

Loggerhead Turtle (*Caretta caretta*) Nesting in Georgia, 2002.

Mark G. Dodd and Adam H. Mackinnon



Georgia Department of Natural Resources
Nongame Wildlife-Natural Heritage Section
One Conservation Way, Brunswick GA 31520

Annual Report submitted to U.S. Fish and Wildlife Service for grant E-5-2 "Coastal Endangered Species Management" 46 pp.

Introduction

The loggerhead turtle *Caretta caretta* was listed as threatened under the Endangered Species Act of 1973 as a result of declines in nesting in the southeastern U.S. and high mortality rates associated with commercial fisheries. The Recovery Plan for the U.S. Population of Loggerhead Turtle *Caretta caretta* (NMFS-USFWS, 1991) delineates reasonable actions required to recover and/or protect loggerhead turtle populations. Monitoring nesting activity is considered a high priority action and is necessary to establish population trends and evaluate the effectiveness of nest protection measures. In this report, we present an overview of loggerhead turtle nesting in Georgia during 2002.

Georgia has a long history of protecting and managing loggerhead turtle (*Caretta caretta*) nesting populations. As a result of concerns over declining loggerhead nesting stocks, researchers on Little Cumberland and Blackbeard Islands established nest protection programs in 1964 and 1965, respectively. By the early 1970's, additional nest protection projects were established on Jekyll and Wassaw Islands. As concern grew over the status of loggerhead turtle populations, the Georgia Department of Natural Resources (GADNR) initiated a program to ensure loggerhead nesting was being monitored on all major nesting beaches. By 1989, all barrier islands with the exception of Wolf, Little Tybee, and Williamson Islands had nest monitoring and protection programs in place.

In Georgia, management and protection activities varied considerably between projects and years. Research activities included saturation tagging efforts and assessments of nest management practices. Management activities ranged from little or no manipulation of loggerhead nesting, to relocation of a large number of nests, non self-releasing hatcheries, and predator control. In 1994, Georgia's island managers adopted the Georgia Loggerhead Recovery and Habitat Protection Plan (GLRHPP) designed to standardize procedures for nest management in the state. The GLRHPP is similar to the Recovery Plan for the U.S. Population of Loggerhead Turtles (NMFS-USFWS, 1991) but addresses issues specific to the state of Georgia.

Methods

Survey Methodology

Managing loggerhead turtles in Georgia is a collaborative effort. The Georgia Department of Natural Resources coordinates a group of volunteers, researchers, and government employees to conduct nest protection and management activities on Georgia beaches (Table 1). This group is known collectively as the *Georgia Sea Turtle Cooperative*.

In 2002, cooperators conducted daily surveys of barrier island beaches for turtle nesting activity. Nest surveys were initiated in early May (1 to 14 May) and continued until the last nest hatched (13 Sept to 18 October). On most beaches, cooperators conducted surveys at dawn unless access was restricted by high tides (Table 1). Cooperators surveyed nesting habitat by ATV, bicycle, or on foot monitoring for signs of loggerhead turtle emergence. When an emergence was

located, observers used field signs (presence of a body pit and thrown sand) to determine if the emergence resulted in a nest (deposition of eggs). Cooperators confirmed the presence of eggs by probing with a blunt dowel or hand digging to locate the egg chamber. A wooden stake was set in the ground approximately 1 m behind each nest cavity. If personnel suspected a turtle nested, but could not locate a nest cavity, it was recorded as an "unknown". Unknowns were marked and monitored through the nesting season. If no hatch was observed, the emergence type was changed from unknown to non-nesting emergence. Observers recorded the date, time, and location (latitude and longitude) of all emergences using a hand-held Garmin GPS12 receiver (Garmin International, 1200 East 151st St, Olathe, KS) issued by GADNR. On Wassaw, Blackbeard, and Little Cumberland Islands personnel collected nesting emergence information during nightly patrols associated with saturation tagging activities (Table 1). We did not conduct regular surveys of Little Tybee, Pine, Williamson, and Wolf Islands because of historically low nesting densities and logistical difficulties in accessing these remote islands. Cooperators visited these islands less than 3 times during the nesting season. Cooperators recorded all non-nesting emergences above the previous night's high tide.

Traditionally, cooperators relocated a large proportion of nests (approx. 70% statewide) to ensure they were not impacted by tidal inundation. However, as a result of concerns over the effects of nest relocation on hatchling sex ratios and fitness, the GADNR asked project leaders to view nest relocation as a management action of last resort. We restricted nest relocation to nests deposited below the spring high tide line. We relocated nests to a nearby dune with a vegetation-free seaward facing slope. We attempted to move all nests within 12 hours of deposition (prior to 10:00 am the next morning). Observers were careful to maintain the vertical orientation of the eggs during transport. For each relocated nest, observers recorded the date, time, and location (latitude and longitude) using a GPS receiver.

Nest protection protocols and levels of effort varied between islands (Table 1). On most undeveloped islands, including Wassaw, Ossabaw, St. Catherines, Blackbeard and Cumberland raccoon populations were reduced by trapping and hunting. In addition, cooperators placed 120 cm x 120 cm sections of 5 cm x 10 cm welded wire fencing over nests to protect from depredations. On Sapelo, plastic screen (4.1 cm x 4.1 cm) was used as part of a pilot study. Cumberland Island Turtle Project personnel used larger sections of screening (183 cm x 183 cm) to discourage raccoons from tunneling into the nest cavity from the side. Fence sections were secured with steel pencil rod at the 4 corners. On some islands, a combination of standard flat screen and wire cage were used to deter raccoons. Feral hogs were generally controlled through hunting and trapping (Table 1).

Cooperators visually inspected each nest every other day for the first 50 days of incubation. Personnel removed sand from the protective screen to ensure it remained flush with the surface sand. After 50 days of incubation, nests were inspected daily for signs of hatchling emergence. On some islands with little or no depredation problems, screens were removed from the nests at

50 days. Cooperators recorded all nest depredations and tidal inundation events.

Nest success evaluations were conducted following the emergence of hatchlings. Cooperators excavated nests 5 days after the first emergence unless fire ants were observed in the nest, in which case, the nest was excavated immediately. If no hatchling emergence was observed, cooperators excavated nests 70 days after deposition. Most nest excavations were conducted during daylight hours, however, personnel on Wassaw, Blackbeard, and Sea Island conducted the majority of excavations at night. During excavations, personnel carefully dug into the nest chamber and removed the contents. If live hatchlings were encountered in the upper chamber, cooperators carefully reburied the hatchlings and continued to monitor the nest. If a few live hatchlings were encountered near the bottom of the nest chamber, cooperators counted and released them several meters above the high tide line. Hatchling tracks were observed and documented. If hatchling tracks followed a direct path to an artificial light source on the beach, the hatching event was categorized as a misorientation. If hatchling tracks were found outside 2 imaginary lines drawn at approximately 45 degrees from the direct line from the nest to the ocean, but no artificial lighting source could be implicated, the hatching event was categorized as a disorientation. Nest contents were sorted by type including hatched eggs, unhatched eggs, and dead hatchlings. Cooperators determined the total number of eggs by adding total eggshells ($\geq 50\%$ of the shell intact) and the number of unhatched eggs. In the case of relocated nests, personnel recorded the total number of eggs during the nest relocation process. We calculated hatching and emergence success based on the following formulas:

$$\text{Hatching Success} = (\text{Hatched Eggs} / \text{Total Eggs}) * 100.$$

$$\text{Emergence Success} = (\text{Hatched Eggs} - (\text{Dead Hatchlings} + \text{Live Hatchlings})) / \text{Total Eggs} * 100.$$

Following nest success evaluations, project personnel removed the nest contents and buried them behind the primary dunes to ensure they are not confused with active nests. Cooperators entered nest data into an MS Excel spreadsheet and submitted the information to the GADNR following the nesting season.

We used SAS version 8.2 (SAS Institute 1990) to summarize descriptive data. We used linear regression (MS Excel) to examine the relationship between nest emergence success and nest relocation. We estimated hatchling sex ratios using a technique developed by Godfrey and Mrosovsky (1997) where incubation duration (deposition to first emergence) is used to estimate the proportion of females in a clutch. Although this technique does not have sufficient precision to be used to determine the sex ratio of hatchlings from individual nests, it provides relatively accurate estimates of ratios over a large geographic area. We used a nonparametric randomized complete block ANOVA to test for differences in hatchling emergence success among nests subjected to tidal inundation (control, 1-3 inundations, > 3 inundations). Islands were used as the blocking factor.

Habitat Assessment

We used a sea turtle nesting habitat assessment technique developed by Bishop and Marsh (1999) to: 1) assess the quality of sea turtle nesting habitat on the Georgia coast; and 2) to develop a model allowing nest protection project personnel to make informed decisions regarding relocation of sea turtle nests. Between 22 May 2002 and 21 August 2002, we measured habitat characteristics for all barrier island beaches. Beginning at the north end of each island, we walked/rode the beach collecting latitude longitude coordinates at each change in habitat type using a GPS receiver. Habitat types were divided into 2 major categories including erosional and accretional habitats (Bishop and Marsh 1999). Erosional habitats were characterized by features indicating the removal of sediment and included bluff, rock armoring, relic root, relic mud, scarp, tree boneyard, washover fans, and washin fans. Accretional habitats were characterized by the deposition of sediment and included accretional terrain (dunefield), beach ridge, and beach terrace. For a more detailed description of habitat types see Bishop and Marsh (1999).

Loggerhead turtle nests, non-nesting emergences, and habitat type beginning and end points were plotted on USGS Digital Orthophoto Quarter Quadrangles (USGS 1993) using Arcview software (ESRI, 380 New York St., Redlands, CA). Nests and non-nesting emergences were assigned habitat types based on their position relative to plotted habitat-type start and end points.

Results

Status

In 2002, sea turtle cooperators located a total of 1,034 loggerhead turtle nests on Georgia beaches (Table 2). A total of 1,028 nests were located during standardized beach surveys. The 2002 nest total was similar to the 13-year average of 1,000 nests (Figure 2). Based on the estimate of 4.1 nests/female (Murphy and Hopkins 1984), approximately 249 loggerhead females nested on Georgia beaches in 2002. We were not able to detect a significant trend in nesting using linear regression analysis ($r^2 = 0.05$, $n=14$, $P= 0.43$). Power analysis (Gerrodette 1993) indicated that the minimum detectable rate of change in nesting was 8% annually.

Nesting totals were highest on Cumberland, Blackbeard, and Ossabaw Islands. These 3 islands have consistently ranked as the top 3 loggerhead nesting rookeries since the inception of comprehensive nest monitoring in 1989. The coastwide average nesting density was 7.0 nests/km, up slightly from 6.0 nests/km in 2001 (Table 2). Nesting densities were variable between islands and ranged from 0.0 nests/km on St. Simons Island to 15.1 nests/km on Blackbeard Island (Table 2). Nesting density on Blackbeard Island was nearly 5 nests/km higher than that of the other islands. Nesting success (the number of

emergences above high tide resulting in a nest) ranged from 34% on Sea Island to 88% on Wassaw Island (statewide avg. = 56.3%).

The spatial distribution of nests was similar to previous years, with loggerhead turtles nesting on all barrier island beaches in Georgia with the exception of St. Simons Island. Although the density of nesting was variable within and between islands, coastwide nesting was relatively evenly distributed (Figures 5-17). Exceptions include sections of Jekyll, Sea, and St. Simons Islands where rock armoring was installed to protect man-made structures. Loggerheads were completely excluded from nesting in these habitats.

The first loggerhead nest of the 2002 season was deposited on Little Cumberland Island on 28 April. Nesting increased dramatically during the third week of May and remained high until mid-July (Figure 18). The last nest was deposited on 31 August on Sapelo Island.

No leatherback or green turtle nests were observed in Georgia in 2002.

Nest Protection and Management

Statewide, loggerhead nest relocations increased from 28% in 2001 to 39% in 2002. Relocation rates were variable between nest protection projects and ranged from 11% on Jekyll Island to 73.4% on Blackbeard Island (Table 2). No nests were relocated to hatcheries in 2002.

Tropical storm activity had minor impacts on sea turtle nesting in 2002. On August 8-10, Tropical Storm Cristobal passed the coast of Georgia resulting in tidal amplitudes that were approximately 0.5 m higher than predicted at the Fort Pulaski and Fernandina Beach tide gauges. The highest tide in 2002 was over 1 m lower than tides associated with Tropical Storm Gabrielle in 2001 (Highest high tide at Fort Pulaski tide gauge: 2001-4.11 m, 2002-2.99 m). Overall, very few nests were lost to tropical storm activity (29 nests; 2.8% of total) during the 2002 nesting season. The highest nest loss was on Ossabaw and Little Cumberland islands with 12.3% and 10% nest loss, respectively. An additional 23% (238) of nests were tidally inundated although not completely lost to storm erosion.

Statewide mean hatching and emergence success was 65.0% and 60.0%, respectively (Table 3). When we adjusted success rates (excluding nests that had been depredated and/or lost to beach erosion), overall hatching and emergence success improved to 74.3% and 69.1%, respectively (Table 3). Hatching success was variable between and within islands. Hatching success was particularly low on Ossabaw (43%) and St. Catherines Islands (32%).

We found a significant positive linear relationship ($F=4.33$, $df=40$, $P=0.038$) between emergence success (calculated excluding depredated nests) and the proportion of nests relocated by island (Figure 19). Based on the regression relationship, we predict a 50.7% relocation rate will result in an emergence success rate of 60%. The complete elimination of nest relocation should result in a nest emergence rate over 50% on average.

Georgia beaches produced a total of 68,367 hatchlings during the 2002 nesting season for an average of 463.5 hatchlings/km (Table 4). The density of hatchlings produced by island ranged from 0.0 to 1,221 hatchlings/km (Table 4).

In 2002, 40.5% of nests excavated had dead hatchlings present (Table 5). However, only a small number of nests (2.5%) had a substantial number of dead hatchlings (>25% of production) at excavation.

Overall, loggerhead turtle nest incubation durations in Georgia averaged 59.9 days ($n=730$, $SD=6.1$), nearly 4 days longer than the 2000 nesting season average (56.1 days, $n=556$, $SD=5.1$; Table 6). Incubation duration varied on the major nesting beaches from 57.4 days on Blackbeard Island to 64.2 days on Little Cumberland Island (Table 6).

Statewide loggerhead turtle hatchling sex ratios derived from incubation durations indicated a female-biased sex ratio (59.1% female, $n=708$ nests, 58,045 hatchlings). The female bias was most pronounced in nests deposited during late June and July bi-weekly sampling periods (Figure 20). All islands had female-biased sex ratios (Figure 21).

Complete nest depredations were low in 2002 (4.3%; Table 7). Statewide, only one nest was lost to feral hogs.

The number of nests partially lost to predators increased slightly from 17.5% in 2001 to 22.8% in 2002 (Table 8). The proportion of partially depredated nests varied between islands and ranged from 0.0% on Tybee to 38.0% on Jekyll Island. Raccoons (9.6%) and ghost crabs (12.5%) accounted for the largest proportions of partial depredations. Fire ants were recorded in 1.9% of loggerhead nests statewide. There was no poaching of nests by humans in Georgia in 2002.

