BIOTIC AND ABIOTIC FACTORS AFFECTING NEST MORTALITY IN THE ATLANTIC LOGGERHEAD TURTLE[a]

S. R. HOPKINS, Nongame and Endangered Species Section, SC Wildlife and Marine Resources Department, Charleston, SC 29412

T. M. MURPHY, JR., Nongame and Endangered Species Section, SC Wildlife and Marine Resources Department, Green Pond, SC 29446

K. B. STANSELL, U. S. Fish & Wildlife Ser., P.O. Box 95067, Atlanta, GA 30347.

P. M. WILKINSON, Nongame and Endangered Species Section, SC Wildlife and Marine Resources Department, Charleston, SC 29412

Abstract: Fates were determined for 458 nests of the Atlantic loggerhead (*Caretta caretta caretta*) on 4 South Carolina barrier islands. Raccoons (*Procyon lotor*) destroyed 56.1% of the nests overall and from 16.4 to 86.3% on individual islands. Poachers took 47.5% from 1 island and abiotic factors accounted for 14.2%. Ghost crabs (*Ocypode quadrata*) were not important predators, destroying only 2.4%. The overall hatch was 6.1%. The spatial and temporal aspects of nesting and predation, age of nest when depredated, density of nesting, and feeding efficiency of raccoons are discussed as they relate to the number of nests affected by each factor.

Proc. Ann. Conf. S.E. Assoc. Fish & Wildl. Agencies 32: 213-223

The reproductive strategy of marine turtles to lay large clutches of eggs several times a season is believed to be an adaptation to offset high mortality of nests and epipelagic young. This strategy has proved successful for millions of years (Carr 1967), but in recent times increased nest losses and increased mortality of subadults and adults have reduced populations as indicated by overall declines in all marine turtle species (IUCN Red Data Book 1970).

The Atlantic loggerhead was considered endangered by the International Union for Conservation of Nature and Natural Resources in 1970, and was officially listed as threatened by the U. S. Department of Interior in 1978 pursuant to the 1973 Endangered Species Act. The criteria for federally listing a species are: 1) alteration or destruction of habitat; 2) disease or predation; 3) over-utilization for commercial, sport, scientific or educational purposes; 4) inadequacy of regulatory mechanisms; and 5) other natural or man-made factors.

Four of these factors impinge on the life cycle of the loggerhead turtle in South Carolina. Nesting habitat is being lost to erosion and beach development. Nests are destroyed by erosion and predators, and because of ineffective laws and enforcement, poaching of eggs is high in some areas. Hatchlings are killed by predators and also die from desiccation when disoriented away from the ocean by artificial lighting near beaches (MacFarlane 1963). In addition, nesting females and sub-adults often drown when accidentally caught in the nets of shrimp trawlers (Ulrich 1978).

Since the survival rates of the pelagic stages of the life cycle are unknown, and may remain so for some time, it is important to document the survival rates of the accessible, terrestrial stages to obtain data on population recruitment for this species.

Several studies attempted to document nest destruction for *C. caretta* (Klukas 1967, Routa 1968, Gallagher et al. 1972, Davis and Whiting 1977, and Mann (1978). One such

[a]This research was supported by a Cooperative Agreement between the U. S. Dept. of Interior, Fish and Wildlife Ser., and the SC Wildlife and Marine Resources Dept., contract no. 14-16-004-3139. Contribution No. 89 from the SC Marine Resources Center.

study conducted in South Carolina by Baldwin and Lofton (1959), provides a data base on the Cape Romain rookery for comparative purposes.

The purpose of the present study was to quantify the types and extent of the biotic and abiotic factors associated with nest failure in the South Carolina loggerhead rookery.

Thanks are expressed to the staff at Cape Romain National Wildlife Refuge for their generous assistance with personnel and vehicles.

METHODS

Study Area

The study area comprised 4 islands on the South Carolina coast from North Inlet estuary in Georgetown County, south to Bulls Bay in Charleston County. These barrier islands were selected because of their relative concentrations of nesting turtles, their physical and biotic attributes and their accessibility for research.

