%	1.6%	0.2
Otter Island	4.3	257	59.8	5.9%	1.7%	3.5
Harbor Island	2.0	22	11.0	0.5%	0.8%	0.6
Hunting Island SP	8.3	52	6.3	1.2%	3.3%	0.4
Fripp Island	6.0	210	35.0	4.8%	2.4%	2.0
Pritchards Island	4.0	86	21.5	2.0%	1.6%	1.2
Little Capers Island	4.0	51	12.8	1.2%	1.6%	0.7
St. Phillips Island	3.6	49	13.6	1.1%	1.4%	0.8
Bay Point Island	5.0	189	37.8	4.4%	2.0%	2.2
Hilton Head Island	24.3	62	2.6	1.4%	9.7%	0.1
Daufuskie Island	8.1	0	0.0	0.0%	3.2%	0.0
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	4334		100.0%	100.0%	

Appendix A cont.

1981

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	25	11.4	0.3%	0.9%	0.4
Litchfield Beach	7.2	27	3.8	0.4%	2.9%	0.1
Pawleys Island	5.8	11	1.9	0.2%	2.3%	0.1
Debidue Beach	7.1	121	17.0	1.7%	2.8%	0.6
North Island	15.0	305	20.3	4.2%	6.0%	0.7
Sand/South Islands	8.0	588	73.5	8.1%	3.2%	2.5
Cedar Island	4.3	193	44.9	2.7%	1.7%	1.5
Murphy Island	9.0	236	26.2	3.2%	3.6%	0.9
Cape/Lighthouse Islands	13.5	1811	134.1	24.9%	5.4%	4.6
Raccoon Key	9.0	435	48.3	6.0%	3.6%	1.7
Bull Island	10.5	494	47.0	6.8%	4.2%	1.6
Capers Island	5.2	49	9.4	0.7%	2.1%	0.3
Dewees Island	4.0	11	2.8	0.2%	1.6%	0.1
Isle of Palms	10.0	97	9.7	1.3%	4.0%	0.3
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	33	6.1	0.5%	2.2%	0.2
Folly Beach	11.0	27	2.5	0.4%	4.4%	0.1
Kiawah Island	16.0	409	25.6	5.6%	6.4%	0.9
Seabrook Island	6.0	61	10.2	0.8%	2.4%	0.3
Edisto Island	18.6	560	30.1	7.7%	7.4%	1.0
Pine Island	4.0	55	13.8	0.8%	1.6%	0.5
Otter Island	4.3	343	79.8	4.7%	1.7%	2.7
Harbor Island	2.0	110	55.0	1.5%	0.8%	1.9
Hunting Island SP	8.3	137	16.5	1.9%	3.3%	0.6
Fripp Island	6.0	176	29.3	2.4%	2.4%	1.0
Pritchards Island	4.0	221	55.3	3.0%	1.6%	1.9
Little Capers Island	4.0	130	32.5	1.8%	1.6%	1.1
St. Phillips Island	3.6	44	12.2	0.6%	1.4%	0.4
Bay Point Island	5.0	313	62.6	4.3%	2.0%	2.2
Hilton Head Island	24.3	254	10.5	3.5%	9.7%	0.4
Daufuskie Island	8.1	0	0.0	0.0%	3.2%	0.0
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	7276		100.0%	100.0%	

Appendix A cont.

1982

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	0	0.0	0.0%	0.9%	0.0
Litchfield Beach	7.2	15	2.1	0.3%	2.9%	0.1
Pawleys Island	5.8	23	4.0	0.5%	2.3%	0.2
Debidue Beach	7.1	38	5.4	0.8%	2.8%	0.3
North Island	15.0	114	7.6	2.5%	6.0%	0.4
Sand/South Islands	8.0	328	41.0	7.1%	3.2%	2.2
Cedar Island	4.3	213	49.5	4.6%	1.7%	2.7
Murphy Island	9.0	152	16.9	3.3%	3.6%	0.9
Cape/Lighthouse Islands	13.5	1500	111.1	32.4%	5.4%	6.0
Raccoon Key	9.0	131	14.6	2.8%	3.6%	0.8
Bull Island	10.5	68	6.5	1.5%	4.2%	0.4
Capers Island	5.2	82	15.8	1.8%	2.1%	0.9
Dewees Island	4.0	8	2.0	0.2%	1.6%	0.1
Isle of Palms	10.0	23	2.3	0.5%	4.0%	0.1
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	23	4.3	0.5%	2.2%	0.2
Folly Beach	11.0	23	2.1	0.5%	4.4%	0.1
Kiawah Island	16.0	257	16.1	5.6%	6.4%	0.9
Seabrook Island	6.0	44	7.3	1.0%	2.4%	0.4
Edisto Island	18.6	355	19.1	7.7%	7.4%	1.0
Pine Island	4.0	8	2.0	0.2%	1.6%	0.1
Otter Island	4.3	331	77.0	7.2%	1.7%	4.2
Harbor Island	2.0	34	17.0	0.7%	0.8%	0.9
Hunting Island SP	8.3	127	15.3	2.7%	3.3%	0.8
Fripp Island	6.0	102	17.0	2.2%	2.4%	0.9
Pritchards Island	4.0	175	43.8	3.8%	1.6%	2.4
Little Capers Island	4.0	35	8.8	0.8%	1.6%	0.5
St. Phillips Island	3.6	8	2.2	0.2%	1.4%	0.1
Bay Point Island	5.0	264	52.8	5.7%	2.0%	2.9
Hilton Head Island	24.3	104	4.3	2.2%	9.7%	0.2
Daufuskie Island	8.1	34	4.2	0.7%	3.2%	0.2
Turtle Island	4.0	8	2.0	0.2%	1.6%	0.1
TOTAL	250.4	4627		100.0%	100.0%	

Appendix A cont.

