This document was produced by the United States Geological Survey, Patuxent Wildlife Research Center, at the request of Cape Hatteras National Seashore. The information and recommendations presented are the professional opinions of the scientists that analyzed and interpreted the scientific data associated with protected species at the Seashore. This information will be considered by the National Park Service (NPS), along with federal laws and mandates, NPS policies, other scientific information, and public input, in developing management plans and conservation strategies implemented at the Seashore.

MANAGEMENT AND PROTECTION PROTOCOLS FOR NESTING SEA TURTLES ON CAPE HATTERAS NATIONAL SEASHORE, NORTH CAROLINA

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EXECUTIVE SUMMARY

1. The southeast U.S. population of the loggerhead turtle (*Caretta caretta*) has increased since the species was listed as federally threatened in 1978. Since standardized monitoring began in North Carolina in 1995, the number of nests at Cape Hatteras National Seashore (CAHA) fluctuated from year to year, and was lowest in 1996 and 1997 (39 nests) and highest in 2003 (101 nests). Green turtles (*Chelonia mydas*) and leatherback turtles (*Dermochelys coriacea*) have nested in small numbers at CAHA, sporadically over time.

2. Hatching success of sea turtle nests typically approaches 80%. At CAHA hatching success from 1999-2003 was low when hurricanes hit during the nesting season (30%-38%), and ranged from 52%-70% otherwise. Hatching success at CAHA is usually correlated with hatching success in the surrounding subpopulation (north Florida to North Carolina).

3. Inclement weather, predation, and human recreation can negatively impact nesting rate and hatching success.

4. Currently there is little protection from recreation at CAHA for nesting females and nests that have not been found by monitors. We propose three management options to provide such protection, and to increase protection for known nests and hatchlings. We propose an adaptive management framework for assessing the effectiveness of these management options in improving sea turtle nesting rate and nest and hatchling survival.

5. We recommend continued efforts to trap and remove mammalian predators from all sea turtle habitat. We further recommend intensive monitoring and surveillance of protected areas to determine the extent and timing of threats to nests and broods, including nest overwash, predation, and disturbance or vandalism by humans.

6. Continue to relocate nests and assist stranded turtles according to North Carolina Wildlife Resources Commission guidelines.

7. Artificial light sources pose a serious threat to sea turtles in some parts of CAHA, which must be remedied immediately. We recommend that CAHA enact turtle-friendly lighting regulations and work with the communities within its borders to reduce light pollution and to eliminate artificial light sources that are directly visible from sea turtle nesting areas.

8. We recommend increased education and outreach to CAHA visitors, including requiring participation in an educational program before being granted nighttime beach access. The long-term success of sea turtle recovery will depend on public cooperation and positive public attitudes toward sea turtles and turtle management actions.

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INTRODUCTION

The loggerhead turtle (*Caretta caretta*) is by far the most numerous sea turtle to nest at Cape Hatteras National Seashore (CAHA, Fig. 1). Green turtles (*Chelonia mydas*) and leatherbacks (*Dermochelys coriacea*) have nested sporadically at CAHA (Altman and Lyons 2003). CAHA is the northernmost nesting site for leatherbacks on the Atlantic Coast (Rabon et al. 2003). Loggerhead turtles were listed as federally threatened in the U.S. in 1978 (NMFS and USFWS 1991a), and the other two species were listed as endangered in 1978 (NMFS and USFWS 1991b) and 1970 (NMFS and USFWS 1992), respectively. The U.S. Atlantic loggerhead population has increased since listing, from approximately 14,150 animals in 1983 (NMFS and USFWS 1991a) to between 32,000 – 56,000 by the year 2000 (Ehrhart et al. 2003). Within the northern subpopulation (north Florida to North Carolina), studies in South Carolina and Georgia have documented a decline in number of nests (Ehrhart et al. 2003). Based on genetic evidence, male loggerheads disperse freely among sites within the U.S. Atlantic population, while females are faithful to their natal sites (Bowen et al. 2005). Because sex ratio is determined by temperature during incubation (Miller et al. 2003), the northern part of the U.S. Atlantic population, which includes North Carolina, apparently provides a disproportionate number of males to the larger population (Mrosovsky et al. 1984, Hansen et al. 1998, Hawkes et al. in review).

One recovery goal for the loggerhead turtle in North Carolina is to attain the pre-listing nesting rate of 800 nests/season (NMFS and USFWS 1991a). The number of nests in NC fluctuated broadly around 800 nests/season from 1990-2003 (Godfrey and Cluse 2003). Since standardized monitoring began in North Carolina in the mid-1990's, the number of sea turtle nests/season at CAHA was lowest in 1995 and 1996 and highest in 2002 (Fig. 2). Only 49 nests were laid in 2004, but that year was poor for the entire southeast Atlantic Coast (M. Godfrey, North Carolina Wildlife Resources Commission, pers. comm.).