North Island, which lies between North Inlet and Winyah Bay, is one of the more stable beaches on the South Carolina coast (Brown 1977). Its moderate to high dunes, some reaching more than 6 m, are covered predominantly with sea oats (*Uniola paniculata*). There is a wide, high berm, and erosion occurs only in the crescentic central portion of the 14-km beach. The island's interior supports a mature maritime forest and is undeveloped except for a small Coast Guard light station on the southwest side where the north jetty extends seaward along the Winyah Bay harbor entrance.

Sand Island, on the southern side of Winyah Bay, has accrued since the south jetty was constructed in the 1890's. It has no trees and only 2 small thickets of wax myrtle (*Myrica cerifera*). The 3-km beach on the seaward side of the jetty is short and steep and is backed by low dunes covered with sea oats, sea beach panic grass (*Panicum amarum*) and beach elder (*Iva imbricata*). Many of the dunes are scarped by erosion, and there are intermittent washover terraces along much of the front beach. The Winyah Bay side of the island has a wide, flat berm which floods on spring tides.

South Island lies to the southwest of Sand Island, and the two are separated by a small tidal inlet. Parts of South Island are eroding, and dunes are absent along the central portion of the 3-km beach where spring tides wash under dead wax myrtles. Low to moderate scarped dunes back the flat beach on the remainder of the island. The interior consists of maritime forest and extensive impoundments managed for waterfowl.

Cape Island, in the Cape Romain National Wildlife Refuge, is located north of Bulls Bay and is part of the Santee River delta complex. The 8-km island is a cuspate foreland and has undergone such severe erosion that the north flank has shifted from a north to a north-northeast orientation (Brown 1977). The portion of the beach surveyed (3 kms) is steep and narrow with a mixture of low to moderate scarped dunes and washover terraces.

Cape Island is unique when compared to other barrier islands. The sand is course rather than fine as on other islands (Brown 1977). The interior has a stand of loblolly pine (*Pinus taeda*) planted in the 1930's with an understory of wax myrtle. The landward side of the island is a flat field of scattered sea oats, Spanish bayonet (*Yucca*, spp.) and prickly pear cactus (*Opuntia* spp.). There is also a man-made impoundment on the north side.

Study Procedures

Prior to the 1977 nesting season each island's study area was divided into numbered segments with permanent marker poles. Each nest was located by segment and also by its approximate location within that segment, estimated to the nearest tenth.

From the onset of nesting, South Island was surveyed daily by jeep from 18 May to 30 August. Sand, North, and Cape Islands, accessible only by boat, were surveyed twice weekly to obtain a stratified regular sample of the nests. Sand and North were surveyed from 18 May to 22 September and 26 May to 26 September respectively. After a slight delay, Cape Island was surveyed from 10 June to 1 September. All work was conducted during the 1977 nesting season.

Initially each beach study area was approximately 3 kms long, since 2 of the islands were this length. However, because of low density nesting on North Island, the survey area was extended to the midpoint of the beach (approximately 8 kms) to provide a larger sample size. The particular 3-km section of Cape Island was chosen for its high nesting density for comparison with moderate and low density nesting areas.

The following procedure was used for each nest. The body pit of emergences was probed with a pointed dowel to locate the nest cavity. A small hole was dug by hand to verify the presence of eggs since othe factors, such as decayed driftwood, or a ghost crab burrow, could be mistaken for a nest cavity. Nests were marked with numbered flags which were offset 1 m on a specified compass direction from the nest. The sand was replaced and all probe marks were erased. In this way the location of the nest could be known and monitored throughout the incubation period without indicating its exact location.

The date laid, nest location relative to the dunes, a description of the nest site and other pertinent information were noted. On each beach survey new nests were marked and previously marked nests were checked for disturbance. When the fate of a nest was determined, the date and cause were recorded. Any undisturbed nest which had not hatched after 70 days was excavated to determine the cause of its failure. Successful nests were also excavated to determine viability and the number of eggs per nest. Wind direction and speed, tide stage, precipitation and temper ure were recorded daily for South Island.