1985

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	6	2.7	0.2%	0.9%	0.2
Litchfield Beach	7.2	0	0.0	0.0%	2.9%	0.0
Pawleys Island	5.8	0	0.0	0.0%	2.3%	0.0
Debidue Beach	7.1	77	10.8	2.1%	2.8%	0.7
North Island	15.0	160	10.7	4.3%	6.0%	0.7
Sand/South Islands	8.0	384	48.0	10.3%	3.2%	3.2
Cedar Island	4.3	121	28.1	3.2%	1.7%	1.9
Murphy Island	9.0	38	4.2	1.0%	3.6%	0.3
Cape/Lighthouse Islands	13.5	887	65.7	23.8%	5.4%	4.4
Raccoon Key	9.0	230	25.6	6.2%	3.6%	1.7
Bull Island	10.5	70	6.7	1.9%	4.2%	0.4
Capers Island	5.2	45	8.7	1.2%	2.1%	0.6
Dewees Island	4.0	13	3.3	0.3%	1.6%	0.2
Isle of Palms	10.0	51	5.1	1.4%	4.0%	0.3
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	26	4.8	0.7%	2.2%	0.3
Folly Beach	11.0	13	1.2	0.3%	4.4%	0.1
Kiawah Island	16.0	177	11.1	4.7%	6.4%	0.7
Seabrook Island	6.0	3	0.5	0.1%	2.4%	0.0
Edisto Island	18.6	319	17.2	8.6%	7.4%	1.2
Pine Island	4.0	13	3.3	0.3%	1.6%	0.2
Otter Island	4.3	195	45.3	5.2%	1.7%	3.0
Harbor Island	2.0	45	22.5	1.2%	0.8%	1.5
Hunting Island SP	8.3	175	21.1	4.7%	3.3%	1.4
Fripp Island	6.0	121	20.2	3.2%	2.4%	1.4
Pritchards Island	4.0	102	25.5	2.7%	1.6%	1.7
Little Capers Island	4.0	83	20.8	2.2%	1.6%	1.4
St. Phillips Island	3.6	32	8.9	0.9%	1.4%	0.6
Bay Point Island	5.0	195	39.0	5.2%	2.0%	2.6
Hilton Head Island	24.3	115	4.7	3.1%	9.7%	0.3
Daufuskie Island	8.1	32	4.0	0.9%	3.2%	0.3
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	3728		100.0%	100.0%	

Appendix A cont.

1986

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	42	19.1	0.8%	0.9%	0.9
Litchfield Beach	7.2	24	3.3	0.5%	2.9%	0.2
Pawleys Island	5.8	12	2.1	0.2%	2.3%	0.1
Debidue Beach	7.1	90	12.7	1.7%	2.8%	0.6
North Island	15.0	198	13.2	3.8%	6.0%	0.6
Sand/South Islands	8.0	526	65.8	10.0%	3.2%	3.1
Cedar Island	4.3	234	54.4	4.4%	1.7%	2.6
Murphy Island	9.0	132	14.7	2.5%	3.6%	0.7
Cape/Lighthouse Islands	13.5	1531	113.4	29.1%	5.4%	5.4
Raccoon Key	9.0	162	18.0	3.1%	3.6%	0.9
Bull Island	10.5	162	15.4	3.1%	4.2%	0.7
Capers Island	5.2	48	9.2	0.9%	2.1%	0.4
Dewees Island	4.0	0	0.0	0.0%	1.6%	0.0
Isle of Palms	10.0	30	3.0	0.6%	4.0%	0.1
Sullivans Island	5.0	12	2.4	0.2%	2.0%	0.1
Morris Island	5.4	48	8.9	0.9%	2.2%	0.4
Folly Beach	11.0	30	2.7	0.6%	4.4%	0.1
Kiawah Island	16.0	234	14.6	4.4%	6.4%	0.7
Seabrook Island	6.0	24	4.0	0.5%	2.4%	0.2
Edisto Island	18.6	539	29.0	10.2%	7.4%	1.4
Pine Island	4.0	6	1.5	0.1%	1.6%	0.1
Otter Island	4.3	168	39.1	3.2%	1.7%	1.9
Harbor Island	2.0	60	30.0	1.1%	0.8%	1.4
Hunting Island SP	8.3	138	16.6	2.6%	3.3%	0.8
Fripp Island	6.0	174	29.0	3.3%	2.4%	1.4
Pritchards Island	4.0	138	34.5	2.6%	1.6%	1.6
Little Capers Island	4.0	156	39.0	3.0%	1.6%	1.9
St. Phillips Island	3.6	42	11.7	0.8%	1.4%	0.6
Bay Point Island	5.0	174	34.8	3.3%	2.0%	1.7
Hilton Head Island	24.3	132	5.4	2.5%	9.7%	0.3
Daufuskie Island	8.1	0	0.0	0.0%	3.2%	0.0
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	5266		100.0%	100.0%	

Appendix A cont.

1987

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	11	5.0	0.4%	0.9%	0.4
Litchfield Beach	7.2	22	3.1	0.7%	2.9%	0.3
Pawleys Island	5.8	0	0.0	0.0%	2.3%	0.0
Debidue Beach	7.1	46	6.5	1.6%	2.8%	0.5
North Island	15.0	112	7.5	3.8%	6.0%	0.6
Sand/South Islands	8.0	307	38.4	10.4%	3.2%	3.3
Cedar Island	4.3	39	9.1	1.3%	1.7%	0.8
Murphy Island	9.0	44	4.9	1.5%	3.6%	0.4
Cape/Lighthouse Islands	13.5	1011	74.9	34.2%	5.4%	6.3
Raccoon Key	9.0	110	12.2	3.7%	3.6%	1.0
Bull Island	10.5	55	5.2	1.9%	4.2%	0.4
Capers Island	5.2	22	4.2	0.7%	2.1%	0.4
Dewees Island	4.0	0	0.0	0.0%	1.6%	0.0
Isle of Palms	10.0	17	1.7	0.6%	4.0%	0.1
Sullivans Island	5.0	5	1.0	0.2%	2.0%	0.1
Morris Island	5.4	22	4.1	0.7%	2.2%	0.3
Folly Beach	11.0	28	2.5	0.9%	4.4%	0.2
Kiawah Island	16.0	115	7.2	3.9%	6.4%	0.6
Seabrook Island	6.0	22	3.7	0.7%	2.4%	0.3
Edisto Island	18.6	242	13.0	8.2%	7.4%	1.1
Pine Island	4.0	5	1.3	0.2%	1.6%	0.1
Otter Island	4.3	110	25.6	3.7%	1.7%	2.2
Harbor Island	2.0	17	8.5	0.6%	0.8%	0.7
Hunting Island SP	8.3	105	12.7	3.6%	3.3%	1.1
Fripp Island	6.0	55	9.2	1.9%	2.4%	0.8
Pritchards Island	4.0	69	17.3	2.3%	1.6%	1.5
Little Capers Island	4.0	33	8.3	1.1%	1.6%	0.7
St. Phillips Island	3.6	39	10.8	1.3%	1.4%	0.9
Bay Point Island	5.0	143	28.6	4.8%	2.0%	2.4
Hilton Head Island	24.3	144	5.9	4.9%	9.7%	0.5
Daufuskie Island	8.1	5	0.6	0.2%	3.2%	0.1
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	2955		100.0%	100.0%	

Appendix A cont.