Nests that were not washed over (inundated) had significantly higher emergence success rates than nests that had been washed over between 1 and 3 times (Table 9; Non-Parametric ANOVA, $F=60.78$, $df=2$, $P<0.0001$). Although emergence success was lower for nests that were infrequently washed over, the emergence rate was relatively high at 58%. Nests that were inundated more than 3 times had significantly lower emergence success rates than those that were not washed over or were washed over between 1-3 times.

Hatchling misorientations are relatively uncommon on the Georgia coast. Approximately 4% of loggerhead nests had hatchlings that did not orient correctly to the ocean (Table 10). Hatchling misorientations were recorded on almost all barrier islands. Because most of Georgia's barrier islands are undeveloped and do not have lights on the beach, we assume the misorientations are a result of skyglow from residential and commercial development on the mainland. Hatchling disorientations on Tybee Island were a result of localized beachfront development and street lights.

Habitat Assessment

According to our habitat index, the total amount of erosional habitat decreased slightly from 37.4% in 2001 to 32.8% in 2002. The proportion of erosional beach varied between islands (Figure 22). Over the past 3 years, St. Catherines Island had the highest proportion of beach categorized as erosional. Cumberland and Wassaw Islands had less than 10% erosional habitat. The developed islands of Sea, St. Simons, and Jekyll had relatively high proportions

of beach in erosional categories as a result of the rock armoring used to protect homes from storm erosion.

Discussion

Status

Assessing the status of loggerhead turtle populations in Georgia is difficult. Traditionally, managers have used population models to determine trends in wildlife populations. The lack of demographic information for several loggerhead life-stages makes current population models unreliable. Nest totals represent one of the few long-term indexes available to managers for assessing loggerhead population status.

The number of loggerhead turtle nests located on Georgia beaches in 2002 was similar to the previous 13-year average (1989-2001 average =1,000 nests, 2002 total=1,028), but approximately half the nest recovery goal adopted for Georgia in the Recovery Plan for the U.S. Population of Loggerhead Turtle *Caretta caretta* (NMFS-USFWS, 1991). A minimum of 2,000 nests must be maintained for a 25-year period for loggerheads to be considered recovered in Georgia.

We were not able to detect a significant trend in loggerhead nesting totals over the last 14 years (Figure 2). However, power analysis (Gerrodette 1993) indicated that only a dramatic change in nesting would be detectable (8% annual change) because of the variability in our annual nest totals and small sample size. We will need approximately 11 more years of data to detect a 3% decline in nesting.

When interpreting annual nesting totals, it is important to consider how changes in survey effort may influence nest estimates. Index nesting beach protocols were not used on any beaches in Georgia in 2002. Survey effort on all barrier islands, with the exception of Little Tybee, Williamson, Pine, and Wolf Islands, was characterized as "standardized daily surveys". The daily survey protocol used in Georgia is standardized although not as rigorous as Index Nesting Beach protocol. In general, surveys began between 1 May and 15 May and continued until hatching was completed. Surveys were conducted daily, however, 1 to 2 days per season may have been missed as a result logistical difficulties or severe weather. GPS latitude/longitude positions were recorded for each nest. Overall, the quality of the survey effort data improved dramatically in 2002. Despite the improvements, 3 nesting projects failed to record daily survey data. We will make it a high priority to ensure all projects collect daily survey effort data in 2003.

Georgia's overall loggerhead turtle nest density ($x=7.0$ nests/km) was similar to nesting densities reported from other southeastern beaches within the range of the northern nesting subpopulation of loggerhead turtles (Hopkins-Murphy et. al 1999; 1994-97 avg.-9.3 nests/km, Meylan et al. 1995 (2000 update); Nassau Co., FL -5.8 nests/km, Duval Co., FL- 3.8 nests/km, St. Johns Co., FL- 4.5 nests/km).

The spatial distribution of nests was similar to past years. Loggerheads nested on all barrier islands with the exception of St. Simons Island. Several factors have contributed to the historically low nesting densities on St. Simons including artificial lighting and human activity on the beach at night. In addition, St. Simons Island has a persistent sandbar adjacent to the nesting beach which restricts turtles from accessing nesting habitat at low tide. Blackbeard Island has consistently had the highest nest densities in the state since the inception of standardized data collection and analysis in 1999.

Nest Protection and Management

Loggerhead turtle nest protection and management in Georgia is adaptive. As new information becomes available, techniques are refined to ensure maximum benefit in recovering threatened loggerhead populations. In the past, maximizing emergence success (hatchling production) has been considered desirable for promoting the recovery of loggerhead turtle populations. In Georgia, the major threats to high emergence success are mammalian depredation and tidal inundation (Dodd and Mackinnon 1999).

Overall, loggerhead turtle nest depredations were low in 2002. Total nest loss to mammalian predators remained below 5% for the second year in a row. The low depredation rate was a result of the strong commitment by island managers to protect and manage loggerhead turtle nests.

On Ossabaw Island, approximately 2,214 hogs were removed in 2002 through a combination of public hunts (263 hogs) and trapping or hunting by GADNR personnel (approx. 1,951 hogs). As a result of intensive hog removal activity, no loggerhead nests were lost to feral hogs on Ossabaw in 2002. On Sapelo Island, feral hogs were removed during public deer hunts and tracking dogs are periodically used to locate and remove hogs (C. Martin, GADNR, pers. comm.). Hog populations on Sapelo are generally considered low and less than 10 animals are removed annually (C. Martin, GADNR, pers. comm.). On Wassaw and Blackbeard Islands, USFWS personnel removed feral hogs and raccoons during 20 dedicated hunting trips and during the course of normal activities. Feral hogs were also removed during 2 public hunts. Project personnel on St. Catherine's Island were instructed to eliminate any hogs spotted during the course of regular duties (G. Bishop pers. comm.). On Cumberland, a total of 294 hogs were removed through a combination of USDA Animal Damage personnel and National Park Service trapping efforts during the turtle nesting season.

Raccoons depredations were reduced substantially in 2002 through a combination of nest protection (screening) and predator removal. Ratnaswamy (et. al. 1997) found nest screening to be more effective at reducing raccoon depredations than lethal removal. However, Mroziak et. al. (2000) found wire cages to be generally ineffective in protecting nests in Florida and speculated that predators used wire cages to locate and depredate nests. A combination of predator removal and nest protection appears to be the most effective combination for reducing raccoon depredations on the Georgia coast. Raccoons were generally trapped and hunted on the beach and dunes during the nesting

season to reduce first-night depredation of nests. Because raccoons commonly reach through the top of standard flat welded wire screen, a combination of flat screening with a wire cage attached to the top has become the most commonly used screen configuration. On Cumberland Island, park personnel enlarged the size of the standard flat screen from 120 cm x 120 cm to 183 cm x 183 cm to further discourage tunneling raccoons.

Plastic screens were used on Sapelo Island in an attempt to eliminate the effects of the steel cages on magnetic cues used by hatchlings to orient. Erwin et al. (2000) found steel cages measurably changed the inclination angle and the intensity of the magnetic field beneath it. If hatchlings imprint on the magnetic features of the natal beach, turtles experiencing an unnatural magnetic field during development may have difficulty navigating back to the natal region to nest. The plastic screens were equally effective as the wire screens in discouraging raccoons. As with the flat wire screens, raccoons were able to reach through the top of the screen and reach a few eggs from the top of the nest. In 2003, we intend to experiment with the construction of plastic cages to further discourage raccoon depredation while eliminating any effects on magnetic cues.

Historically, reducing threats associated with tidal inundation has been accomplished by relocating nests deposited on the fore-beach (low elevation) to relatively "safer" locations on top of the primary dunefield. However, recent research has questioned this practice. Foley (1998) found changes in incubation environment (from the center to the outside of the nest cavity) resulted in differences in the characteristics of eggs and hatchlings. Some of these characteristics have influences on lifetime fitness. In order to reduce impacts hatchling sex ratios and fitness associated with manipulation of nests, loggerhead turtle nest relocations have been reduced from approximately 60% statewide in 1998 to 28% in 2001 (Winn and Mackinnon 1998). In 2002, nest relocations increased slightly to 39%. This increase was a result of higher relocation rates on Sapelo Island associated with a research project examining the effects of GADNR management recommendations on hatchling emergence success and increased movement of nests on Little Cumberland Island in response to erosional conditions on the beach. Because the long-term effects of modifying the nest incubation environment are poorly understood, the challenge for managers is to strike a balance between minimizing loggerhead nest manipulation (potential effects on hatchling fitness) while maintaining sufficient hatchling production to recover loggerhead populations.

Determining the minimum hatchling production to recover Georgia's loggerhead turtle population (northern nesting subpopulation) is not currently possible due to a lack of a reliable population model. The Recovery Plan for the U.S. Population of Loggerhead Turtle *Caretta caretta* (NMFS-USFWS, 1991) specifies a 60% hatch success on all major nesting beaches as a major action necessary to recover loggerhead populations. However, this goal was not based on empirical data (S. Macpherson, USFWS, pers. com. 2001). At least one loggerhead population model (Grand and Beissinger 1997), suggests that the hatchling production necessary to effect recovery may be substantially less than 60% (32% for a female biased population). Until more data becomes available to

accurately estimate hatchling production necessary to recover populations, a goal of 60% hatching success may be reasonable. However, it is important to remember that this goal is probably very conservative and should not be used to justify large-scale manipulation of loggerhead nests.

A closer examination of the relationship between nest relocation rates and nest emergence success on a gross scale (by island/yr) indicates that relocating an average of approximately 51% of loggerhead nests will result in a 60% emergence success (figure 19). Interestingly, eliminating nest relocation completely will generally result in an emergence success over 50%. Although these results should be considered preliminary because of a relatively small sample size, island managers should strive to keep nest relocations below a maximum of 50%.

In addition to potential effects on hatchling fitness, nest relocation has been implicated in having impacts on the incubation temperatures and hatchling sex ratios. The relocation of nests to hotter drier sections of the beach is presumed to result in female biased sex ratios. The overall loggerhead hatchling sex ratio estimate in Georgia was female biased (59% female) and was similar to the 2001 estimate (58% female) and to the 6 year estimate of 56.3% female hatchling production reported by Mrosovsky et. al. (1984) for nests sampled in South Carolina and Georgia. As with previous studies conducted in Georgia (Mrosovsky et. al 1984), male hatchlings were produced throughout the nesting season. In 2002, none of the islands had overall male-biased sex ratios (Figure 20).

Currently, the optimal sex ratio for recovery of the northern nesting subpopulation of loggerhead turtles is not known, and it is assumed that the safest course of action is to maintain natural hatchling sex ratios. We intend to continue to use the technique developed by Godfrey and Mrosovsky (1997) to monitor statewide sex ratios and hope to improve the regression curve by adding samples in 2003.

Hatchling misorientations are relatively uncommon on the Georgia coast. Approximately 4% of loggerhead nests had hatchlings that did not orient correctly to the ocean (Table 10). Surprisingly, hatchling misorientation rates were high on several of the undeveloped barrier island. In 2003, we hope further explore the causes of these misorientations and take steps to minimize them.

Habitat Assessment

St. Catherines Island has consistently been one of the most highly erosional of Georgia's barrier islands. Griffin and Henry (1984) suggest that the erosional nature of St. Catherines Island is because of its distance from a major sediment input (river). Sea, Jekyll, and St. Simons Islands also had relatively high proportions of erosional habitat as a result of rock armoring placed on the beach to protect man-made structures. The combination of rock armoring and small jetties on Sea Island beach makes it particularly susceptible to erosional forces. Cumberland and Wassaw Islands have maintained consistently low proportions of erosional habitat since 1999.

Management Recommendations

1. Minimize loggerhead nest depredations by mammalian predators (<5% total nests). Reducing loggerhead nest depredations by feral hogs and raccoons should be accomplished through a combination of nest protection (screen, cage) and predator removal.
2. Relocate a minimum number of nests (maximum of 45-50%). Nests should be relocated only when nest destruction is certain or the nest is below the spring high tide line.
3. Complete habitat surveys by mid-June.
4. Ensure survey effort data is collected and submitted to GADNR in a timely and organized manner
5. Ensure nesting data is submitted to GADNR in a timely and organized manner.
6. Quantify the magnitude of hatchling misorientations and explore potential causes.

Acknowledgements

Managing loggerhead turtles in Georgia is a collaborative effort. Without the dedication and extraordinary effort of project leaders, interns, technicians and volunteers, the management of loggerhead nesting populations in Georgia would not be possible. The following is a list of organizations and personnel who contributed significantly to the Georgia Sea Turtle Cooperative in 2002. Tybee Island Public Works staff; Billy Pye, Danny Carpenter, Maurice Fitzgibbon, and Jimmy Bostwick. Tybee Island Marine Science Center staff; Allen Jacks, Lianne Pierrard, Melanie Hoffman, Chris Askey, Marsha Kevill, Bernie Goode, Elizabeth Plageman, Tammy Smith, Dorothy Griggs and Christian Jordan. Carretta Research Project and Wassaw Island National Wildlife Refuge staff and support personnel; John Robinette, Kris Carrol, Mike Frick, Heather Woodson, Peter Range, and all the Carretta Research Project volunteers. GADNR Ossabaw Island staff; Jim Simmons, Jessica Brzyski, Ellie Covington, Chad Hall, Darrel Hartley and Andy Meadows. St. Catherines Island staff; Royce Hayes, Dr. Gale Bishop, Tim Pranger, Nancy Marsh, David Abbot and Dr. Terry Norton. Blackbeard National Wildlife Refuge and support personnel; Debra Barnard-Keinath, Robert Cail, Karen Pacheco, Scott Gilge, Darryl Woodward, Laure Csboth, Allison Brady, Anne Marie LeBlanc and David Rostal. GADNR personnel on Sapelo Island; Kimberly Stewart, Joe Sellars, and Dorset Hurley. Little St. Simons staff; Jordan Lundy, Mark Kanyok, and Elizabeth Gardner. Sea Island staff; Stacia Hendrix, Anne Ditmer, Mary Driscoll, Jeffery Benson and Gail O-Hara. St. Simons Island; Virginia Herrman, Gloria Ramsmauer, Anne-Marie

Wilson and all the Coastal Encounters staff. Jekyll Island staff and support personnel; Bill Donahue, Jan Caton, Katherine Edwards, Catherine Arning, Ralf Brooks, Oscar Cummings, and Vu Trinh. Little Cumberland Island staff and support personnel; Rebecca Bell, Jay and Kelly Scott, Steve Owens, Gina Rosetti and Rachel Tapp. Cumberland Island staff; Andy Ferguson, Carrie Lowe, Kelly Duschine, John Wilder, Pauline Seville, John Jones, John Fry and Edward O'Connel. Barb Zoodsma, Leigh Youngner, Dana Castellano and Brad Winn provided technical assistance coastwide. Bob Monroe, Wildlife Resources Coastal Area Supervisor, provided housing for technicians on Sapelo and Ossabaw Islands.