RESULTS AND DISCUSSION

Abiotic Factors

Abiotic factors are generally considered to be: freshwater flooding from rainfall, windblown sand covering the nests, saltwater inundation by high tides, and severe beach erosion.

Nests destroyed by freshwater inundation were reported by Klukas (1967) and by Ragotskie (1959). South Carolina experienced a drought during the summer of 1977, and on South Island there was no precipitation from 26 June to 22 July, so freshwater flooding did not appear to be a factor. Salt and freshwater inundation appears to affect nests in a like manner, i.e. causing low oxygen conditions surroundings the eggs, depending on the severity of the flooding (Ragotskie 1959). Nests destroyed this way were either partially successful (less than 10% hatch), contained embryos arrested at various developmental stages, or eggs and sand below the water table had blackened from anaerobic conditions. Nests lost to severe beach erosion were completely washed away. Wind-blown sand accumulation was not a factor on the beaches studied.

Beach erosion is common along the southeast Atlantic coast and results from a slight but persistent rise in sea level and a reduction in riverborne sand over the past 50 years from damming (Hillestad et al. 1975). The periods of greatest erosion, except for hurricanes, occur whenever the highest monthly tides coincide with strong onshore winds. On our study areas this combination of factors occurred the week of 27 July 1977.

The number of nests destroyed by salt water inundation or erosion on each island was dependent on the island's beach profile, the location of the nest, and the availability of nests relative to the biotic factors. Of 458 nests sampled, 65 (14.2%) were lost to these 2 abiotic factors on all 4 islands (Table 1). On North Island the 4 nests affected were located in the central, eroding portion of the island. Even though 1 nest was situated at the top of a 1.3 m dune, it and most of the dune washed away. The low number of nests lost to erosion on South Island (3 of 87) was due, not to the beach profile, but to most nests being already depredated by raccoons (*Procyon lotor*); therefore, few were available for the tides to affect. All 3 nests affected were laid on the berm, and the embryos had died at various

	NORTH N=79 %	SAND N=158 %	SOUTH N=87 %	CAPE N=134 %	TOTAL N=458 %
ABIOTIC FACTORS					
Beach Erosion	3.8	17.1	1.1	17.9	12.0
Saltwater Inundation	1.4	2.5	2.3	2.2	2.2
BIOTIC FACTORS					
Humans	2.5	47.5	0.0	0.0	16.8
Ghost Crabs *Ocypode quadrata*	2.5	3.2	4.6	0.0	2.4
Crabs/Raccoons	8.9	6.3	1.1	1.5	4.4
Raccoons *Procyon lotor*	69.5	16.4	86.3	75.4	56.1
HATCHED	11.4	7.0	4.6	3.0	6.1
TOTALS	100.0	100.0	100.0	100.0	100.0

Table 1. Fates of 458 *C. caretta* nests on 4 barrier islands in South Carolina during the 1977 nesting season.

stages of development from the saltwater inundation. On Sand Island 31 of 158 nests were destroyed by both abiotic factors. Twenty-four of these were located in segments 1 to 6 on the southern portion of the island. Here the scarped dunes and washover terraces showed previous erosion, and 17 of the nests thus fated were laid on washover terraces, 3 on scarped dunes and 2 out on the berm. Of 9 nests laid on unscarped dunes, 7 were on low dunes (0.3-1 m high) where waves washed completely over them, pushing the sand back into the marsh thereby expanding the existing washover terraces.

Although the percentage of nests destroyed on Cape Island was similar to that on Sand Island, the effects of the tides on the Cape Island beach were more severe. The front face of the foredunes retreated landward about 10 m. In addition 6 of the segment markers, which were initially driven almost 2 meters into the sand, were washed away as the waves created a steeper beach profile. It is a conservative estimate that from 1/4 to 1/3 of the nesting substrate was removed from the 3-km study area and nests on or at the base of these dunes were lost. The high tides occurred after the nesting peak but before the hatching peak, thus most of the year's production not depredated by raccoons, was affected by these 2 abiotic factors.