1990

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	12	5.5	0.3%	0.9%	0.3
Litchfield Beach	7.2	12	1.7	0.3%	2.9%	0.1
Pawleys Island	5.8	12	2.1	0.3%	2.3%	0.1
Debidue Beach	7.1	42	5.9	0.9%	2.8%	0.3
North Island	15.0	226	15.1	5.0%	6.0%	0.8
Sand/South Islands	8.0	488	61.0	10.9%	3.2%	3.4
Cedar Island	4.3	89	20.7	2.0%	1.7%	1.2
Murphy Island	9.0	77	8.6	1.7%	3.6%	0.5
Cape/Lighthouse Islands	13.5	1450	107.4	32.3%	5.4%	6.0
Raccoon Key	9.0	36	4.0	0.8%	3.6%	0.2
Bull Island	10.5	95	9.0	2.1%	4.2%	0.5
Capers Island	5.2	30	5.8	0.7%	2.1%	0.3
Dewees Island	4.0	6	1.5	0.1%	1.6%	0.1
Isle of Palms	10.0	6	0.6	0.1%	4.0%	0.0
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	24	4.4	0.5%	2.2%	0.2
Folly Beach	11.0	12	1.1	0.3%	4.4%	0.1
Kiawah Island	16.0	268	16.8	6.0%	6.4%	0.9
Seabrook Island	6.0	24	4.0	0.5%	2.4%	0.2
Edisto Island	18.6	553	29.7	12.3%	7.4%	1.7
Pine Island	4.0	0	0.0	0.0%	1.6%	0.0
Otter Island	4.3	190	44.2	4.2%	1.7%	2.5
Harbor Island	2.0	24	12.0	0.5%	0.8%	0.7
Hunting Island SP	8.3	149	18.0	3.3%	3.3%	1.0
Fripp Island	6.0	42	7.0	0.9%	2.4%	0.4
Pritchards Island	4.0	172	43.0	3.8%	1.6%	2.4
Little Capers Island	4.0	125	31.3	2.8%	1.6%	1.7
St. Phillips Island	3.6	24	6.7	0.5%	1.4%	0.4
Bay Point Island	5.0	131	26.2	2.9%	2.0%	1.5
Hilton Head Island	24.3	160	6.6	3.6%	9.7%	0.4
Daufuskie Island	8.1	12	1.5	0.3%	3.2%	0.1
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	4491		100.0%	100.0%	

Appendix A cont.

1991

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	42	19.1	1.1%	0.9%	1.3
Litchfield Beach	7.2	18	2.5	0.5%	2.9%	0.2
Pawleys Island	5.8	18	3.1	0.5%	2.3%	0.2
Debidue Beach	7.1	102	14.4	2.8%	2.8%	1.0
North Island	15.0	108	7.2	3.0%	6.0%	0.5
Sand/South Islands	8.0	360	45.0	9.8%	3.2%	3.1
Cedar Island	4.3	102	23.7	2.8%	1.7%	1.6
Murphy Island	9.0	90	10.0	2.5%	3.6%	0.7
Cape/Lighthouse Islands	13.5	1172	86.8	32.0%	5.4%	5.9
Raccoon Key	9.0	48	5.3	1.3%	3.6%	0.4
Bull Island	10.5	108	10.3	3.0%	4.2%	0.7
Capers Island	5.2	36	6.9	1.0%	2.1%	0.5
Dewees Island	4.0	0	0.0	0.0%	1.6%	0.0
Isle of Palms	10.0	0	0.0	0.0%	4.0%	0.0
Sullivans Island	5.0	12	2.4	0.3%	2.0%	0.2
Morris Island	5.4	24	4.4	0.7%	2.2%	0.3
Folly Beach	11.0	18	1.6	0.5%	4.4%	0.1
Kiawah Island	16.0	144	9.0	3.9%	6.4%	0.6
Seabrook Island	6.0	24	4.0	0.7%	2.4%	0.3
Edisto Island	18.6	445	23.9	12.2%	7.4%	1.6
Pine Island	4.0	0	0.0	0.0%	1.6%	0.0
Otter Island	4.3	144	33.5	3.9%	1.7%	2.3
Harbor Island	2.0	48	24.0	1.3%	0.8%	1.6
Hunting Island SP	8.3	72	8.7	2.0%	3.3%	0.6
Fripp Island	6.0	60	10.0	1.6%	2.4%	0.7
Pritchards Island	4.0	126	31.5	3.4%	1.6%	2.2
Little Capers Island	4.0	132	33.0	3.6%	1.6%	2.3
St. Phillips Island	3.6	12	3.3	0.3%	1.4%	0.2
Bay Point Island	5.0	114	22.8	3.1%	2.0%	1.6
Hilton Head Island	24.3	72	3.0	2.0%	9.7%	0.2
Daufuskie Island	8.1	6	0.7	0.2%	3.2%	0.1
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	3657		100.0%	100.0%	

Appendix A cont.