Literature Cited

- Bishop, G. A. and N. B. Marsh. 1999. Sea turtle nesting habitat assessment: A rapid , integrated, technological approach. Proc. Of Electronic Earth Science Education: An Integrated, Holistic Approach.
<http://www.peachnet.edu/oit/re/re99/proceedings/RITA/rita.html>
- Foley, A. M. 1998. The nesting ecology of the loggerhead turtle (*Caretta caretta*) in the Ten Thousand Islands, Florida. Ph.D. Dissertation. Univ. of South Florida. 164 pp.
- Gerrodette, T. 1993. Program TRENDS. <http://mercury.bio.uaf.edu/~biolwild.organizations/courses/97wlf625/guide.htm>
- Godfrey, M.H. and N. Mrosovsky. 1997. Estimating the time between hatching of sea turtles and their emergence from the nest. *Chelonian Conservation and Biology* 2(4):581-585.
- Griffin, M. M. and V. J. Henry. 1984. Historical changes in the mean high water shoreline of Georgia, 1857-1982. Georgia Dept. of Nat. Res., Georgia Geologic Survey Bulletin 98. 96 pp.
- Hopkins-Murphy, S. R., Hope, C. P., and M. E. Hoyle. 1999. A history of research and management of the loggerhead turtle (*Caretta caretta*) on the South Carolina coast. Final Report to the USFWS. South Carolina Dept. Nat. Res. 72 pp.
- Irwin, W. P., A. J. Horner, L. J. Askins, and K. L. Lohmann. 2000. Magnetic field distortions produced by wire nest cages. in H. Kalb and T. Wibbels (comp.), *Proceedings of the Nineteenth Annual Symposium on Sea Turtle Conservation and Biology*. NOAA Tech. Memo. NMFS-SEFSC-443, pp. 181-184.
- Meylan, A., B. Schroeder, A. Mosier. 1995. Sea turtle nesting activity in the State of Florida 1979-1992. *Fl. Mar. Res. Pub. No. 52*. Fl. Mar. Res. Inst. 51 pp.

- Mrosovsky, N., Hopkins-Murphy, S. R., and J. I. Richardson. 1984. Sex ratio of sea turtles: seasonal changes. *Science* 225:739-741.
- Mroziak, M. L., M. Salmon, K. Rusenko. 2000. Do wire cages protect sea turtles from foot traffic and mammalian predators? *Chelonian Conservation and Biology*. 3(4):693-698.
- Murphy, T. M., and S. R. Hopkins. 1984. Aerial and ground surveys of marine turtle nesting beaches in the southeast region, United States. Final report to National Marine Fisheries Service (Contract NA83-GA-C-00021). 73 p.
- National Marine Fisheries Service and the U. S. Fish and Wildlife Service. 1991. Recovery plan for U.S. population of loggerhead turtle. National Fisheries Service, Washington, DC.
- NOAA. 2001. Verified/Historic water level data. National Oceanographic and Atmospheric Administration. Center for Operational Oceanographic Products and Services (CO-OPS), Silver Spring, MD.
- Richardson, J. L. and T. H. Richardson. 1982. An experimental population model for the loggerhead sea turtle (*Caretta caretta*). Pp 165-176. in K. A. Bjorndal (eds.), *Biology and Conservation of Sea Turtles*. Smithsonian Institution Press, Washington D.C.
- SAS/STAT. 1990. Users Guide, Version 6, fourth edition, volume 2.
- Trexler, J. C. and J. Travis. 1993. Nontraditional regression analysis. *Ecology* 74:1629-1637.
- Winn, C. B. and A. H. Mackinnon. 1998. Loggerhead sea turtle nesting on the Georgia coast in 1998. Study Completion Report to USFWS. 44 pp.

Table 1. Barrier island ownership and nest protection strategies employed by loggerhead turtle projects in Georgia, 2002.

Island	Ownership	Nest protection project	<u>Survey Method</u>		<u>Nest Protection</u>							
			Morning survey	Night survey- (Saturation tagging)	Flat screen (welded wire)	Supp. screen (hard-ware cloth)	Cage (welded wire)	Hatchery	Live- trap raccoons	Live- trap feral hogs	Trap/ remove ghost crabs	Removal predators (firearms)
Tybee Island	Private	Tybee Island Public Works	X		X							
Little Tybee Island	GADNR	None										
Williamson Island	GADNR	None										
Wassaw Island	USFWS	Caretta Research Project		X	X	X			X			X
Pine Island	USFWS	None										
Ossabaw Island	GADNR	GADNR Staff	X		X		X		X	X	X	X
St. Catherine's Is.	Private	St. Catherines Is. Sea Turtle Res. and Conserv. Prog.	X		X		X		X			X
Blackbeard Island	USFWS	USFWS, Savannah Coastal Refuges		X	X	X	X				X	X
Sapelo Island	GADNR	GADNR Staff	X		X ¹						X	X
Wolf Island	USFWS	None										
Little St. Simon's Is.	Private	Little St. Simon's Is. Resort Staff	X		X				X			X
Sea Island	Private	Sea Island Co. Staff	X		X		X				X	
St. Simon's Island	Private	St. Simons Island Sea Turtle Project	X									
Jekyll Island	State of Georgia	Jekyll Island Authority	X		X				X		X	
Little Cumberland Is.	Private	LCI Homeowners Assoc.		X	X		X				X	
Cumberland Island	USNPS	Cumberland Island National Seashore Staff	X		X		X		X	X	X	X

¹ Plastic screening (4.1 cm x 4.1 cm mesh) was used instead of welded-wire

Table 2. Summary of Loggerhead Nesting in Georgia, 2002.

Island	Length of beach (km)	No. of nests	Nesting density (Nests/km)	Non-nesting emergences- above high tide (NEA)	Nesting success (Nests/ (nests+ NEA))	Nests left <i>in-situ</i>	Nests relocated to the dunes	% of total nests relocated	Nests subjected to tidal washover	% washed over	Nests lost to storm events (erosion)	% nests lost to storm events
Tybee Island	7.6	6	0.8	3	66.7	6	0	0.0	3	50.0	0	0.0
Little Tybee Island ¹	8.7	0										
Wassaw Island	10.7	56	5.2	8	87.5	18	38	67.9	6	10.7	0	0.0
Pine Island ¹	1.8	1										
Ossabaw Island	18.0	154	8.6	99	60.9	133	21	13.6	88	57.1	19	12.3
St. Catherines Island	19.5	76	3.9	146	34.2	27	49	64.5	0	0.0	0	0.0
Blackbeard Island	11.7	177	15.1	120	59.6	47	130	73.4	0	0.0	0	0.0
Sapelo Island	10.1	105	10.4	78	57.4	61	44	41.9	28	26.7	1	1.0
Wolf Island ¹	4.0	5										
Little St. Simons Island	9.8	33	3.4	41	44.6	21	12	36.4	9	27.3	3	9.1
Sea Island	9.0	73	8.1	51	58.9	42	31	42.5	7	9.6	3	4.1
St. Simons Island	4.2	0	0.0	0	0.0	0	0	0.0	0	0.0	0	0.0
Jekyll Island ²	15.1	129	8.5	156	45.3	113	14	11.0	38	29.5	0	0.0
Little Cumberland Island	5.0	30	6.0	26	53.6	13	17	56.7	11	36.7	3	10.0
Cumberland Island	26.8	189	7.1	70	73.0	143	46	24.3	48	25.4	0	0.0
Survey Beach Totals	147.5	1,028	7.0	798	56.3	624	402	39.2	238	23.2	29	2.8
Statewide Totals	162.0	1,034	6.4									

¹ Regular surveys were not conducted because of logistical difficulties and low nesting densities. Cooperators visited these islands less than 5 times during the nesting season.

² Incomplete data were obtained from two nests

Table 3. Loggerhead turtle nest hatching and emergence success in Georgia, 2002.

Island	<u>Hatching success</u>			<u>Hatching success</u>			<u>Emergence success</u>			<u>Emergence success</u>		
	N	Mean	SD	N	Adjusted mean ¹	SD	N	Mean	SD	N	Adjusted mean ¹	SD
Tybee Island	6	66.3	34.4	5	79.6	12.5	6	49.6	37.5	5	59.5	31.9
Wassaw Island	56	74.1	28.6	40	71.9	28.0	56	60.9	32.6	40	59.7	31.6
Ossabaw Island	135	42.6	40.8	77	56.7	40.9	135	36.9	41.4	77	49.1	44.0
St. Catherines Island	74	46.2	42.1	16	85.5	13.9	74	42.8	40.3	16	79.9	18.9
Blackbeard Island	177	74.3	26.8	128	80.8	22.3	177	67.1	30.5	128	72.3	29.5
Sapelo Island	105	66.7	37.6	81	75.4	32.1	105	62.0	38.6	81	71.6	32.7
Little St. Simons Island	33	58.6	36.9	16	73.9	28.2	33	51.6	37.9	16	72.0	28.9
Sea Island	72	69.7	34.5	49	76.8	28.9	72	66.4	33.7	49	73.6	28.4
St. Simons Island	0			0			0			0		
Jekyll Island	122	64.8	35.4	68	69.7	32.9	122	62.7	34.8	68	67.8	32.7
Little Cumberland Island	30	52.2	43.4	22	63.8	39.9	30	50.1	41.8	22	61.2	38.4
Cumberland Island	186	77.6	28.7	174	78.6	27.9	186	74.4	30.7	174	75.8	29.9
Survey Beach Totals	996	65.0	36.3	676	74.3	30.8	996	60.0	37.2	676	69.1	33.3

¹Excluding depredated nests and nests completely lost as a result of beach erosion.

Table 4. Loggerhead turtle hatchling production in Georgia, 2002.

Island	Length of beach (km)	No. of nests	Total hatchlings produced	Hatchlings/km
Tybee Island	7.6	6	329	43.3
Wassaw Island	10.7	56	4,419	413.0
Ossabaw Island	18.0	133	5,619	312.2
St. Catherines Island	19.5	61	3,950	202.6
Blackbeard Island	11.7	170	14,285	1,220.9
Sapelo Island	10.1	96	7,004	693.5
Little St. Simons Island	9.8	29	2,066	210.8
Sea Island	9.0	69	5,600	622.2
St. Simons Island	4.2	0	0	0.0
Jekyll Island	15.1	123	8,004	530.1
Little Cumberland Island	5.0	25	1,636	327.2
Cumberland Island	26.8	188	15,455	576.7
Survey Beach Totals	147.5	956	68,367	463.5

Table 5. Summary of dead loggerhead turtle hatchlings in Georgia, 2002.

Island	n	No. of nests with at least 1 dead hatchling at excavation		No. of nests with >25% of hatchlings dead at excavation	
			%		%
Tybee Island	5	4	80.0	1	20.0
Wassaw Island	56	22	39.3	2	3.6
Ossabaw Island	110	45	40.9	8	7.3
St. Catherines Island	58	21	36.2	0	0.0
Blackbeard Island	170	66	38.8	3	1.8
Sapelo Island	95	39	41.1	3	3.2
Little St. Simons Island	26	10	38.5	1	3.8
Sea Island	66	37	56.1	0	0.0
St. Simons Island	0	0	0.0	0	0.0
Jekyll Island	115	45	39.1	1	0.9
Little Cumberland Island	24	13	54.2	0	0.0
Cumberland Island	185	67	36.2	4	2.2
Survey Beach Totals	910	369	40.5	23	2.5

Table 6. Loggerhead sea turtle nest incubation durations (deposition to first hatching) in Georgia, 2002.

Island	<u>Incubation Duration</u>						Mean- nests relocated		
	N	Overall mean	SD	N	Mean- <i>in- situ</i> nests	SD	N	dunes	SD
Tybee Island	5	61.4	4.6	5	61.4	4.6	0		
Wassaw Island	42	58.9	7.0	15	59.3	5.8	27	58.6	7.7
Ossabaw Island	66	59.5	5.2	57	60.0	5.0	9	56.4	5.2
St. Catherines Island	20	61.5	8.4	3	54.0	0.0	17	62.8	8.5
Blackbeard Island	146	57.4	4.8	38	60.2	5.5	108	56.4	4.1
Sapelo Island	89	62.0	6.1	48	63.3	6.2	41	60.5	5.8
Little St. Simons Island	20	58.5	5.5	11	59.6	6.2	9	57.1	4.7
Sea Island	59	56.6	4.7	28	57.8	4.8	31	55.5	4.4
St. Simons Island	0			0			0		
Jekyll Island	95	60.2	7.1	83	60.5	7.3	11	58.6	5.3
Little Cumberland Island	24	64.2	7.6	8	67.1	7.6	16	62.8	7.4
Cumberland Island	164	61.7	4.9	121	61.4	5.1	43	62.6	4.2
Survey Beach Totals	730	59.9	6.1	417	60.8	6.0	312	58.7	5.9

Table 7. Summary of total loggerhead nest depredations (complete depredations only) in Georgia, 2002.

Island	No. nests	Total nests depredated		Nests depredated by hogs		Nests depredated by raccoons	
		(complete loss)	%	(complete loss)	%	(complete loss)	%
Tybee Island	6	0	0.0	0	0.0	0	0.0
Wassaw Island	56	0	0.0	0	0.0	0	0.0
Ossabaw Island	154	3	1.9	0	0.0	1	0.6
St. Catherine's Island	76	15	19.7	1	1.3	14	18.4
Blackbeard Island	177	7	4.0	0	0.0	7	4.0
Sapelo Island	105	8	7.6	0	0.0	6	5.7
Little St. Simons Island	33	1	3.0	0	0.0	1	3.0
Sea Island	73	1	1.4	0	0.0	0	0.0
St. Simons Island							
Jekyll Island	129	6	4.7	0	0.0	1	0.8
Little Cumberland Island	30	2	6.7	0	0.0	2	6.7
Cumberland Island	189	1	0.5	0	0.0	1	0.5
Statewide Totals	1028	44	4.3	1	0.1	33	3.2

Table 8. Summary of loggerhead partial nest depredations in Georgia, 2002.

Island	No. nests	Partial nest depredation	%	No. feral hog depredations	%	No. raccoon depredations	%	No. ghost crab depredations	%	No. fire ants depredations	%
Tybee Island	6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Wassaw Island	56	16	28.6	0	0.0	12	21.4	5	8.9	1	1.8
Ossabaw Island	154	52	33.8	0	0.0	18	11.7	33	21.4	9	5.8
St. Catherines Island	76	20	26.3	0	0.0	11	14.5	0	0.0	0	0.0
Blackbeard Island	177	42	23.7	0	0.0	37	20.9	6	3.4	0	0.0
Sapelo Island	105	14	13.3	0	0.0	6	5.7	10	9.5	0	0.0
Little St. Simons Is.	33	11	33.3	0	0.0	0	0.0	9	27.3	6	18.2
Sea Island	73	17	23.3	0	0.0	2	2.7	14	19.2	4	5.5
St. Simons Island											
Jekyll Island	129	49	38.0	0	0.0	7	5.4	40	31.0	0	0.0
Little Cumberland Is.	30	2	6.7	0	0.0	2	6.7	1	3.3	0	0.0
Cumberland Island	189	11	5.8	0	0.0	4	2.1	11	5.8	0	0.0
Survey Beach Totals	1028	234	22.8	0	0.0	99	9.6	129	12.5	20	1.9

Table 9. Loggerhead turtle hatchling emergence success by tidal inundation category in Georgia, 2002. Emergence success is calculated excluding depredated and relocated nests.