In the 1977 nesting season, and in previous seasons according to Cape Romain personnel, the highest nesting density was on the southeastern part of the island. This section (also our study area) was comprised almost entirely of scarped dunes and recent or re-vegetated washover terraces. The wide beach type described by Baldwin and Lofton (1959) is found today on the northeast end of the island where nesting is relatively sparse. Baldwin and Lofton (1959) reported almost 1/3 of their nests and the most dense nesting were on the wide, sloping beach type and the least nesting at the base of scarped dunes and on washover areas.

Prior to the 1930's the Santee Delta was in a stable or constructional phase. Diversion of a major portion of the river's flow in 1942 has had a dramatic effect on the islands of the delta complex. Since then they have been in a continuing destructive phase.

Since 1941, Cape Island has eroded over 215 m (Stephen et al. 1975). Either the turtles are utilizing a different type of beach now or the section of the island where they formerly preferred to nest has eroded faster than their ability to change their nesting to more favorable wide beach areas.

Biotic Factors

Biotic factors were considered to be those factors involving other living organisms. These factors may be plant roots overgrowing the eggs, invertebrate predators entering a nest, vertebrate predators and/or poachers. The three biotic factors affecting nests on the islands studied were: the ghost crab, the raccoon, and man (Table 1).

Clearly the major predator of turtle nests was raccoons. On any given nesting beach, the number of nests destroyed by any predator, not just raccoons, may be determined by the inter-relationship of any or all of these 8 factors.

1. The spatial distribution of nests
2. The spatial distribution of predators
3. The temporal distribution of nests
4. The temporal distribution of predators
5. The age of nests
6. The predator feeding efficiency
7. Predator density relative to habitat
8. Relative density of nests

Generally, the spatial distribution of nests on Cape and South Islands was about even in all segments with slight differences in frequency depending on beach quality. Nesting on Sand and North Islands was not as evenly distributed. Several segments on the Winyah Bay side of both the north and south jettys had no nesting, and one segment on Sand Island (11% of the study area) contained 30% of the nesting for that island. The percentage of raccoon depredation, by segment, for each island was similar to the overall percentage raccoon depredation for each island. Even the 1 segment on Sand Island with the high degree of nesting had a proportionate number of nests destroyed in that segment relative to the entire island. Thus the location of a nest, while important with regard to abiotic factors, did not appear to be important in determining if a nest was eaten by raccoons.

Klukas (1967) noted areas of the beach at Cape Sable where raccoon concentrations were high and it was on these same areas that nesting was most intense. This beach type was backed by tall trees and shrubs. He did not report the amount of predation in these beach segments versus the other segments but indicated that even with trapping, raccoon tracks were always present, and he reasoned that these were core areas for raccoon dispersal.

In our study, depredation closely followed the spatial distribution of nesting. Raccoons appeared to be ubiquitous on all of our beaches and because of the relatively short distance of the islands' study areas, they appeared to be evenly distributed. Thus, any nest had about the same likelihood of being taken by a raccoon as any other nest. All areas of the beaches utilized by turtles for nesting were likewise utilized by raccoons to prey upon those nests.

In general the temporal distribution of nesting and predation (Fig. 1) was parallel with a slight lag time on some islands. Predator activity intensified toward the latter part of the nesting season. This was also noted by Gallagher et al. (1972) on Hutchinson Island, Florida.

There was about a week's lag time on South Island before raccoons began to find nests. After several weeks the depredation equalled, or in some cases exceeded, the nesting effort as raccoons preyed upon older nests to compensate for the decrease in nesting.