1992

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	0	0.0	0.0%	0.9%	0.0
Litchfield Beach	7.2	5	0.7	0.1%	2.9%	0.0
Pawleys Island	5.8	0	0.0	0.0%	2.3%	0.0
Debidue Beach	7.1	50	7.0	1.3%	2.8%	0.4
North Island	15.0	151	10.1	3.8%	6.0%	0.6
Sand/South Islands	8.0	373	46.6	9.5%	3.2%	3.0
Cedar Island	4.3	50	11.6	1.3%	1.7%	0.7
Murphy Island	9.0	61	6.8	1.5%	3.6%	0.4
Cape/Lighthouse Islands	13.5	1130	83.7	28.7%	5.4%	5.3
Raccoon Key	9.0	20	2.2	0.5%	3.6%	0.1
Bull Island	10.5	116	11.0	2.9%	4.2%	0.7
Capers Island	5.2	20	3.8	0.5%	2.1%	0.2
Dewees Island	4.0	5	1.3	0.1%	1.6%	0.1
Isle of Palms	10.0	35	3.5	0.9%	4.0%	0.2
Sullivans Island	5.0	10	2.0	0.3%	2.0%	0.1
Morris Island	5.4	5	0.9	0.1%	2.2%	0.1
Folly Beach	11.0	20	1.8	0.5%	4.4%	0.1
Kiawah Island	16.0	192	12.0	4.9%	6.4%	0.8
Seabrook Island	6.0	50	8.3	1.3%	2.4%	0.5
Edisto Island	18.6	414	22.3	10.5%	7.4%	1.4
Pine Island	4.0	5	1.3	0.1%	1.6%	0.1
Otter Island	4.3	262	60.9	6.6%	1.7%	3.9
Harbor Island	2.0	40	20.0	1.0%	0.8%	1.3
Hunting Island SP	8.3	136	16.4	3.5%	3.3%	1.0
Fripp Island	6.0	20	3.3	0.5%	2.4%	0.2
Pritchards Island	4.0	106	26.5	2.7%	1.6%	1.7
Little Capers Island	4.0	141	35.3	3.6%	1.6%	2.2
St. Phillips Island	3.6	25	6.9	0.6%	1.4%	0.4
Bay Point Island	5.0	182	36.4	4.6%	2.0%	2.3
Hilton Head Island	24.3	272	11.2	6.9%	9.7%	0.7
Daufuskie Island	8.1	45	5.6	1.1%	3.2%	0.4
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	3941		100.0%	100.0%	

Appendix A cont.

1995

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	17	7.9	0.6%	0.9%	0.7
Litchfield Beach	7.2	26	3.6	0.9%	2.9%	0.3
Pawleys Island	5.8	17	3.0	0.6%	2.3%	0.3
Debidue Beach	7.1	35	4.9	1.2%	2.8%	0.4
North Island	15.0	235	15.7	7.9%	6.0%	1.3
Sand/South Islands	8.0	244	30.5	8.2%	3.2%	2.6
Cedar Island	4.3	52	12.1	1.8%	1.7%	1.0
Murphy Island	9.0	52	5.8	1.8%	3.6%	0.5
Cape/Lighthouse Islands	13.5	975	72.2	32.9%	5.4%	6.1
Raccoon Key	9.0	26	2.9	0.9%	3.6%	0.2
Bull Island	10.5	113	10.8	3.8%	4.2%	0.9
Capers Island	5.2	9	1.7	0.3%	2.1%	0.1
Dewees Island	4.0	9	2.2	0.3%	1.6%	0.2
Isle of Palms	10.0	61	6.1	2.1%	4.0%	0.5
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	17	3.2	0.6%	2.2%	0.3
Folly Beach	11.0	35	3.2	1.2%	4.4%	0.3
Kiawah Island	16.0	174	10.9	5.9%	6.4%	0.9
Seabrook Island	6.0	35	5.8	1.2%	2.4%	0.5
Edisto Island	18.6	191	10.3	6.5%	7.4%	0.9
Pine Island	4.0	0	0.0	0.0%	1.6%	0.0
Otter Island	4.3	183	42.5	6.2%	1.7%	3.6
Harbor Island	2.0	35	17.4	1.2%	0.8%	1.5
Hunting Island SP	8.3	61	7.3	2.1%	3.3%	0.6
Fripp Island	6.0	9	1.5	0.3%	2.4%	0.1
Pritchards Island	4.0	104	26.1	3.5%	1.6%	2.2
Little Capers Island	4.0	78	19.6	2.6%	1.6%	1.7
St. Phillips Island	3.6	0	0.0	0.0%	1.4%	0.0
Bay Point Island	5.0	26	5.2	0.9%	2.0%	0.4
Hilton Head Island	24.3	131	5.4	4.4%	9.7%	0.5
Daufuskie Island	8.1	9	1.1	0.3%	3.2%	0.1
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	2959		100.0%	100.0%	

Appendix A cont.

1996

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	6	2.9	0.2%	0.9%	0.2
Litchfield Beach	7.2	13	1.8	0.3%	2.9%	0.1
Pawleys Island	5.8	13	2.2	0.3%	2.3%	0.1
Debidue Beach	7.1	25	3.6	0.7%	2.8%	0.2
North Island	15.0	134	8.9	3.4%	6.0%	0.6
Sand/South Islands	8.0	271	33.8	7.0%	3.2%	2.2
Cedar Island	4.3	32	7.4	0.8%	1.7%	0.5
Murphy Island	9.0	32	3.5	0.8%	3.6%	0.2
Cape/Lighthouse Islands	13.5	1023	75.8	26.3%	5.4%	4.9
Raccoon Key	9.0	13	1.4	0.3%	3.6%	0.1
Bull Island	10.5	153	14.6	3.9%	4.2%	0.9
Capers Island	5.2	13	2.5	0.3%	2.1%	0.2
Dewees Island	4.0	0	0.0	0.0%	1.6%	0.0
Isle of Palms	10.0	19	1.9	0.5%	4.0%	0.1
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	38	7.1	1.0%	2.2%	0.5
Folly Beach	11.0	25	2.3	0.7%	4.4%	0.1
Kiawah Island	16.0	223	13.9	5.7%	6.4%	0.9
Seabrook Island	6.0	19	3.2	0.5%	2.4%	0.2
Edisto Island	18.6	573	30.8	14.7%	7.4%	2.0
Pine Island	4.0	6	1.6	0.2%	1.6%	0.1
Otter Island	4.3	248	57.8	6.4%	1.7%	3.7
Harbor Island	2.0	38	19.1	1.0%	0.8%	1.2
Hunting Island SP	8.3	89	10.7	2.3%	3.3%	0.7
Fripp Island	6.0	45	7.4	1.1%	2.4%	0.5
Pritchards Island	4.0	159	39.8	4.1%	1.6%	2.6
Little Capers Island	4.0	121	30.2	3.1%	1.6%	1.9
St. Phillips Island	3.6	83	23.0	2.1%	1.4%	1.5
Bay Point Island	5.0	134	26.7	3.4%	2.0%	1.7
Hilton Head Island	24.3	325	13.4	8.3%	9.7%	0.9
Daufuskie Island	8.1	13	1.6	0.3%	3.2%	0.1
Turtle Island	4.0	6	1.6	0.2%	1.6%	0.1
TOTAL	250.4	3892		100.0%	100.0%	

Appendix A cont.