These protocols provide guidance for improving protection for sea turtle females and nests based on the results of current knowledge and adaptive management, in order to assist the Park in furthering its contribution to the recovery of sea turtle species while quantifying the effects of human recreation on sea turtles with more precision than has been done before. These protocols, as per the request of the National Park Service (NPS), are designed to provide as much protection for sea turtles (i.e., as little “take” as possible, as defined under the Endangered Species Act of 1973), without regard to budget, staffing, or impacts on other CAHA uses such as recreation. It will be up to the NPS to decide how best to incorporate these protocols into a more comprehensive management plan, given the logistical and political realities faced by CAHA.

The USGS Patuxent Wildlife Research Center developed this protocol, based on the best available scientific information, to guide management, monitoring and research activity at CAHA that would result in the protection and recovery of each species. These protocols do not attempt to balance the need for protection of these species with other activities that occur at CAHA, nor was NPS management policy considered in detail. A draft of the protocols was sent to species experts for scientific review; the final draft of protocols were reviewed by NPS personnel to ensure that description of recent management at CAHA was accurately represented and that the approach was consistent with our work agreement.

SPECIES DESCRIPTIONS

The loggerhead is the smallest of the turtles to use CAHA, with a mean carapace length of 92 cm and a mean mass of 133 kg (NMFS and USFWS 1991a) , compared to 102 cm and 136 kg in the green turtle (National Research Council 1990) and 155 cm and 204-696 kg in the leatherback (NMFS and USFWS 1992). Leatherbacks and green turtles breed primarily in the tropics and are rarer nesters at higher latitudes, while loggerheads have significant nesting populations outside the tropics (National Research Council 1990). Approximately 95% of the sea turtle nests at CAHA are of the loggerhead (Altman and Lyons 2003). For this reason we focus the remainder of the species account on loggerheads, with notes where the biology of the other two species differ in ways relevant to nesting site management.

Loggerhead females reach sexual maturity at 12-37 years (Witherington 2003), with more recent research pointing to a minimum age of 30 years (Snover 2002). At the start of the breeding season, they migrate from foraging areas on the continental shelf to mating grounds near their nesting beaches (Schroeder et al. 2003). Reproductive females exhibit natal philopatry (Miller et al. 2003). Females may be inseminated by multiple males (Bollmer et al. 1999). After mating, males return to their foraging areas while the females emerge onto their nesting beaches. The following account of nesting biology is a synopsis of Miller et al. (2003). Loggerhead females tend to nest on high wave energy, sandy ocean beaches. Gravid females emerge from the swash zone and crawl toward the dune line until they encounter a suitable nest site, typically on open sand at the seaward base of a dune, but sometimes in vegetation. The female clears away surface debris with the front flippers, creating a "body pit", then excavates a flask-shaped nest cavity with her hind flippers. Loggerheads lay an average of 112 eggs/nest. After laying, the female covers the nest with sand using all four flippers. Once the nest-covering phase is complete, she crawls back into the sea. Individual females may nest 1 to 6 times per nesting season, at intervals of 12-16 days, during the late spring to late summer. Intervals between nests shorter than 10 days indicate that the previous nest attempt was likely aborted due to disturbance. Mature loggerheads nest every 2 to 3 years, on average (Schroeder *et al*. 2003). Nest incubation period (from laying to hatching) depends on temperature, and ranges from 48 to 90 days at the extremes. Emergence of hatchlings from the nest cavity may take up to 2 weeks longer, but usually occurs within 4 days of hatch. Hatchling emergence from nests usually occurs at night when temperatures are lower and diurnal predators are inactive. Hatching success typically approaches 80%, but survival to 1 year of age is 67% (National Research Council 1990). Sex ratio of hatchlings depends on temperature during incubation. Below 29 °C, more males are produced than females, and above that temperature more females are produced (Carthy *et al*. 2003). Furthermore, fluctuating incubation temperatures often produce more females than stable temperatures, and temperature, hydration, and gas exchange during incubation can determine hatchling size, early swimming behavior, growth rate, and hatchling robustness (Carthy *et al*. 2003). Newly emerged hatchlings immediately head for the sea, most likely orienting toward the water by moving toward the brightest horizon and away from dark silhouettes (Lohmann and Lohmann 2003). Sea turtles are most sensitive to blue and green light, and loggerheads in particular are averse to yellow light (Witherington and Martin 1996). Once in the sea, hatchling loggerheads swim into the waves and eventually enter the open ocean, where they will spend the first 6.5 to 11.5 years of their lives primarily at the top of the water column, until finally moving to foraging areas on the continental shelf (Bolten 2003).