Island	<u>Emergence Success</u>								
	N	No Washover	SD	N	Washover (1-3)	SD	N	Washover (>3)	SD
Tybee Island	3	56.5	44.3	2	64.0	9.2			
Wassaw Island	10	74.8	20.2	3	49.7	43.1	1	0.0	
Ossabaw Island	31	71.0	31.9	22	45.7	53.4	22	11.9	26.7
St. Catherines Is.	2	76.4	32.0						
Blackbeard Island	34	80.0	23.6						
Sapelo Island	24	83.1	22.6	12	61.4	34.2	12	33.5	39.5
Little St. Simons Is.	6	72.0	31.7	4	76.8	21.8			
Sea Island	23	66.9	35.2	2	92.0	1.1	1	0.0	
St. Simons Island									
Jekyll Island	49	66.4	35.0	15	56.9	35.1	3	61.5	53.3
Little Cumberland Is.	1	83.2		2	80.4	16.4	5	11.3	24.3
Cumberland Island	91	82.0	23.9	38	60.2	40.8	8	50.1	29.5
Survey Beach Totals	274	75.8	28.7	100	58.1	40.9	52	25.1	34.9

Table 10. Loggerhead turtle hatchling misorientations in Georgia, 2002.

Island	No. of nests	Total No. of nests with hatchling misorientation	% of nests with misoriented hatchlings
Tybee Island	6	4	66.7
Wassaw Island	56	1	1.8
Ossabaw Island	133	10	7.5
St. Catherines Island	61	2	3.3
Blackbeard Island ¹	170		
Sapelo Island	96	6	6.3
Little St. Simons Island	29	4	13.8
Sea Island	69	2	2.9
St. Simons Island	0		
Jekyll Island	123	1	0.8
Little Cumberland Island	25	1	4.0
Cumberland Island	188	20	10.6
Survey Beach Totals	956	31	4.0

¹ Hatchling orientation data not available

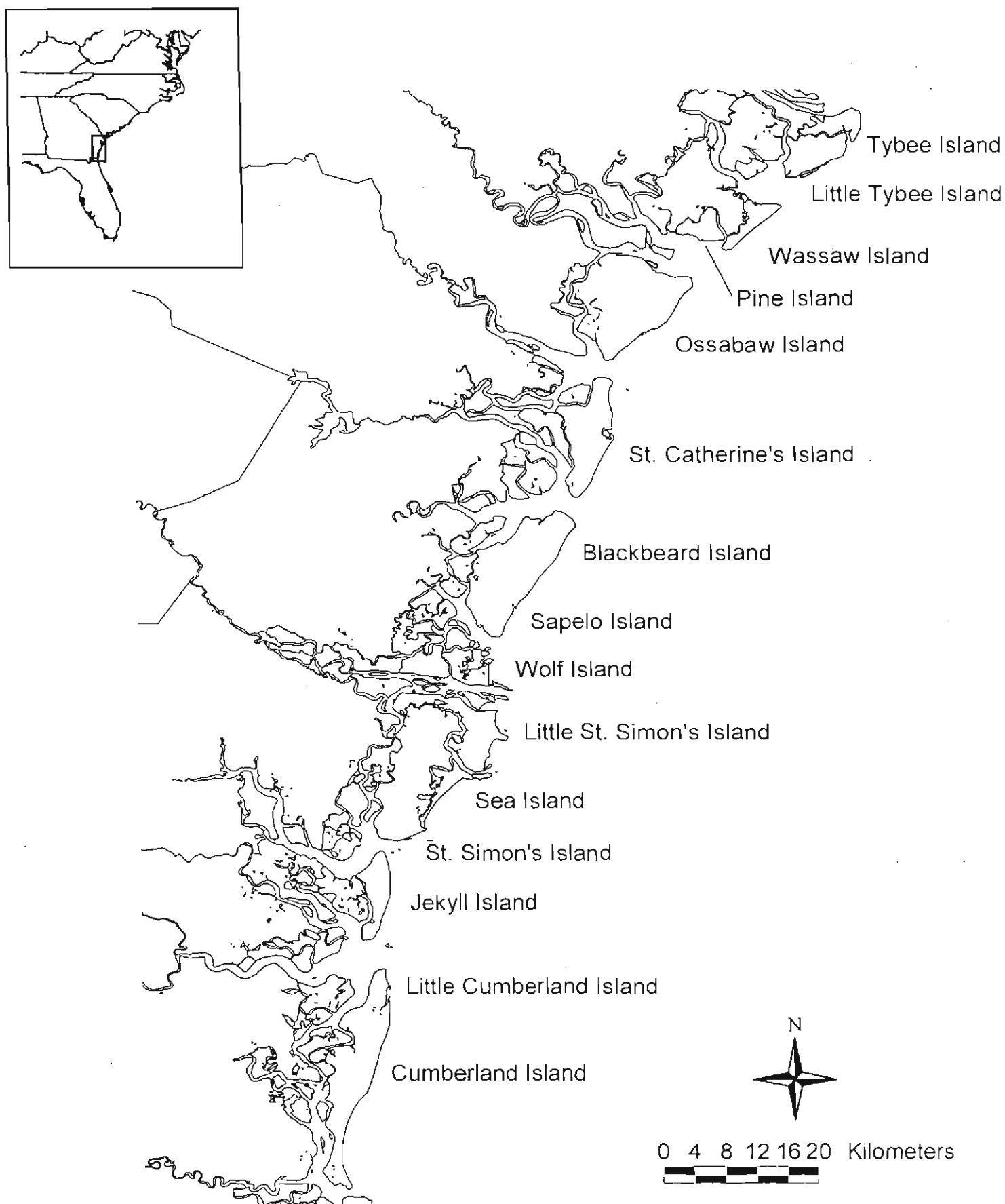


Figure 1. Location of Study Area in Georgia, 2002 .

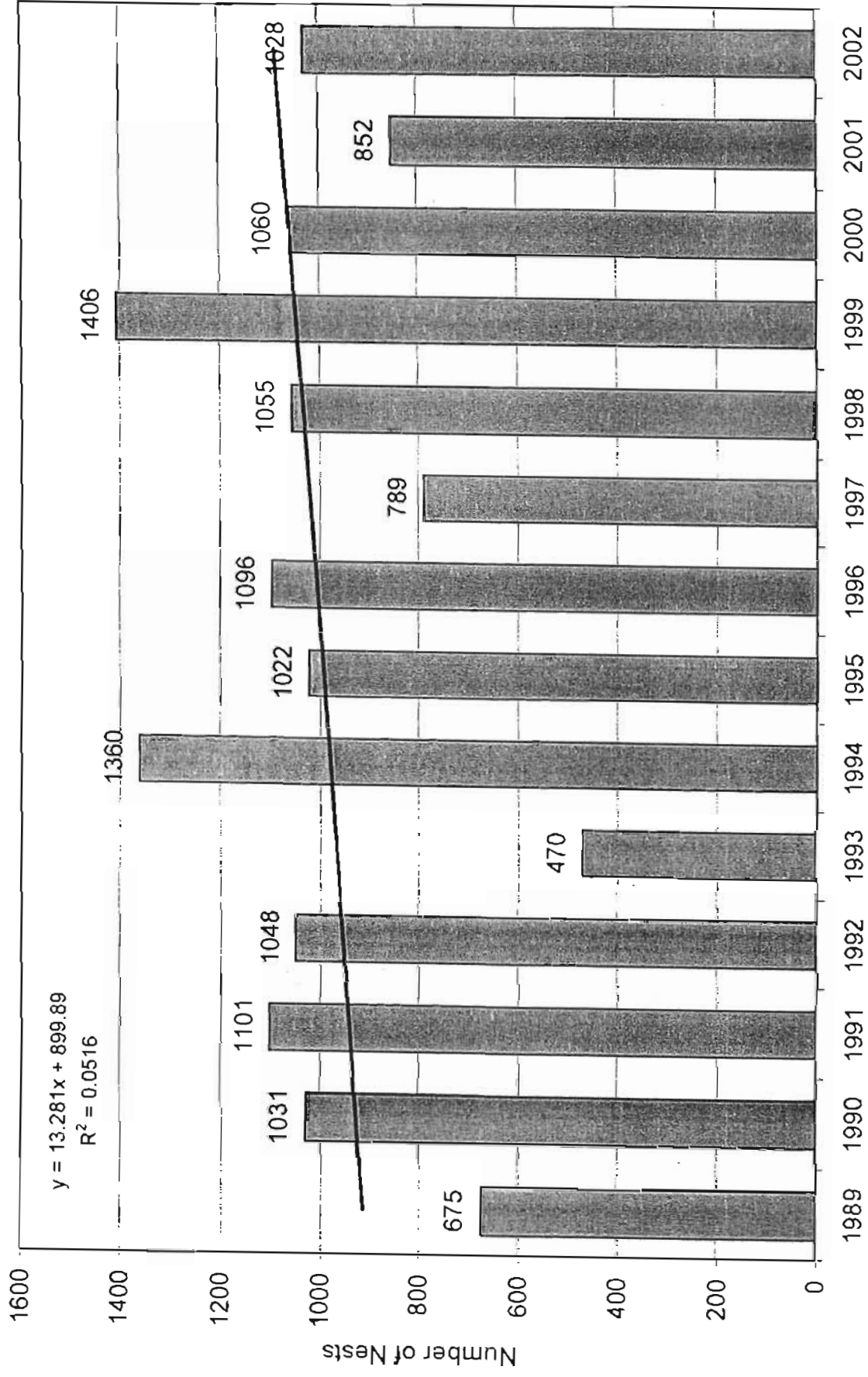


Figure 2. Loggerhead Turtle Nesting on standardized survey beaches in Georgia, 1989-2002.

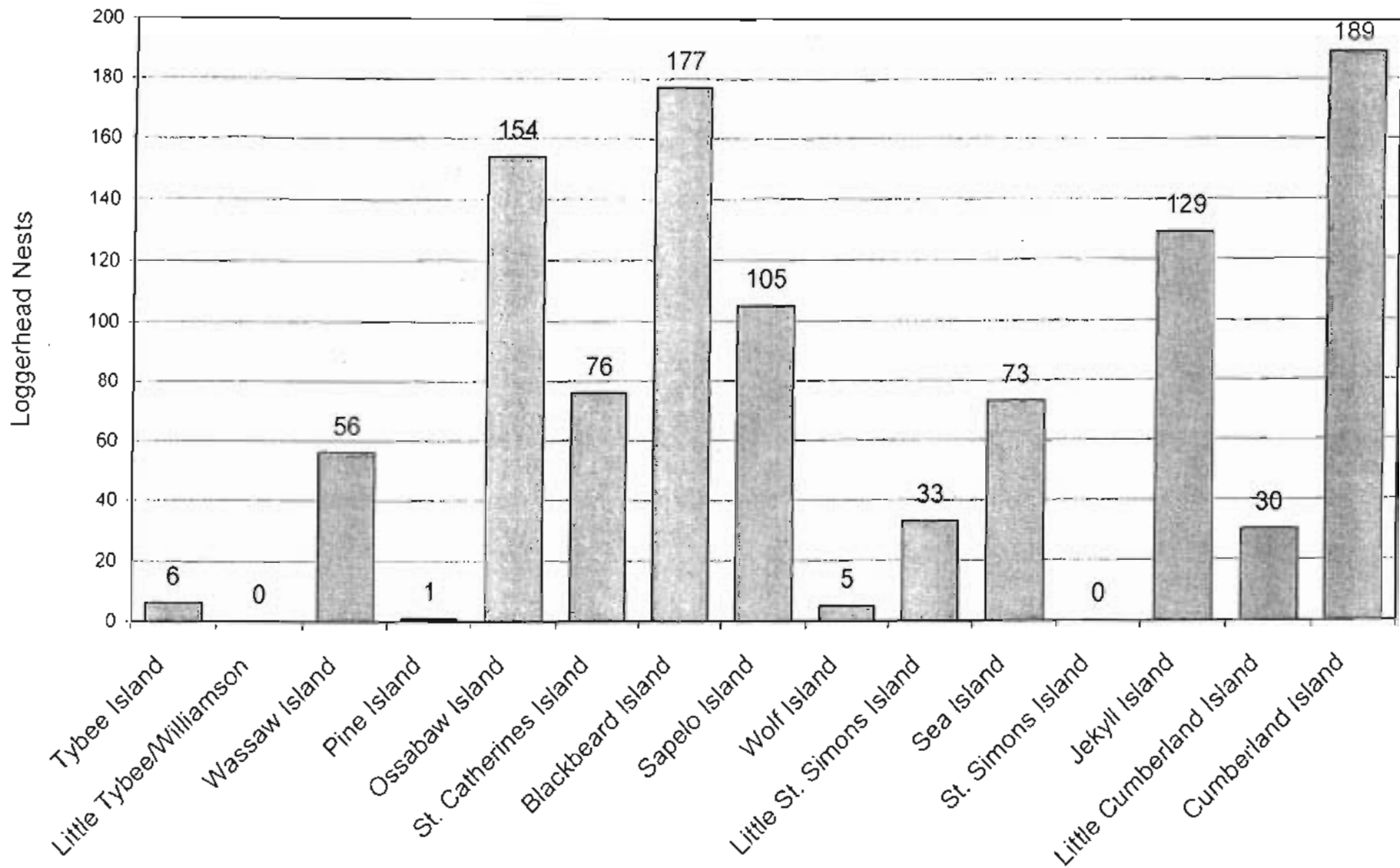


Figure 3. Loggerhead turtle nesting on Georgia barrier island beaches, 2002. Daily surveys were not conducted on Little Tybee/Williamson, Pine, and Wolf Islands.