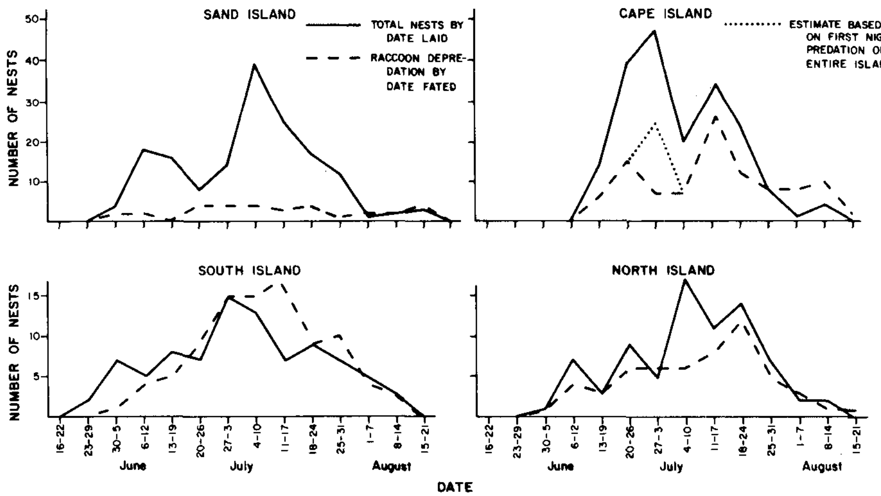

Fig. 1. The relationship between the temporal distribution of nesting and the temporal distribution of raccoon predation for *C. caretta* nests on 4 barrier islands in South Carolina during the 1977 nesting season.

Talbert and Dean (1975) also noted a lag time in depredation at the beginning of the nesting season in Kiawah Island, SC. They reported, "This period of grace usually enables 80 percent or more of the first 40-50 nests to incubate undisturbed." Based on their estimate of 200 nests per year laid on the island, this figure greatly exceeds the 3% survival rate mentioned earlier in their report. Based on our data, it seems doubtful that so large a number of nests could go undetected by raccoons.

Predation paralleled nesting on Cape Island also. The dotted line (Fig. 1) is an estimate based on first night predation for the entire island. Cape Romain personnel were screening nests for a transfer project during this time and it was felt that marking the nests not screened would bias the data on abiotic factors toward poorer nest sites. Therefore, raccoon depredation was estimated for this period. The graph also shows predation exceeded laying toward the end of the season.

North Island's predation likewise paralleled the nesting effort except for a lag at the peak of the season. However, predation decreased along with nesting at the close of the season.

Sand Island did not follow the pattern of the other islands and showed a low but sustained predation rate throughout the season.

Most nests were taken by raccoons during the first 2 or 3 nights (Fig. 2). First night predation was highest on Cape Island at 51%. First night predation was the same on North and South Islands, at 36%, and South Island had the same percentage taken the second night. Sand Island showed no high first night predation. Davis and Whiting (1977) reported 87% first-night predation at Cape Sable and Gallagher et al. (1972) had 34% of the nests destroyed the first 48 hours after laying.

The fact that second-night predation was as high as the first night's on South Island can be explained by supply and demand. During the nesting season, 1/3 of the nights had no nests laid and another 1/3 had only 1 nest laid. Thus raccoons hunting South Island beach every night had to resort to other than fresh nests.

Nest age appears to be an important factor in determining if a predator can locate and destroy a nest. As previously mentioned, there was lower than average rainfall for

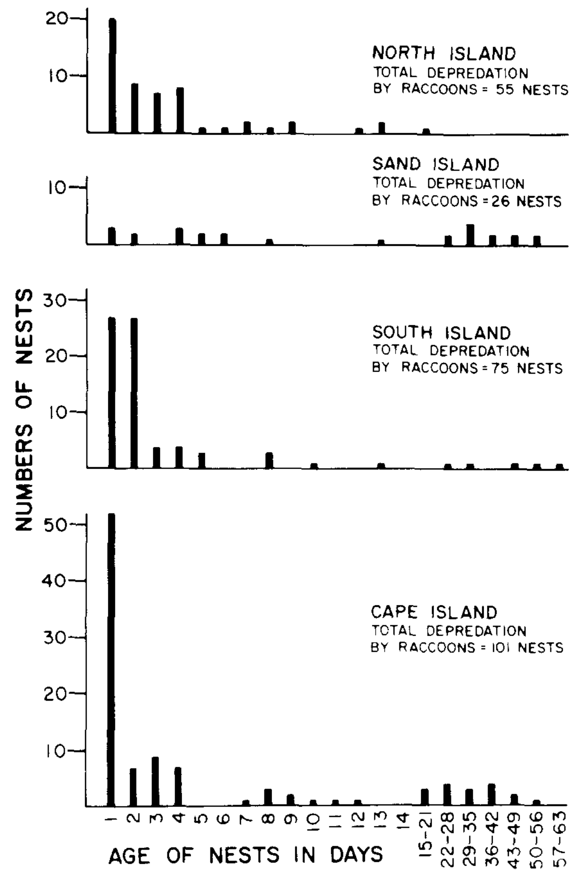

Fig. 2. Age specific nest losses for raccoon depredated nests only of *C. caretta* on 4 barrier islands in South Carolina during the 1977 nesting season.