1997

Zone name	km of beach	est. nests	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	0	0.0	0.0%	0.9%	0.0
Litchfield Beach	7.2	6	0.8	0.3%	2.9%	0.1
Pawleys Island	5.8	0	0.0	0.0%	2.3%	0.0
Debidue Beach	7.1	26	3.7	1.2%	2.8%	0.4
North Island	15.0	84	5.6	3.9%	6.0%	0.6
Sand/South Islands	8.0	244	30.5	11.2%	3.2%	3.5
Cedar Island	4.3	32	7.4	1.5%	1.7%	0.9
Murphy Island	9.0	39	4.3	1.8%	3.6%	0.5
Cape/Lighthouse Islands	13.5	593	43.9	27.3%	5.4%	5.1
Raccoon Key	9.0	26	2.9	1.2%	3.6%	0.3
Bull Island	10.5	148	14.1	6.8%	4.2%	1.6
Capers Island	5.2	6	1.2	0.3%	2.1%	0.1
Dewees Island	4.0	0	0.0	0.0%	1.6%	0.0
Isle of Palms	10.0	19	1.9	0.9%	4.0%	0.2
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	13	2.4	0.6%	2.2%	0.3
Folly Beach	11.0	32	2.9	1.5%	4.4%	0.3
Kiawah Island	16.0	148	9.3	6.8%	6.4%	1.1
Seabrook Island	6.0	0	0.0	0.0%	2.4%	0.0
Edisto Island	18.6	258	13.9	11.9%	7.4%	1.6
Pine Island	4.0	0	0.0	0.0%	1.6%	0.0
Otter Island	4.3	58	13.5	2.7%	1.7%	1.6
Harbor Island	2.0	19	9.5	0.9%	0.8%	1.1
Hunting Island SP	8.3	19	2.3	0.9%	3.3%	0.3
Fripp Island	6.0	13	2.2	0.6%	2.4%	0.3
Pritchards Island	4.0	71	17.8	3.3%	1.6%	2.0
Little Capers Island	4.0	77	19.3	3.6%	1.6%	2.2
St. Phillips Island	3.6	19	5.3	0.9%	1.4%	0.6
Bay Point Island	5.0	97	19.4	4.5%	2.0%	2.2
Hilton Head Island	24.3	122	5.0	5.6%	9.7%	0.6
Daufuskie Island	8.1	0	0.0	0.0%	3.2%	0.0
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	2169		100.0%	100.0%	

Appendix B

1980-1982

Zone name	km of beach	est. nests avg.	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	12	5.6	0.2%	0.9%	0.3
Litchfield Beach	7.2	18	2.5	0.3%	2.9%	0.1
Pawleys Island	5.8	11	2.0	0.2%	2.3%	0.1
Debidue Beach	7.1	80	11.3	1.5%	2.8%	0.5
North Island	15.0	189	12.6	3.5%	6.0%	0.6
Sand/South Islands	8.0	413	51.6	7.6%	3.2%	2.4
Cedar Island	4.3	181	42.2	3.4%	1.7%	2.0
Murphy Island	9.0	179	19.9	3.3%	3.6%	0.9
Cape/Lighthouse Islands	13.5	1612	119.4	29.8%	5.4%	5.5
Raccoon Key	9.0	248	27.6	4.6%	3.6%	1.3
Bull Island	10.5	214	20.3	3.9%	4.2%	0.9
Capers Island	5.2	67	12.8	1.2%	2.1%	0.6
Dewees Island	4.0	10	2.6	0.2%	1.6%	0.1
Isle of Palms	10.0	46	4.6	0.8%	4.0%	0.2
Sullivans Island	5.0	4	0.8	0.1%	2.0%	0.0
Morris Island	5.4	19	3.5	0.3%	2.2%	0.2
Folly Beach	11.0	32	2.9	0.6%	4.4%	0.1
Kiawah Island	16.0	292	18.3	5.4%	6.4%	0.8
Seabrook Island	6.0	47	7.9	0.9%	2.4%	0.4
Edisto Island	18.6	403	21.7	7.5%	7.4%	1.0
Pine Island	4.0	25	6.3	0.5%	1.6%	0.3
Otter Island	4.3	310	72.2	5.7%	1.7%	3.3
Harbor Island	2.0	55	27.7	1.0%	0.8%	1.3
Hunting Island SP	8.3	105	12.7	1.9%	3.3%	0.6
Fripp Island	6.0	163	27.1	3.0%	2.4%	1.3
Pritchards Island	4.0	161	40.2	3.0%	1.6%	1.9
Little Capers Island	4.0	72	18.0	1.3%	1.6%	0.8
St. Phillips Island	3.6	34	9.4	0.6%	1.4%	0.4
Bay Point Island	5.0	255	51.1	4.7%	2.0%	2.4
Hilton Head Island	24.3	140	5.8	2.6%	9.7%	0.3
Daufuskie Island	8.1	11	1.4	0.2%	3.2%	0.1
Turtle Island	4.0	3	0.7	0.0%	1.6%	0.0
TOTAL	250.4	5412		100.0%	100.0%	

Appendix B cont.