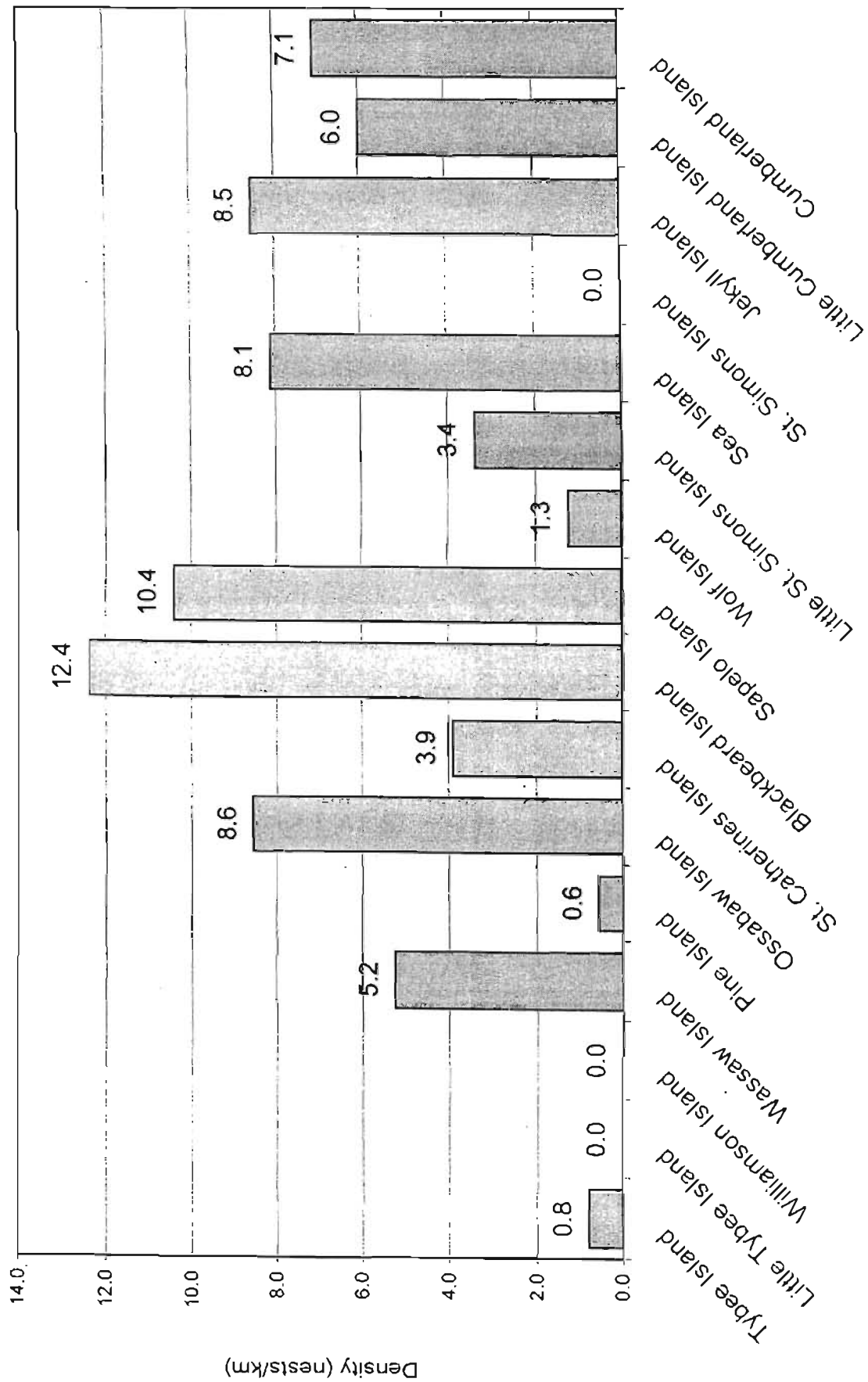
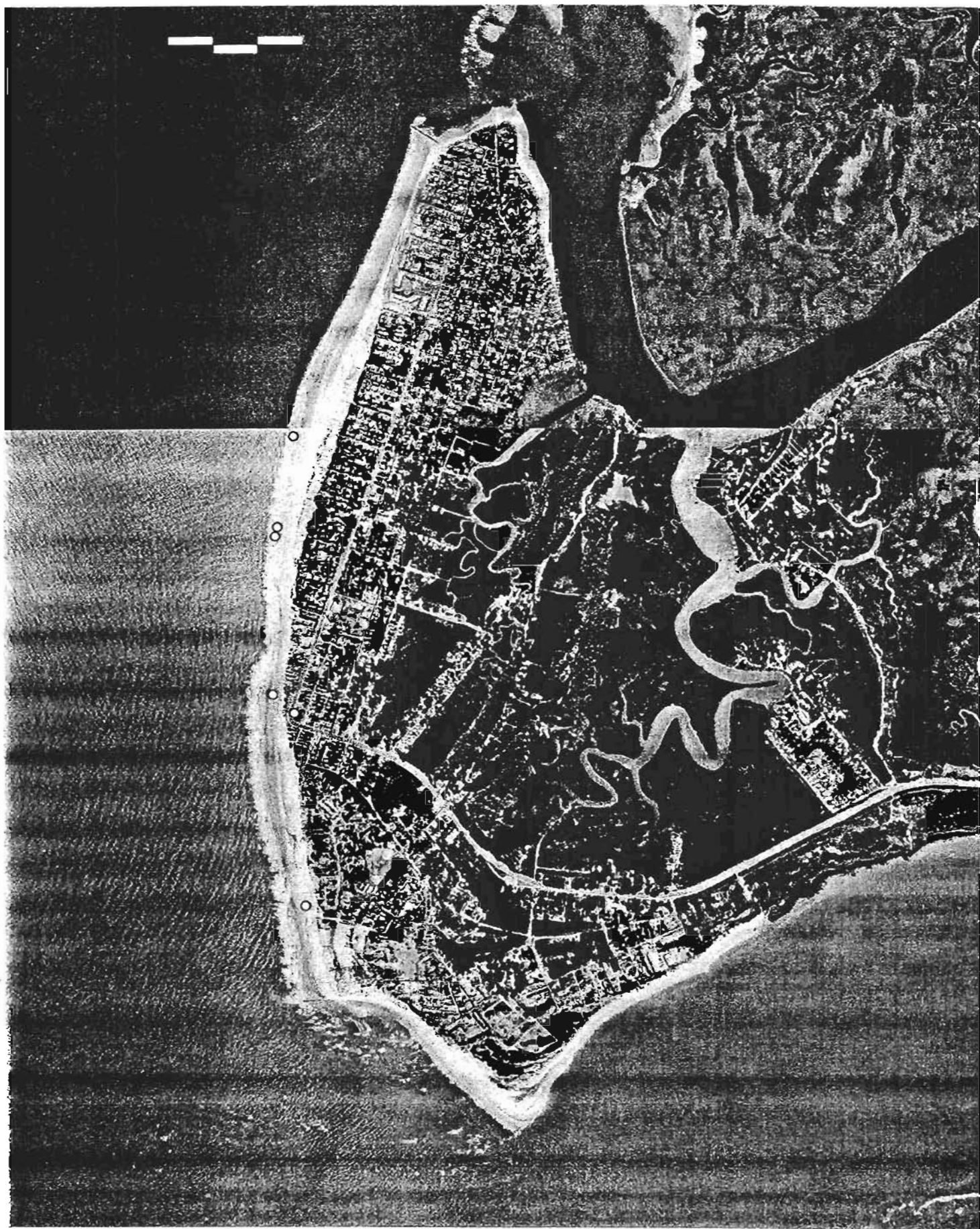


Figure 4. Loggerhead turtle nesting density in Georgia, 2002.

Figure 5. Spatial distribution of loggerhead sea turtle nests on Tybee Island, Georgia, 2002. Data plotted on 1993 Digital Orthophoto Quarter Quadrangles.



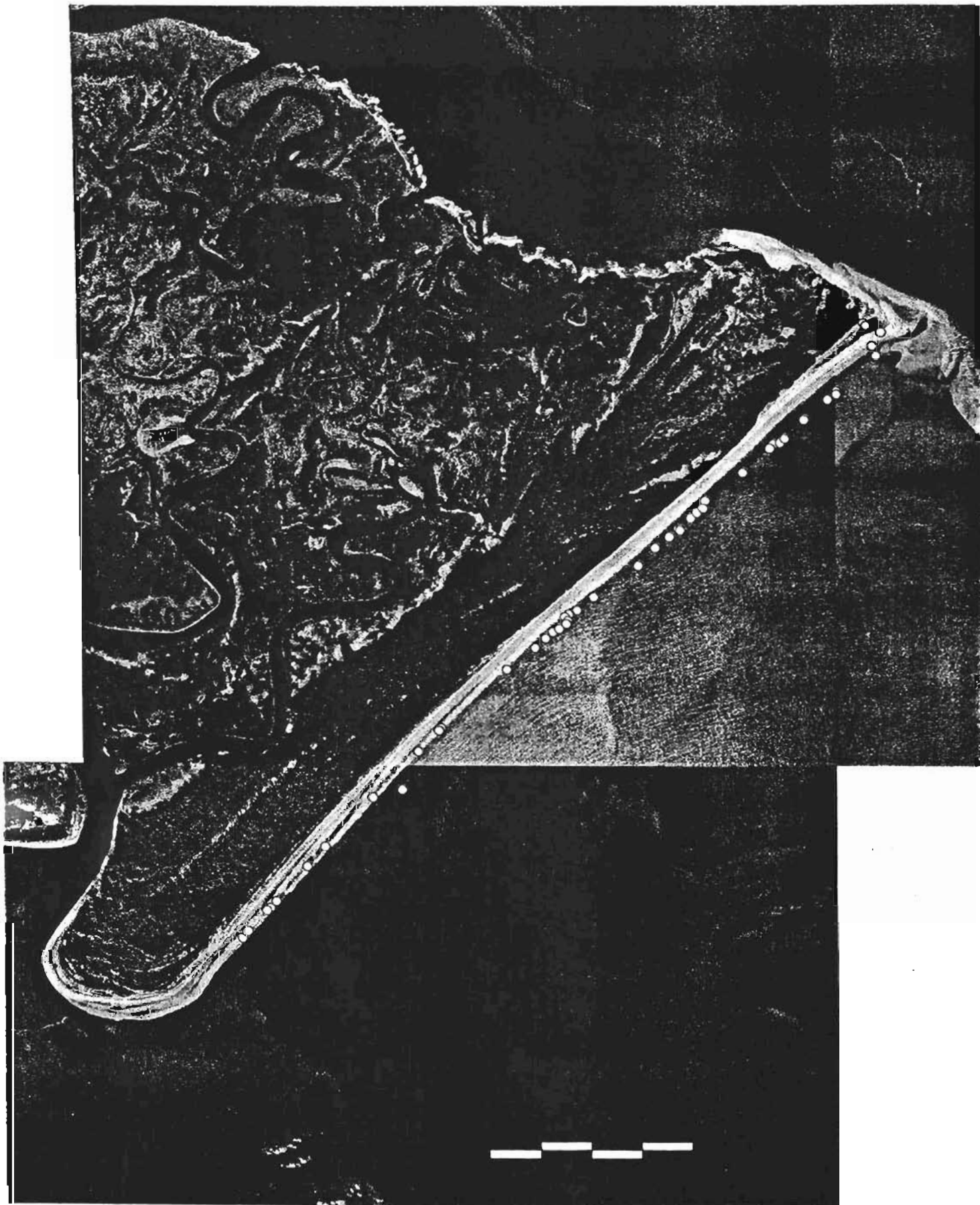
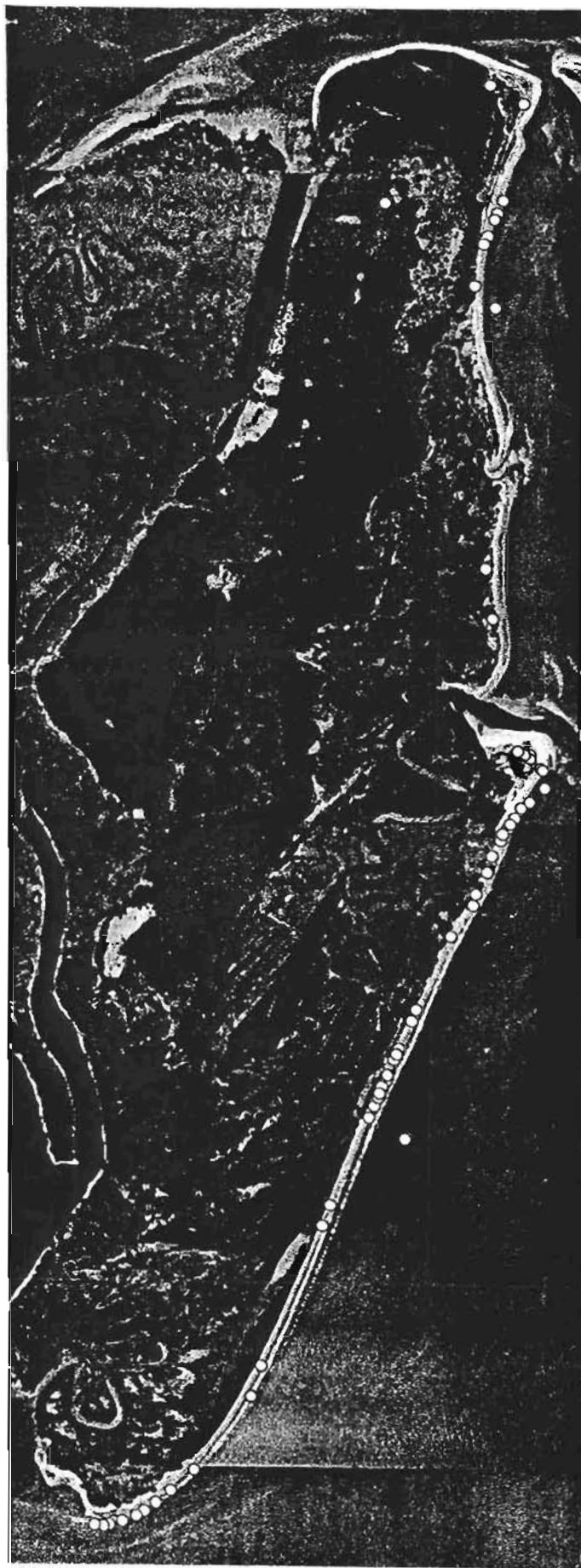


Figure 6. Spatial distribution of loggerhead sea turtle nests on Wassaw Island, Georgia, 2002. Data plotted on 1993 Digital Orthophoto Quarter Quadrangles.



Figure 7. Spatial distribution of loggerhead sea turtle nests on Ossabaw Island, Georgia, 2002. Data plotted on 1993 Digital Orthophoto Quarter Quadrangles.



0 0.6 1.2 1.8 2.4 3 Kilometers



Figure 8. Spatial distribution of loggerhead sea turtle nests on St. Catherine's Island, Georgia, 2002. Data plotted on 1993 Digital Orthophoto Quarter Quadrangles.