most of the summer and the turtle's scent and the visual cues of the crawls probably remained longer at the nest site this year.

These data are consistent with those of Holden (1964) and Klukas (1967) for Cape Sable. They reported few nests taken after they were 2-3 days old. They also noted a slight rise in predation when nests were within a few weeks of hatching. Bustard (1972) observed this same phenomenon for foxes in Australia and it likewise occurred on the islands in this study.

The feeding efficiency of predators it also related to a nest's age. But feeding efficiency is difficult to calculate since it is an indication of learned behavior in the animal.

Since South Island was surveyed daily, the exact number of nests on the beach was known for any given day. The availability of nests is expressed as *nest-nights* (Table 2) and the data are grouped by weeks. *Nest-nights* are the number of nests on the beach multiplied by the number of nights each is available to raccoons. The feeding efficiency was calculated by dividing the number depredated by *nest-nights*.

The efficiency of raccoons increased past the peak of the nesting season and ended at a higher point than at the beginning of the season. A more accurate assessment of efficiency would take nest age into consideration when determining availability or nest

Date	Range of Nests Available	"Nests Nights" Number of Nests x Number of Nights Each is Available	Number of Nests Laid	Number Depredated by Raccoons	Percent Depredation by Nest Nights
May 16-22	1-2	4	2	0	0.0
May 23-29	2-8	41	7	1	2.4
May 30–June 5	6-8	45	5	4	8.9
June 6-12	10-13	79	8	5	6.3
June 13-19	8-11	67	7	8	11.9
June 20-26	14-18	107	15	10	9.3
June 27–July 3	12-19	104	15	10	9.6
July 4-10	12-18	110	7	12	10.9
July 11-17	11-13	82	9	9	11.0
July 18-24	7-11	60	6	9	15.0
July 25-31	6-9	52	5	4	7.7
August 1-7	4-8	45	3	3	6.7

Table 2. Raccoon depredation as related to *C. caretta* nest availability as an indication of feeding efficiency for South Island, 1977 nesting season.

nights. The figures given here are an attempt to quantify feeding efficiency, but the authors recognize that much more is involved in this concept.

The relative density of nests and the density of predators relative to habitat are obviously the two important factors affecting the number of nests destroyed. There are no data for the raccoon populations on the islands studied, so the designations of high and low to describe them are estimates based on tracks along the beaches and subjective evaluation of habitat.

Sand Island had moderately high nesting density, about 100 nests per 1.6 km but poor raccoon habitat. The presence of only a few raccoons resulted in low predation even with fairly high nesting. North Island had low density nesting, about 15 to 20 nests per 1.6 km. Although it has good raccoon habitat, it had the lower over-all predation of the 3 large islands and no older nests were taken. This indicated that nest density may fall below a level to support beach use by raccoons. This was shown by depredation dropping from 84% for the first half of the season to 60% for the second half.

Cape Island has probably the highest nesting density for the species in the United States. There were an estimated 250 to 300 nests per 1.6 km this season, and nesting estimates by refuge personnel were even higher in past seasons. It also has an extremely high raccoon population. The high first-night predation, mentioned earlier, results from many fresh nests being laid each night for most of the season, and predation never exceeded laying except at the end of the season. The predation on Cape Island this year far exceeds that of 1939 when Baldwin and Lofton reported only a 5.6% loss after a winter of extensive raccoon control.