1985-1987

Zone name	km of beach	est. nests avg.	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	20	8.9	0.5%	0.9%	0.6
Litchfield Beach	7.2	15	2.1	0.4%	2.9%	0.1
Pawleys Island	5.8	4	0.7	0.1%	2.3%	0.0
Debidue Beach	7.1	71	10.0	1.8%	2.8%	0.6
North Island	15.0	157	10.4	3.9%	6.0%	0.7
Sand/South Islands	8.0	406	50.8	10.2%	3.2%	3.2
Cedar Island	4.3	131	30.5	3.3%	1.7%	1.9
Murphy Island	9.0	71	7.9	1.8%	3.6%	0.5
Cape/Lighthouse Islands	13.5	1143	84.7	28.7%	5.4%	5.3
Raccoon Key	9.0	167	18.6	4.2%	3.6%	1.2
Bull Island	10.5	96	9.1	2.4%	4.2%	0.6
Capers Island	5.2	38	7.4	1.0%	2.1%	0.5
Dewees Island	4.0	4	1.1	0.1%	1.6%	0.1
Isle of Palms	10.0	33	3.3	0.8%	4.0%	0.2
Sullivans Island	5.0	6	1.1	0.1%	2.0%	0.1
Morris Island	5.4	32	5.9	0.8%	2.2%	0.4
Folly Beach	11.0	24	2.2	0.6%	4.4%	0.1
Kiawah Island	16.0	175	11.0	4.4%	6.4%	0.7
Seabrook Island	6.0	16	2.7	0.4%	2.4%	0.2
Edisto Island	18.6	367	19.7	9.2%	7.4%	1.2
Pine Island	4.0	8	2.0	0.2%	1.6%	0.1
Otter Island	4.3	158	36.7	4.0%	1.7%	2.3
Harbor Island	2.0	41	20.3	1.0%	0.8%	1.3
Hunting Island SP	8.3	139	16.8	3.5%	3.3%	1.1
Fripp Island	6.0	117	19.4	2.9%	2.4%	1.2
Pritchards Island	4.0	103	25.8	2.6%	1.6%	1.6
Little Capers Island	4.0	91	22.7	2.3%	1.6%	1.4
St. Phillips Island	3.6	38	10.5	0.9%	1.4%	0.7
Bay Point Island	5.0	171	34.1	4.3%	2.0%	2.1
Hilton Head Island	24.3	130	5.4	3.3%	9.7%	0.3
Daufuskie Island	8.1	12	1.5	0.3%	3.2%	0.1
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	3983		100.0%	100.0%	

Appendix B cont.

1990-1992

Zone name	km of beach	est. nests avg.	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	18	8.2	0.4%	0.9%	0.5
Litchfield Beach	7.2	12	1.6	0.3%	2.9%	0.1
Pawleys Island	5.8	10	1.7	0.2%	2.3%	0.1
Debidue Beach	7.1	65	9.1	1.6%	2.8%	0.6
North Island	15.0	162	10.8	4.0%	6.0%	0.7
Sand/South Islands	8.0	407	50.9	10.1%	3.2%	3.2
Cedar Island	4.3	80	18.7	2.0%	1.7%	1.2
Murphy Island	9.0	76	8.4	1.9%	3.6%	0.5
Cape/Lighthouse Islands	13.5	1251	92.7	31.0%	5.4%	5.8
Raccoon Key	9.0	35	3.9	0.9%	3.6%	0.2
Bull Island	10.5	106	10.1	2.6%	4.2%	0.6
Capers Island	5.2	29	5.5	0.7%	2.1%	0.3
Dewees Island	4.0	4	0.9	0.1%	1.6%	0.1
Isle of Palms	10.0	14	1.4	0.3%	4.0%	0.1
Sullivans Island	5.0	7	1.5	0.2%	2.0%	0.1
Morris Island	5.4	18	3.3	0.4%	2.2%	0.2
Folly Beach	11.0	17	1.5	0.4%	4.4%	0.1
Kiawah Island	16.0	201	12.6	5.0%	6.4%	0.8
Seabrook Island	6.0	33	5.5	0.8%	2.4%	0.3
Edisto Island	18.6	470	25.3	11.7%	7.4%	1.6
Pine Island	4.0	2	0.4	0.0%	1.6%	0.0
Otter Island	4.3	199	46.2	4.9%	1.7%	2.9
Harbor Island	2.0	37	18.7	0.9%	0.8%	1.2
Hunting Island SP	8.3	119	14.3	3.0%	3.3%	0.9
Fripp Island	6.0	41	6.8	1.0%	2.4%	0.4
Pritchards Island	4.0	135	33.7	3.3%	1.6%	2.1
Little Capers Island	4.0	133	33.2	3.3%	1.6%	2.1
St. Phillips Island	3.6	20	5.7	0.5%	1.4%	0.4
Bay Point Island	5.0	142	28.4	3.5%	2.0%	1.8
Hilton Head Island	24.3	168	6.9	4.2%	9.7%	0.4
Daufuskie Island	8.1	21	2.6	0.5%	3.2%	0.2
Turtle Island	4.0	0	0.0	0.0%	1.6%	0.0
TOTAL	250.4	4031		100.0%	100.0%	

Appendix B cont.

1995-1997

Zone name	km of beach	est. nests avg.	density (nest/km)	% of nesting (n=5412.3)	% of area (250.4km)	relative importance
Huntington Beach SP	2.2	8	3.6	0.3%	0.9%	0.3
Litchfield Beach	7.2	15	2.1	0.5%	2.9%	0.2
Pawleys Island	5.8	10	1.7	0.3%	2.3%	0.2
Debidue Beach	7.1	29	4.1	1.0%	2.8%	0.4
North Island	15.0	151	10.1	5.2%	6.0%	0.9
Sand/South Islands	8.0	204	25.6	7.1%	3.2%	2.2
Cedar Island	4.3	39	9.0	1.3%	1.7%	0.8
Murphy Island	9.0	41	4.6	1.4%	3.6%	0.4
Cape/Lighthouse Islands	13.5	791	58.6	27.4%	5.4%	5.1
Raccoon Key	9.0	22	2.4	0.7%	3.6%	0.2
Bull Island	10.5	138	13.1	4.8%	4.2%	1.1
Capers Island	5.2	9	1.8	0.3%	2.1%	0.2
Dewees Island	4.0	3	0.7	0.1%	1.6%	0.1
Isle of Palms	10.0	33	3.3	1.1%	4.0%	0.3
Sullivans Island	5.0	0	0.0	0.0%	2.0%	0.0
Morris Island	5.4	23	4.2	0.8%	2.2%	0.4
Folly Beach	11.0	31	2.8	1.1%	4.4%	0.2
Kiawah Island	16.0	182	11.4	6.3%	6.4%	1.0
Seabrook Island	6.0	18	3.0	0.6%	2.4%	0.3
Edisto Island	18.6	341	18.3	11.8%	7.4%	1.6
Pine Island	4.0	2	0.5	0.1%	1.6%	0.0
Otter Island	4.3	163	37.9	5.7%	1.7%	3.3
Harbor Island	2.0	31	15.3	1.1%	0.8%	1.3
Hunting Island SP	8.3	56	6.8	2.0%	3.3%	0.6
Fripp Island	6.0	22	3.7	0.8%	2.4%	0.3
Pritchards Island	4.0	112	27.9	3.9%	1.6%	2.4
Little Capers Island	4.0	92	23.0	3.2%	1.6%	2.0
St. Phillips Island	3.6	34	9.4	1.2%	1.4%	0.8
Bay Point Island	5.0	86	17.1	3.0%	2.0%	1.5
Hilton Head Island	24.3	192	7.9	6.7%	9.7%	0.7
Daufuskie Island	8.1	7	0.9	0.2%	3.2%	0.1
Turtle Island	4.0	2	0.5	0.1%	1.6%	0.0
TOTAL	250.4	2886		100.0%	100.0%	