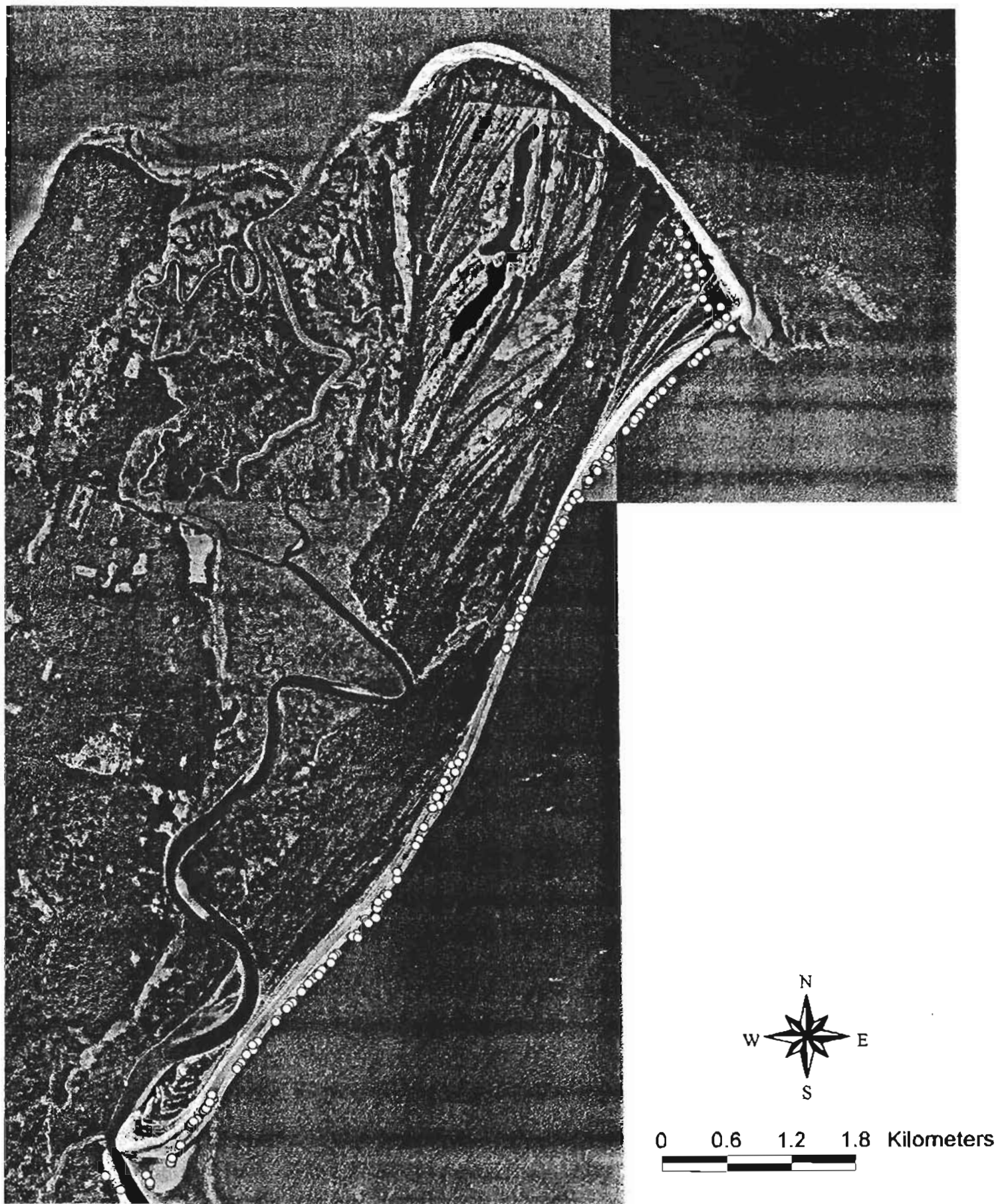


Figure 9. Spatial distribution of loggerhead sea turtle nest on Blackbeard Island, Georgia, 2002. Data plotted on 1993 Digital Orthophoto Quarter Quadrangles.



Figure 10. Spatial distribution of loggerhead sea turtle nests on Sapelo Island, Georgia, 2002. Data plotted on USGS Digital Orthophoto Quarter Quadrangles.

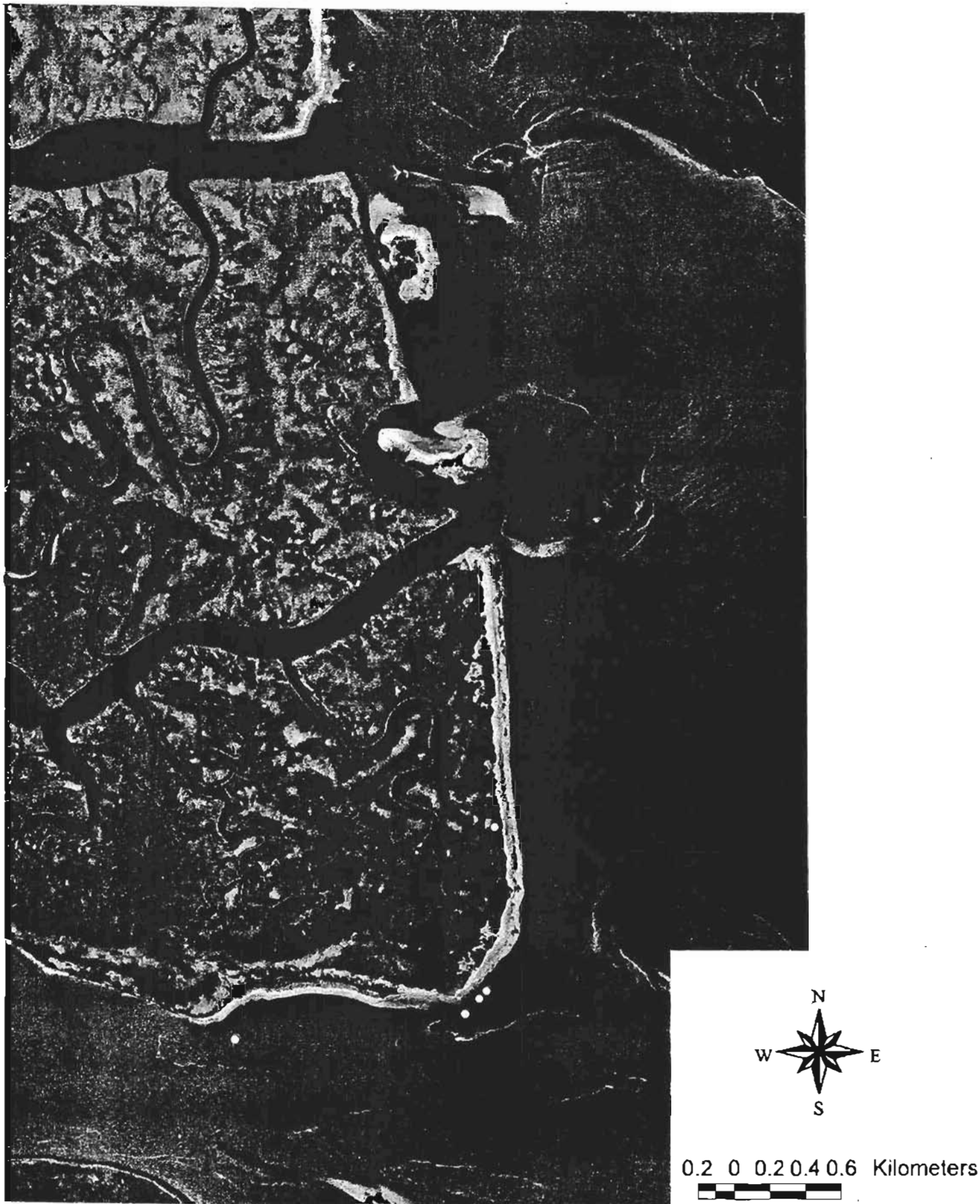


Figure 11. Spatial distribution of loggerhead sea turtle nests on Wolf Island, Georgia, 2002. Data plotted on USGS Digital Orthophoto Quarter Quadrangles.

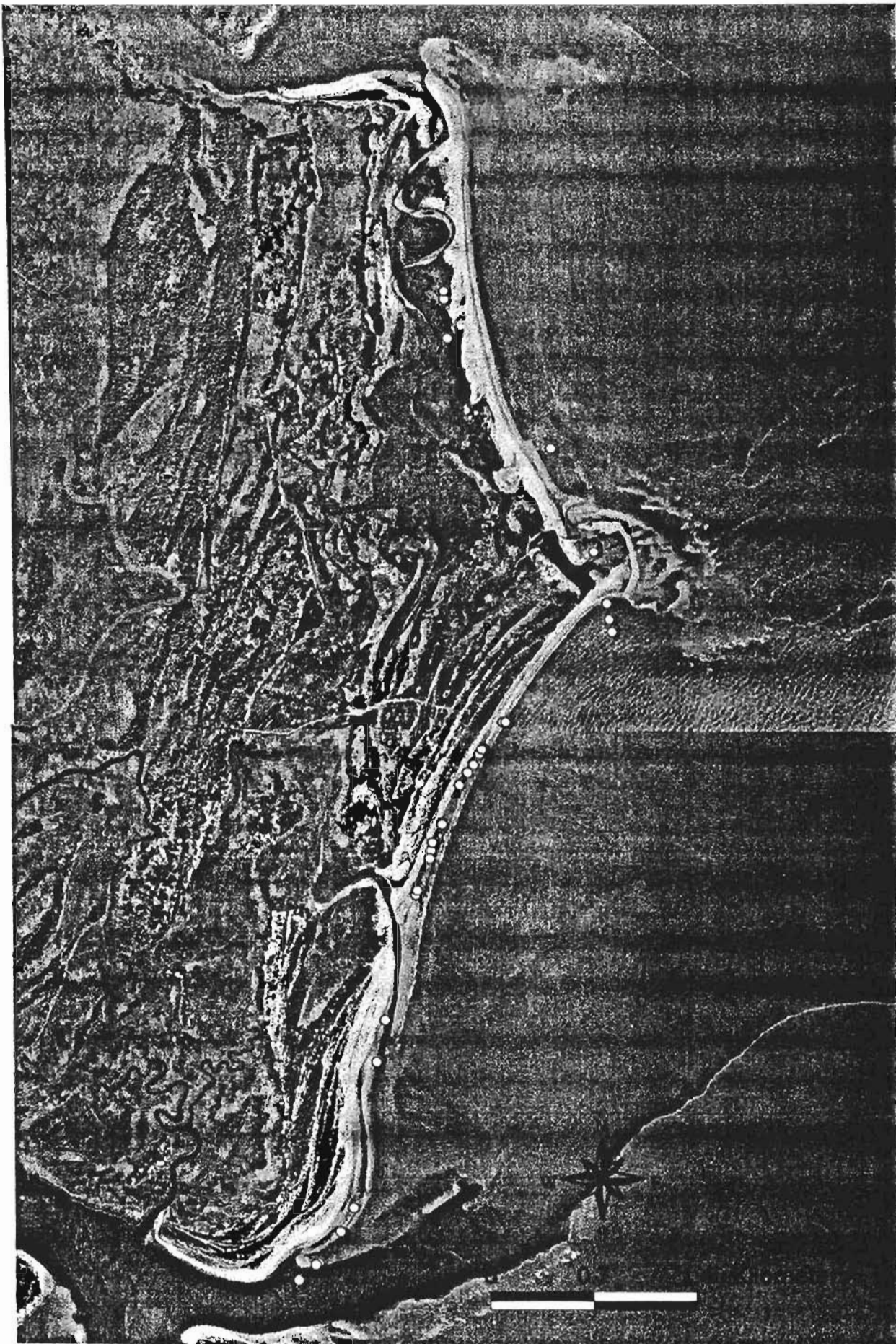
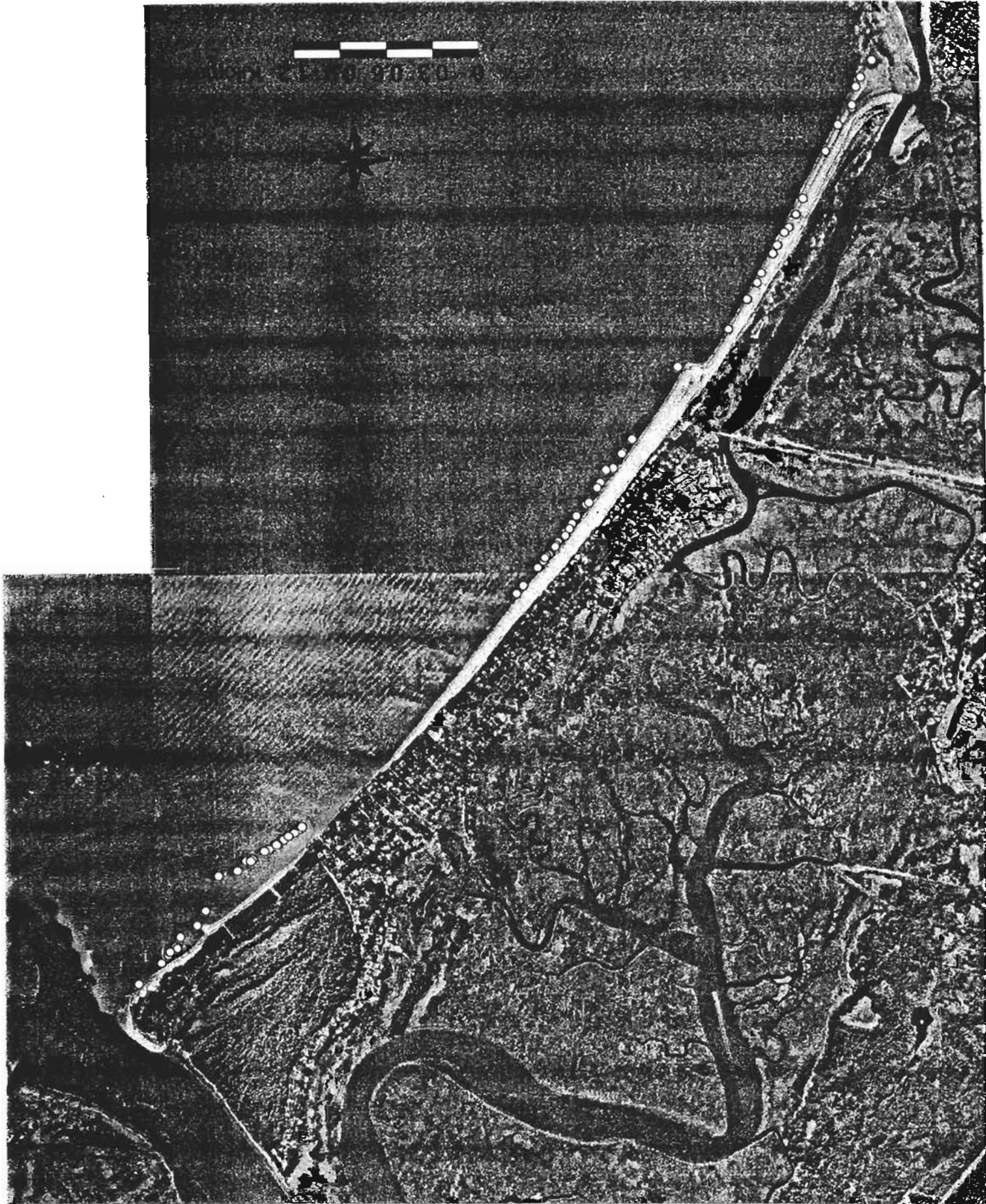


Figure 12. Spatial Distribution of loggerhead sea turtle nests on Little St. Simons Island, Georgia, 2002. Data plotted on 1993 USGS Digital Orthophoto Quarter Quadrangles.

Figure 13. Spatial distribution of loggerhead sea turtle nests on Sea Island, Georgia, 2002. Data plotted on 1993 USGS Digital Orthophoto Quarter Quadrangles.