South Island had the highest predation 86.2%, because the nesting density was high enough to support beach use by raccoons (45 nest per 1.6 km), but it was not high enough to overwhelm them as on Cape Island. More raccoons may have been drawn to the beach as the season progressed since depredation was 58% the first half of the season and 114% the second half.

On the beaches of the east coast of Florida, raccoon predation is lower than in South Carolina. Routa (1968) reported 7.8% predation on Hutchinson Island in 1967 and

Gallagher et al. (1972) had a 28% depredation of 1420 nests surveyed 4 years later. At Cape Sable where there is good raccoon habitat in the national park, predation rates were similar to those found in this study. Predation was reduced to 25% in 1966 and to 44% in 1967 on portions of beaches where experimental, daily trapping was carried out. Because of park policy, raccoons were not controlled after that and predation was back up to 85% in 1972 and 75% in 1973 (Davis and Whiting 1977).

Of the 8 factors affecting predation, those acting on the 4 islands studied in order of importance were: density of predators, nest age as it relates to feeding efficiency, relative density of nests, and to a lesser extent, the temporal distribution of nest and predators. Spatial distribution of raccoons did not appear to be a factor since they were everywhere, and spatial distribution of nests was important only with regard to abiotic causes of nest failure.

In their younger stages, ghost crabs must remain nearer the water to keep their gills wet. With each succeeding molt, the crab is able to spend less time near a source of water, and digs its burrows higher in the dunes (Phillips 1940). Therefore, because of this life cycle, the ghost crab appears to be more prevalent near nests later in the nesting season. However, adults which over winter can invade early nests.

The data indicate that ghost crabs were not an important source of depredation in 1977, taking only 11 nests of 458 (Table 1). In some cases it was impossible to discern whether raccoons dug into a nest first, followed by a crab, or whether egg shells on the surface brought there by a crab, lured raccoons to the nest. Therefore, for 20 nests, both predators were listed together (Table 1).

Seventy-five nests were taken by poachers from Sand Island and 2 from North Island. Several factors may account for Sand Island being the preferred location for poachers. First, it has easy access from Georgetown via Winyah Bay and safe anchorage on the landward side out of the surf zone. Second, the number of nests is moderately high to make a trip profitable. It was rumored that turtle eggs were being sold illegally in Georgetown for $3.50 per dozen. and third, there is low raccoon predation so that nests are still available, unlike the nearby islands.

Twenty-eight nests of 458 nests hatched successfully (6.1%). Of these, 11 were disturbed by raccoons after the eggs hatched, making an accurate count impossible. The average number of eggs for the 17 remaining nests was 105.6 with a range of 78 to 139, and the overall nest viability was 75.5%.

Only 4 nests hatched successfully on South Island. Of the 134 nests sampled on Cape Island only 4 hatched. While this was only a twice weekly sample, we are confident that it was indicative of the overall hatch for that 3-km section of the beach. Hatching was probably slightly higher on the more northern end of the island which had less flooding and erosion. Nine nests hatched in the survey area on North Island. This figure is probably close to the actual number for that island since nesting was relatively sparse along the northern portion of beach not surveyed because of shoaling offshore. Eleven of 158 nests sampled on Sand Island hatched. This also may be a fairly accurate estimate of production for this island since all crawls still visible were marked during the twice weekly surveys for most of the season. On 2 occasions only nests laid the preceding night were marked and, later in the season, high tides washed away evidence of some crawls and body pits before they could be marked. However, since nesting was diminishing at this time, it is doubtful that the actual number of nests hatched exceeded 20 for Sand Island.

It is difficult to believe that loggerheads could withstand such severe losses to reproduction over a sustained period of time. As indicated by its current status, it may be that the loggerhead can no longer withstand them, especially when these losses represent only 1 stage of its life cycle.

There are many unanswered questions surrounding marine turtles, but 2 are of utmost importance to their survival and management. What is the survivorship in the sea? And by how much should terrestrial losses to reproduction be reduced to have a selfsustaining population? Until these answers are known, management must be directed toward reducing them as much as possible.