Appendix C

Nest Estimations 1980-1987

Zone	1980	1981	1982	AVG	1985	1986	1987	AVG
Huntington Beach SP	12	25	0	12.3	6	42	11	19.7
Litchfield Beach	12	27	15	18.0	0	24	22	15.3
Pawleys Island	0	11	23	11.3	0	12	0	4.0
Debidue Beach	81	121	38	80.0	77	90	46	71.0
North Island	148	305	114	189.0	160	198	112	156.7
Sand/South Islands	324	588	328	413.3	384	526	307	405.7
Cedar Island	138	193	213	181.3	121	234	39	131.3
Murphy Island	148	236	152	178.7	38	132	44	71.3
Cape/ Lighthouse Islands	1525	1811	1500	1612.0	887	1531	1011	1143.0
Raccoon Key	178	435	131	248.0	230	162	110	167.3
Bull Island	79	494	68	213.7	70	162	55	95.7
Capers Island	69	49	82	66.7	45	48	22	38.3
Dewees Island	12	11	8	10.3	13	0	0	4.3
Isle of Palms	18	97	23	46.0	51	30	17	32.7
Sullivans Island	12	0	0	4.0	0	12	5	5.7
Morris Island	0	33	23	18.7	26	48	22	32.0
Folly Beach	46	27	23	32.0	13	30	28	23.7
Kiawah Island	210	409	257	292.0	177	234	115	175.3
Seabrook Island	37	61	44	47.3	3	24	22	16.3
Edisto Island	295	560	355	403.3	319	539	242	366.7
Pine Island	12	55	8	25.0	13	6	5	8.0
Otter Island	257	343	331	310.3	195	168	110	157.7
Harbor Island	22	110	34	55.3	45	60	17	40.7
Hunting Island SP	52	137	127	105.3	175	138	105	139.3
Fripp Island	210	176	102	162.7	121	174	55	116.7
Pritchards Island	86	221	175	160.7	102	138	69	103.0
Little Capers Island	51	130	35	72.0	83	156	33	90.7
St. Phillips Island	49	44	8	33.7	32	42	39	37.7
Bay Point Island	189	313	264	255.3	195	174	143	170.7
Hilton Head Island	62	254	104	140.0	115	132	144	130.3
Daufuskie Island	0	0	34	11.3	32	0	5	12.3
Turtle Island	0	0	8	2.7	0	0	0	0.0
TOTAL	4334	7276	4627	5412.3	3728	5266	2955	3983.0

Appendix C cont.