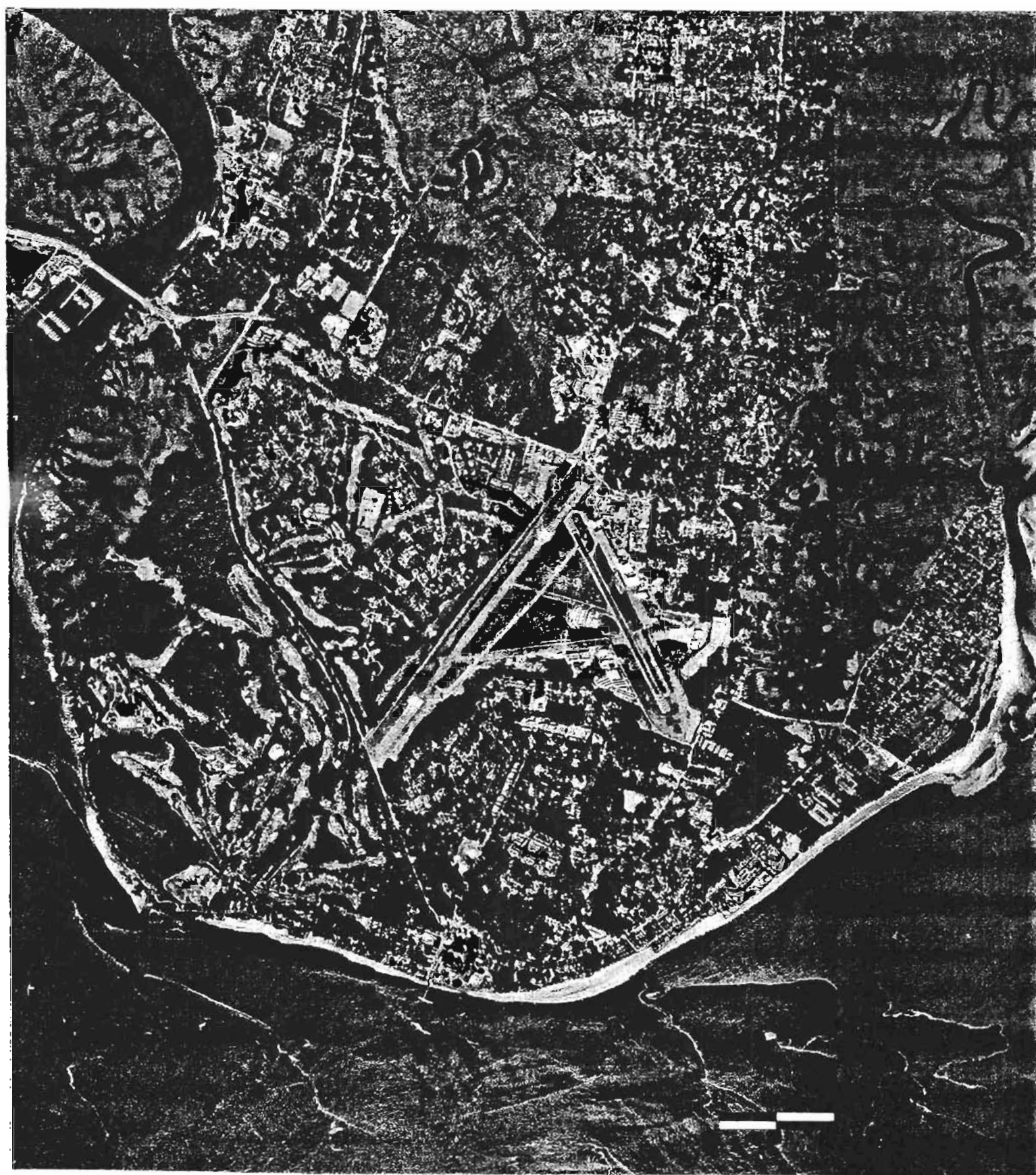


Figure 14. Spatial distribution of loggerhead sea turtle nests on St. Simons Island, Georgia, 2002. Data plotted on 1993 USGS Digital Orthophoto Quarter Quadrangles.



Figure 15. Spatial distribution of loggerhead sea turtle nests on Jekyll Island, Georgia, 2002. Data plotted on 1993 USGS Digital Orthophoto Quarter Quadrangles.

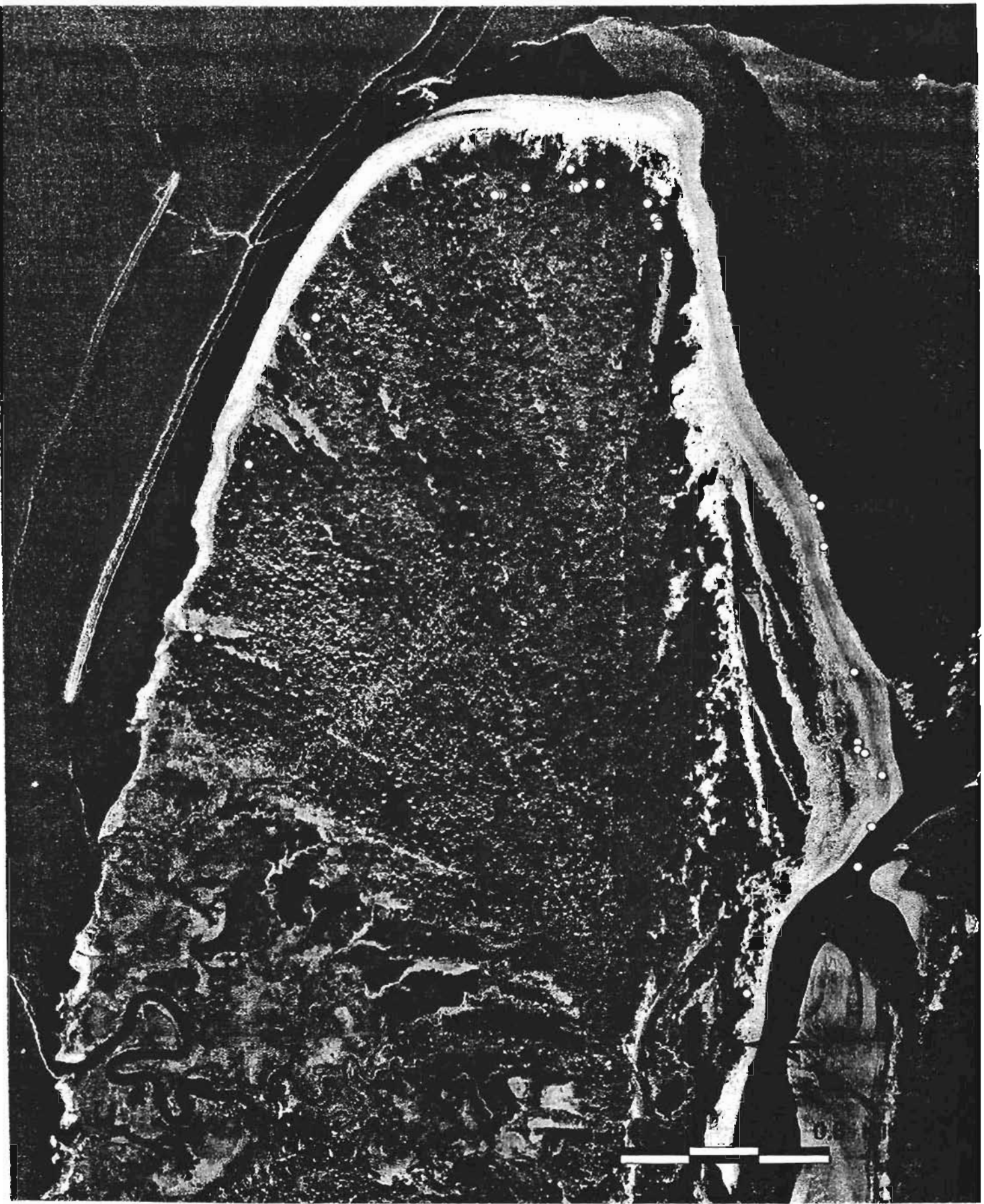
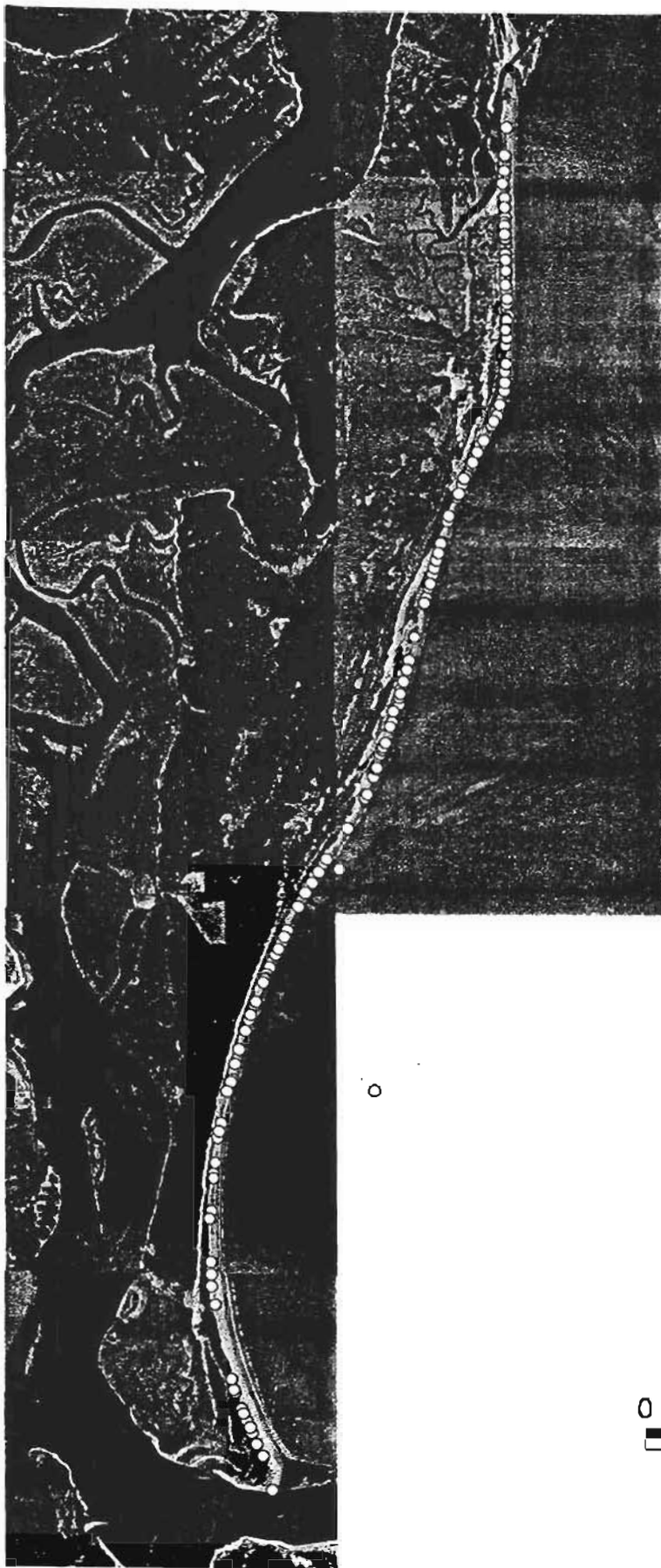


Figure 16. Spatial distribution of loggerhead sea turtle nests on Little Cumberland Island, Georgia, 2002. Data plotted on 1993 USGS Digital Orthophoto Quarter Quadrangles.

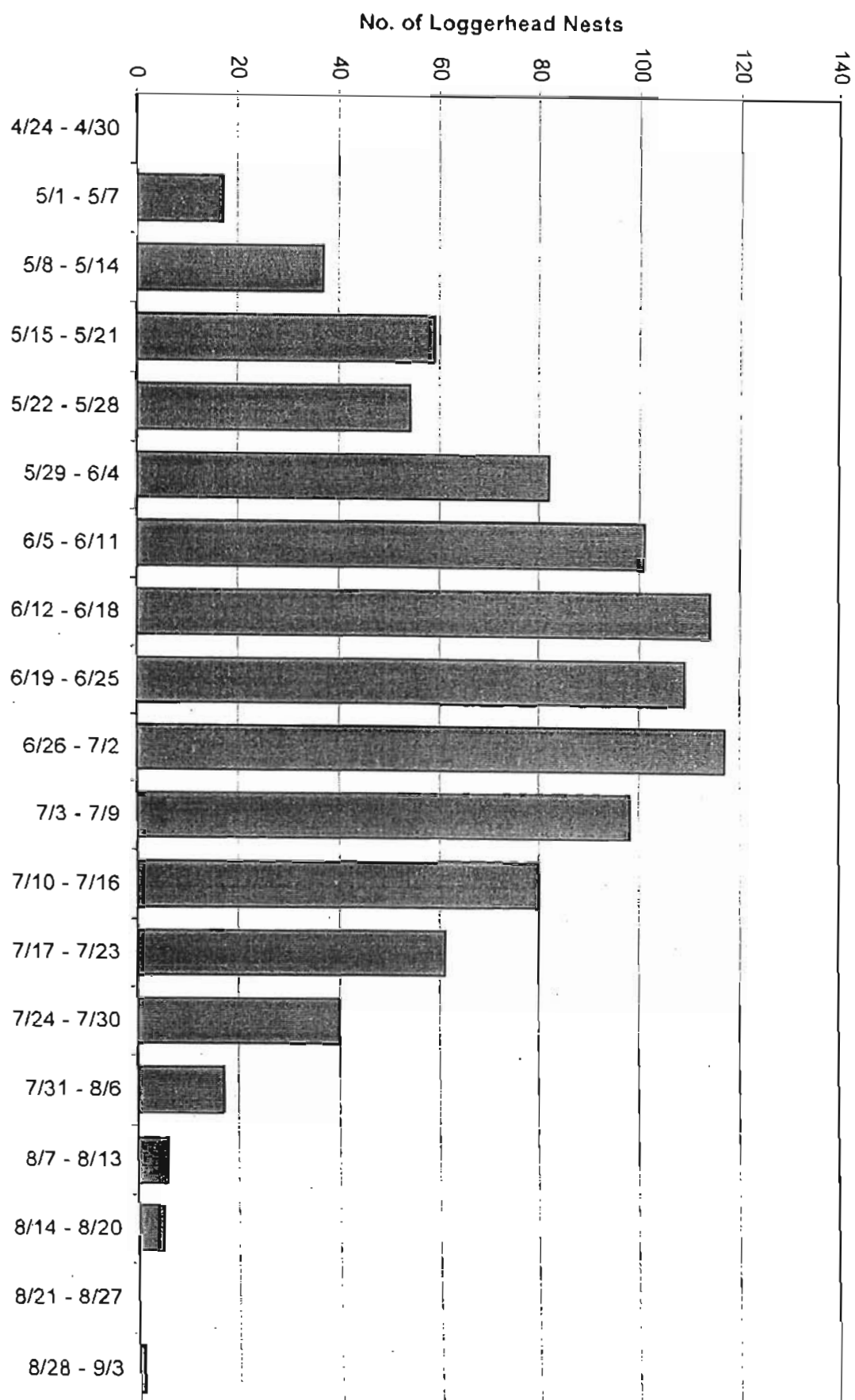


0 1 2 3 4 5 6 Kilometers

A horizontal scale bar with alternating black and white segments, representing distances from 0 to 6 kilometers.

Figure 17. Spatial distribution of loggerhead sea turtle nests on Cumberland Island, Georgia, 2002. Data plotted on 1993 USGS Digital Orthophoto Quarter Quadrangles.