Management Recommendations

Stricter laws, actively enforced, would reduce the losses to poachers, and the recent federal listing should be a deterrent. Beach stabilization might alleviate the losses to erosion, and regulation of coastal development would reduce habitat loss and hatchling deaths. Gear modification may improve the incidental catch problem and hatchery projects should be continued where they are already established.

The 4 islands in this study constitute more than 70% of the nesting effort for the entire South Carolina coast (Stancyk and Talbert pers. comm.). In view of the importance of these islands to the turtles, data indicate that raccoon control methods should be initiated where needed on these rookery beaches. In addition to raccoon control, nests may have to be moved to other areas of the beach to protect them from erosion.

LITERATURE CITED

Baldwin, W. P., and J. P. Lofton, Jr. 1959. The loggerhead turtles of Cape Romain, South Carolina. *In*. D. K. Caldwell and A. Carr coordinators] The Atlantic loggerhead sea turtle, *Caretta caretta caretta* (L.) Annu. Bull. Fla. State. Mus. Biol. Sci. 4(10):319-348.

Brown, P. J. 1977. Variations in South Carolina coastal morphology. S. E. Geol. 18(4):249-264.

Bustard, H. R. 1972. Sea turtles – their natural history and conservation. London: Collins Sons and Co., Glasgow, Scotland. 220 pp.

Carr, A. 1967. So excellent a fishe. The Natural History Press, Garden City, New York. 248 pp.

Davis. G. E., and M. C. Whiting. 1977. Loggerhead sea turtle nesting in Everglades Natl. Park, Fla., USA Herptl. 33(1):18-28.

Gallagher, R. M., M. L. Hollinger, R. M. Ingle and C. R. Futch. 1972. Marine turtle nesting on Hutchinson Island, Florida in 1971. Fla. Dept. Nat. Res. Spec. Sci. Rep. 37:1-11.

Hillestad, H. O., J. R. Bozeman, A. S. Johnson, C. W. Berisford and J. I. Richardson. 1975. The ecology of the Cumberland Island National Seashore. Camden County, Ga. Rep. to the Nat. Park. Ser.

Holden, M. F. 1964. Sea turtle nesting survey on Cape Sable beach, Everglades National Park, Fla. 1964 season. Rep. from File No. N1415 (1964), Everglades Nat. Park, P.O. Box 279, Homestead, Fla. 33030.

IUCN. 1970. Red Data Book 3, Morges Switzerland, Internat. Union for Conserv. of Nature and Nat. Res. R/7/ERETM/IMB.

Klukas, R. W. 1967. Factors affecting nesting success of loggerhead turtles at Cape Sable, Everglades Nat. Park. File No. N1415. Nat. Park Ser., P.O. Box 279, Homestead, Fla. 33030. 58 pp. mimeo.

MacFarlane, R. W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia. 151 p.

Mann, T. M. 1978. The impact of developed coastline on nesting and hatchling sea turtles in southeast Florida. Fla. Mar. Res. Publ. 33:53-55.
Turtles. 24-25 July 1976. Jensen Beach, Fla.

Phillips, A. M. 1940. The ghost crab. Nat. Hist. Vol. 46, 36-41.

Ragotskie, R. A. 1959. Mortality to loggerhead turtle eggs from excessive rainfall. Ecology. 40(2):303-305.

Routa, R. A. 1968. Sea turtle nest survey of Hutchinson Island, Florida. Q. J. Fla. Acad. Sci. 30(4):287-294.

Stancyk, S. E., and O. R. Talbert. Personal Communication.

Stephen, M. F., P. J. Brown, D. M. Fitzgerald, D. K. Hubbard and M. O. Hayes. 1975. Beach erosion inventory of Charleston County, South Carolina; a preliminary report. SC Sea Grant Tech. Rep. No. 4, 79 p.

Talbert, O. R., and J. M. Dean. 1975. The loggerhead turtles of Kiawah Island, SC. From an Environmental Inventory of Kiawah Island, SC, Environ. Research Center, Inc., Columbia, South Carolina.

Ulrich, G. F. 1978. Incidental catch of loggerhead turtles by South Carolina commercial fisheries. Report to NMFS Contract Nos. 03-7-042-35151 and 03-7-042-35121. 36 pp.