Nest Estimations 1990-1997

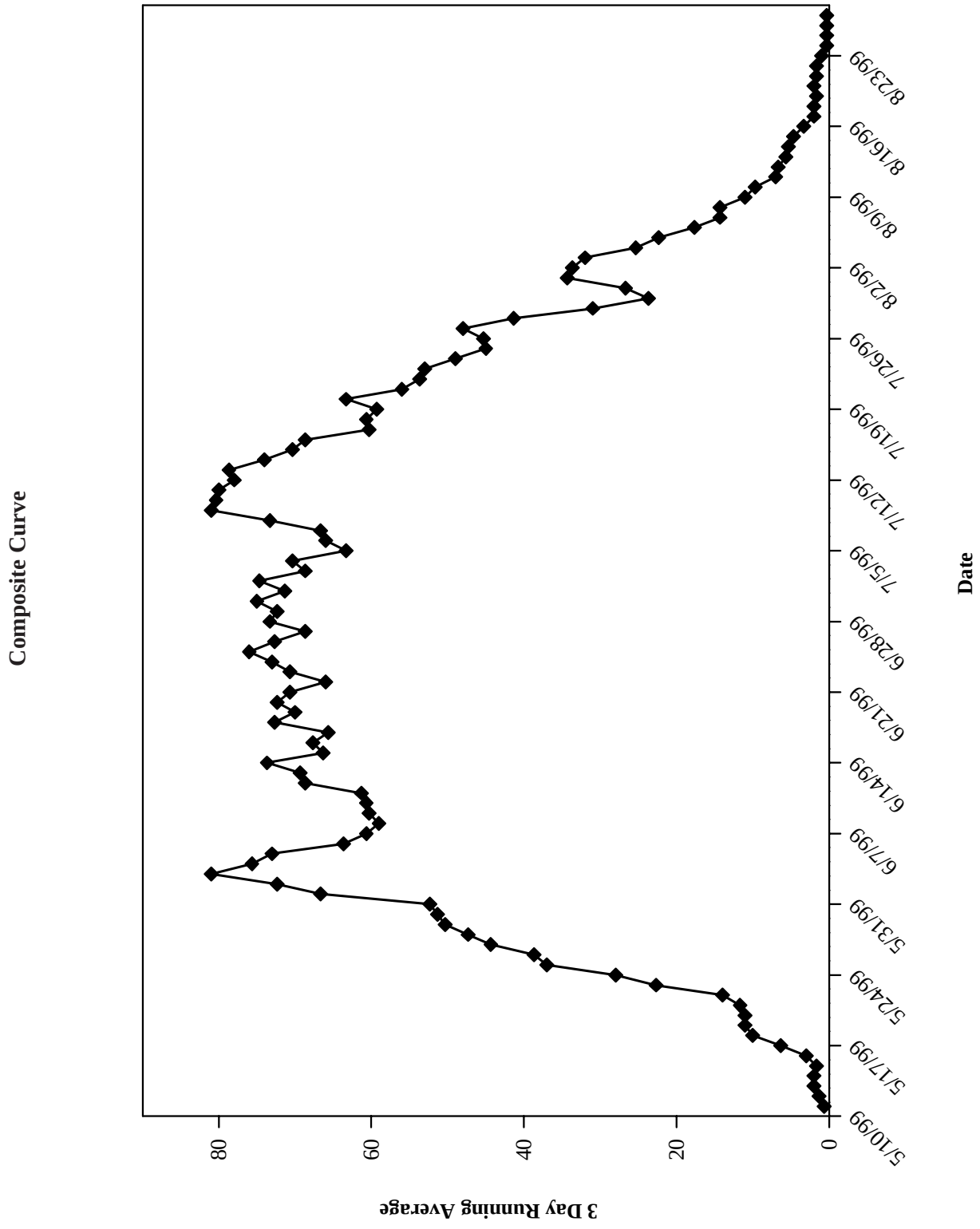
Zone	1990	1991	1992	AVG	1995	1996	1997	AVG
Huntington Beach SP	12	42	0	18.0	17	6	0	7.9
Litchfield Beach	12	18	5	11.7	26	13	6	14.9
Pawleys Island	12	18	0	10.0	17	13	0	10.0
Debidue Beach	42	102	50	64.8	35	25	26	28.8
North Island	226	108	151	161.8	235	134	84	150.9
Sand/South Islands	488	360	373	407.0	244	271	244	253.0
Cedar Island	89	102	50	80.5	52	32	32	38.7
Murphy Island	77	90	61	75.8	52	32	39	41.0
Cape/ Lighthouse Islands	1450	1172	1130	1250.5	975	1023	593	863.7
Raccoon Key	36	48	20	34.7	26	13	26	21.6
Bull Island	95	108	116	106.3	113	153	148	138.0
Capers Island	30	36	20	28.7	9	13	6	9.1
Dewees Island	6	0	5	3.7	9	0	0	2.9
Isle of Palms	6	0	35	13.8	61	19	19	33.0
Sullivans Island	0	12	10	7.4	0	0	0	0.0
Morris Island	24	24	5	17.7	17	38	13	22.9
Folly Beach	12	18	20	16.7	35	25	32	30.8
Kiawah Island	268	144	192	201.2	174	223	148	181.6
Seabrook Island	24	24	50	32.8	35	19	0	18.0
Edisto Island	553	445	414	470.7	191	573	258	340.8
Pine Island	0	0	5	1.7	0	6	0	2.1
Otter Island	190	144	262	198.7	183	248	58	163.1
Harbor Island	24	48	40	37.4	35	38	19	30.7
Hunting Island SP	149	72	136	119.0	61	89	19	56.4
Fripp Island	42	60	20	40.7	9	45	13	22.1
Pritchards Island	172	126	106	134.6	104	159	71	111.5
Little Capers Island	125	132	141	132.7	78	121	77	92.1
St. Phillips Island	24	12	25	20.4	0	83	19	33.9
Bay Point Island	131	114	182	142.2	26	134	97	85.6
Hilton Head Island	160	72	272	168.1	131	325	122	192.4
Daufuskie Island	12	6	45	21.1	9	13	0	7.1
Turtle Island	0	0	0	0.0	0	6	0	2.1
TOTAL	4491	3657	3943	4030.5	2959	3892	2169	3006.8

Appendix D

Composite Curve
N=4669

May	No. of Nests	3Day Running Average	June	No. of Nests	3Day Running Average	July	No. of Nests	3Day Running Average	August	No. of Nests	3Day Running Average
10	1	*	1	55	66.67	1	76	71.33	1	35	34.33
11	0	0.67	2	94	72.33	2	66	74.67	2	43	33.67
12	1	1.33	3	68	81.00	3	82	68.67	3	23	32.00
13	3	2.00	4	81	75.67	4	58	70.33	4	30	25.33
14	2	2.00	5	78	73.00	5	71	63.33	5	23	22.33
15	1	1.67	6	60	63.67	6	61	66.00	6	14	17.67
16	2	3.00	7	53	60.67	7	66	66.67	7	16	14.33
17	6	6.33	8	69	59.00	8	73	73.33	8	13	14.33
18	11	10.00	9	55	60.33	9	81	81.00	9	14	11.00
19	13	11.00	10	57	60.67	10	89	80.67	10	6	9.67
20	9	11.00	11	70	61.33	11	72	80.00	11	9	7.00
21	11	11.67	12	57	68.67	12	79	78.00	12	6	6.67
22	15	14.00	13	79	69.33	13	83	78.67	13	5	5.67
23	16	22.67	14	72	73.67	14	74	74.00	14	6	5.33
24	37	28.00	15	70	66.33	15	65	70.33	15	5	4.67
25	31	37.00	16	57	67.67	16	72	68.67	16	3	3.33
26	43	38.67	17	76	65.67	17	69	60.33	17	2	2.00
27	42	44.33	18	64	72.67	18	40	60.67	18	1	2.00
28	48	47.33	19	78	70.00	19	73	59.33	19	3	1.67
29	52	50.33	20	68	72.33	20	65	63.33	20	1	2.00
30	51	51.33	21	71	70.67	21	52	56.00	21	2	1.67
31	51	52.33	22	73	66.00	22	51	53.67	22	2	1.67
			23	54	70.67	23	58	53.00	23	1	1.00
			24	85	73.00	24	50	49.00	24	0	0.33
			25	80	76.00	25	39	45.00	25	0	0.33
			26	63	72.67	26	46	45.33	26	1	0.33
			27	75	68.67	27	51	48.00	27	0	0.33
			28	68	73.33	28	47	41.33	28	0	*
			29	77	72.33	29	26	31.00			
			30	72	75.00	30	20	23.67			
						31	25	26.67			

Figure D-1


Composite Curve
3 Day Running Average
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20
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60
80
5/10/99
5/17/99
5/24/99
5/31/99
6/7/99
6/14/99
6/21/99
6/28/99
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