Figure 18. Temporal distribution of loggerhead nests in Georgia, 2002 (n=1028)



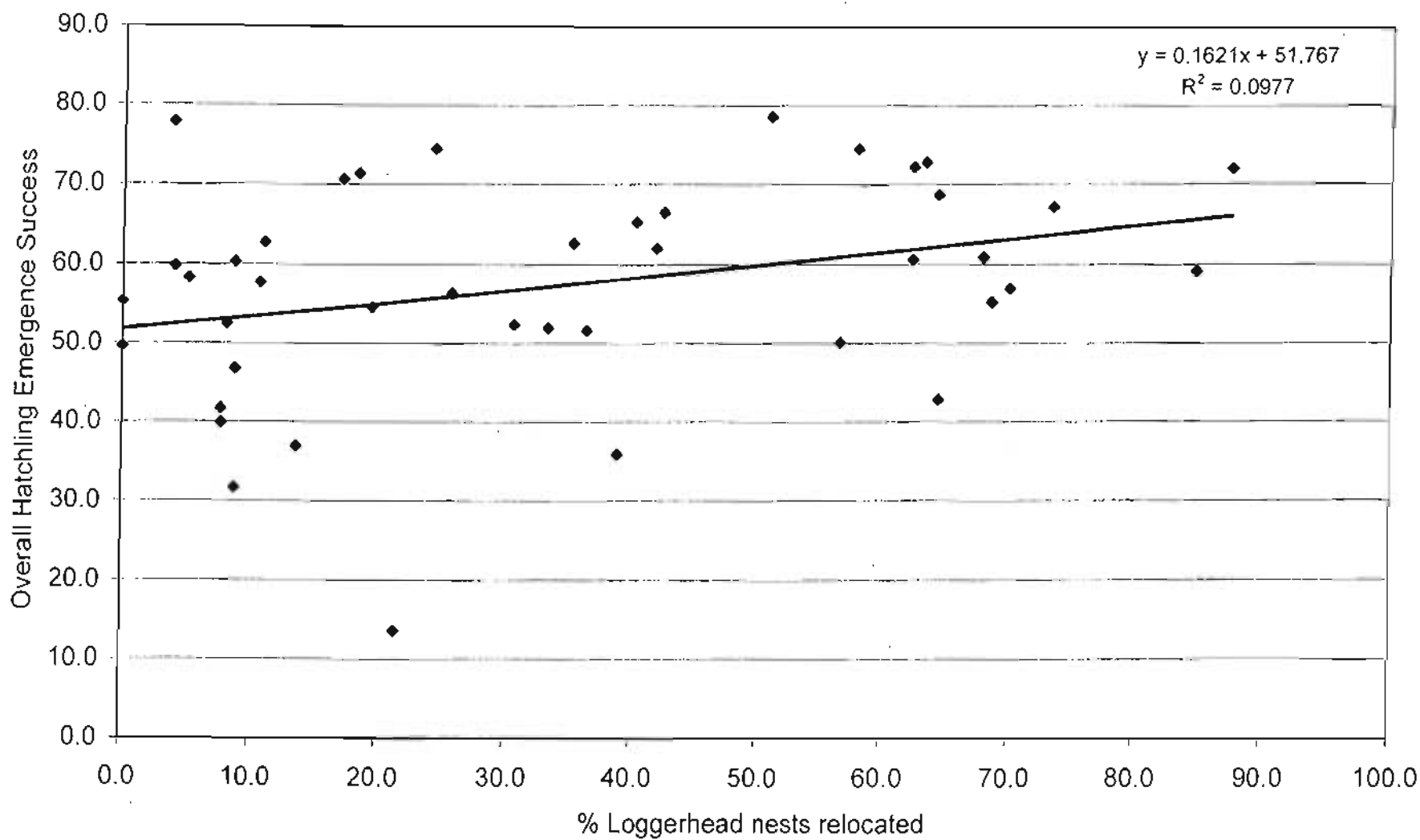


Figure 19. Relationship between the proportion of loggerhead nests relocated to avoid tidal inundation and nest emergence success (calculated excluding depredated nests) on Georgia's barrier islands, 1999-2002.

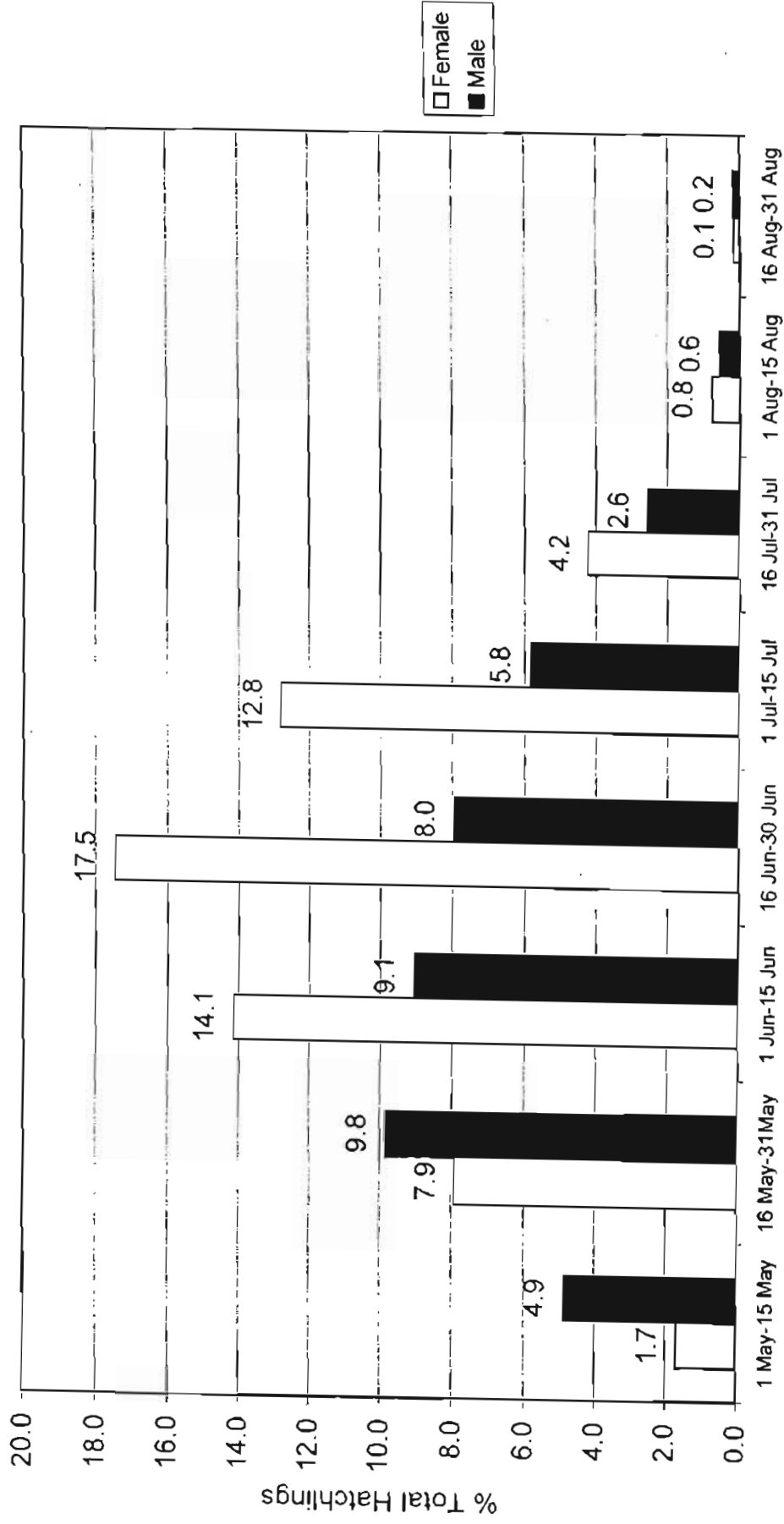


Figure 20. Seasonal loggerhead turtle sex ratios in Georgia, 2002 (n= 708 nests; 58,045 hatchlings). Sex ratios estimated from Godfrey and Mrosovsky 1997.

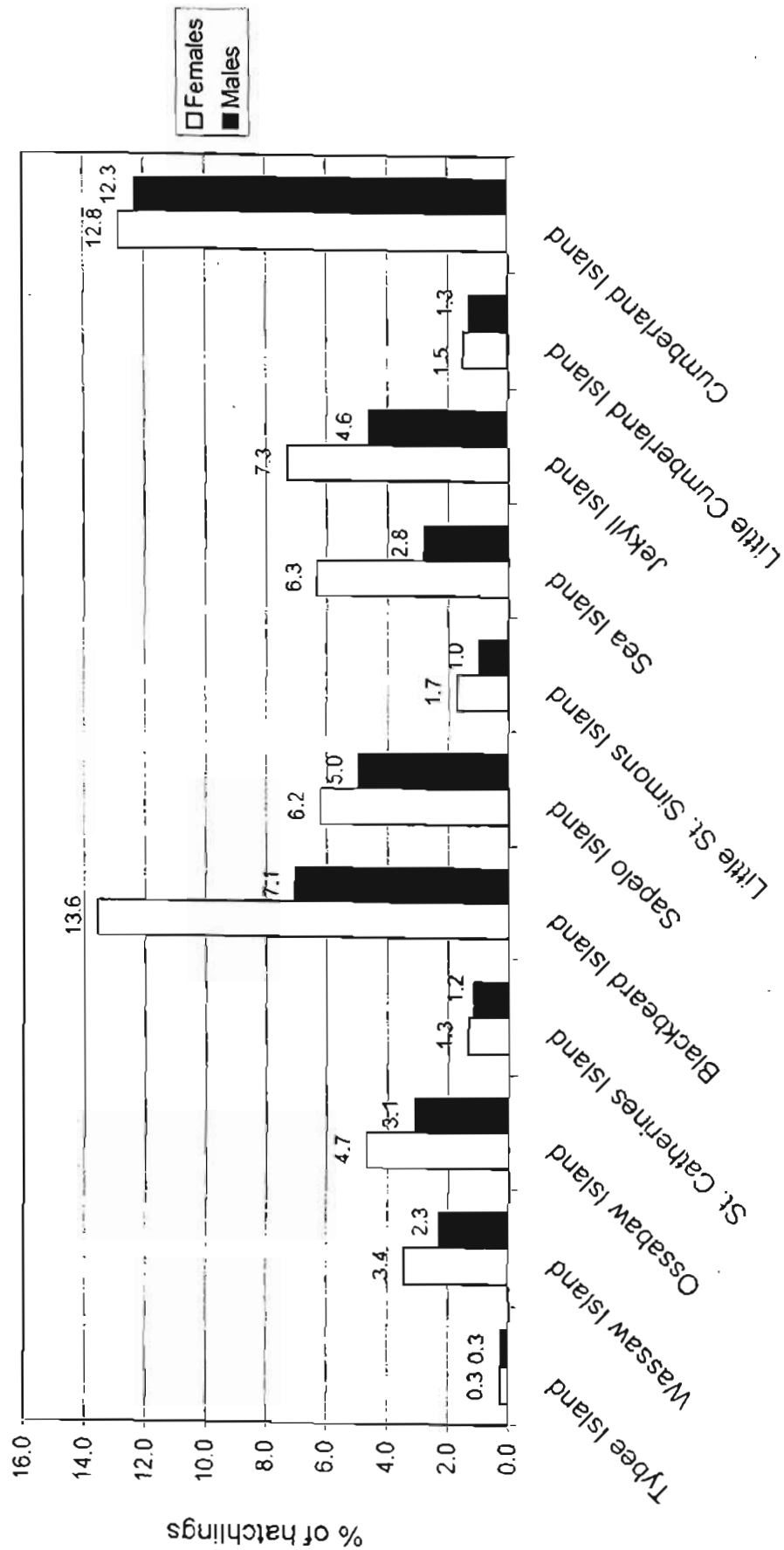


Figure 21. Loggerhead turtle sex ratios for Georgia barrier islands, 2002 (n=708; 58,045 hatchlings). Sex Ratios estimated from Godfrey and Mrosovsky 1997.

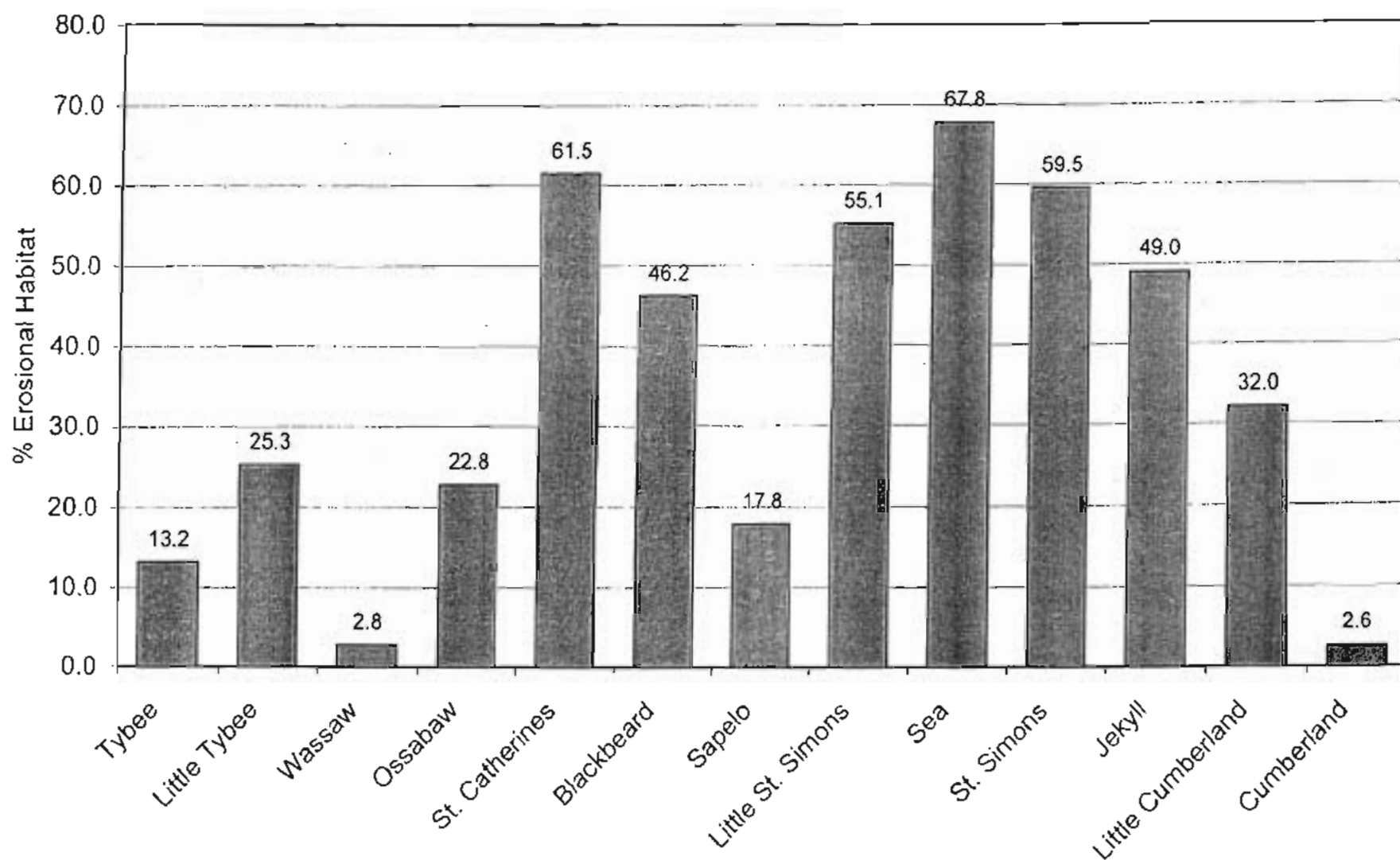


Figure 22. Proportion of loggerhead turtle nesting habitat categorized as erosional (Bishop and Marsh 1999) in Georgia, 2002.