NESTING HABITAT

Less is known about factors that cue nest site selection than about anthropogenic disturbances that discourage nesting (Miller et al. 2003). Typical nesting areas are “sandy, wide, open beaches backed by low dunes, with a flat, sandy approach from the sea” (Miller et al. 2003). Nesting is nonrandom along the shoreline, but studies of the physical characteristics associated with nests *vs*. random or non-nesting sites on the beach have produced varying results. Some factors that have been found to determine nest selection in certain studies are beach slope (3 of 3 studies), temperature (2 of 3 studies), distance to the ocean (1 of 3 studies), sand type (2 of 2 studies), and moisture (1 of 3 studies), although the results were occasionally contradictory (Miller et al. 2003). Other factors examined but not found to be significant were compaction, erosion, pH, and salinity. Although the process of nest site selection is not well understood, a successful nest must be laid in a low salinity, high humidity, well-ventilated substrate that is not prone to flooding or burying due to tides and storms, and where temperature is optimal for development (Miller *et al*. 2003).

THREATS TO SURVIVAL AND REPRODUCTION

Threats to the loggerhead on the nesting grounds, as outlined in their recovery plan (NMFS and USFWS 1991a), are representative of those faced by green and leatherback turtles.

Weather and Tides

Direct effects.—Storm events may destroy nests due to flooding or piling of eroded sand on the nest site.

Indirect effects.—Beach erosion due to wave action may decrease the availability of suitable nesting habitat (Steinetz et al. 1998), which leads to a decline in nesting rate.

Predation

Direct effects.— Predation by mammals, birds, and ghost crabs may eliminate 100% of productivity on beaches where it is not managed (National Research Council 1990). Fire ants may also kill hatchlings about to emerge from the nest cavity.

Human Activities

Direct Effects.— Crowding of nesting beaches by pedestrians can disturb nesting females and prevent laying (NMFS and USFWS 1991). Furthermore, the use of flashlights and campfires may interfere with sea-finding behavior by hatchlings. Beach driving by off-road vehicles may harm sea turtles by running over nests, which may increase sand compaction and decrease hatching success or kill pre-emergent hatchlings (NMFS and USFWS 1991). Beach driving poses a risk of injury to females and live stranded turtles, can leave ruts that trap hatchlings attempting to reach the ocean (Hosier et al. 1981), can disturb adult females and cause them to abort nesting attempts, and can interfere with sea-finding behavior if headlights are used at night (NMFS and USFWS 1991). Artificial lighting on human structures may affect turtle behavior in a similar manner (Martin and Witherington 1996). Beach cleaning can directly destroy nests. Poaching is a problem in some countries, and occurs at a low level in the United States.

Indirect Effects.— An increased human presence may lead to an increase in the presence of domestic pets that can depredate nests, and an increase in litter that may attract wild predators (National Research Council 1990). Pedestrian and ORV traffic and beach-cleaning activities can create ruts that trap emerging hatchling and prevent them from finding the sea (Hosier et al. 1981). Trampling can increase sand compaction that may damage nests or hatchlings (Kudo et al. 2003). When artificial lighting impairs sea-finding behavior of nesting females and emerging hatchlings, the affected animals face increased exposure to the elements and predation.

The rate of habitat loss due to erosion and escarpment may be increased when humans attempt to stabilize the shoreline, either through renourishment (Dolan et al. 1973), or placement of hard structures such as sea walls or pilings (Bouchard et al. 1998). ORV traffic may alter the beach profile, leading to steeper foredunes (Anders and Leatherman 1987), which may be unsuitable for nesting. Improperly placed erosion-control structures such as drift-fencing can act as a barrier to nesting females. Humans may also introduce exotic vegetation in conjunction with beach development, which can overrun nesting habitat or make the substrate unsuitable for digging nest cavities.

Threats at CAHA

The following data are from CAHA sea turtle monitoring reports, 1999-2003. The majority of nest losses at CAHA from 1999 to 2003 were due to weather, particularly hurricanes and other storms. In 2003 Hurricane Isabel destroyed so many nests that losses to other sources were difficult to document. Foxes were first seen at CAHA in 1999, and on Hatteras Island in winter 2001/2002. Foxes disturbed or destroyed 1 to 9 nests/yr from 1999 to 2003, except in 2000 when no predation was reported. Ghost crab predation has been reported sporadically, with crabs seen at 0 to 17 nest sites/yr from 1999 to 2003 and observed predation of 0 to 3 nests/yr. Pedestrian tracks are recorded inside closures, and counts ranged from 8 to 92 trails/yr. Pedestrians disturbed or destroyed 2-6 nests/yr from 1999-2002 by digging them up, and none in 2003. Violation of closed areas by ORVs has become increasingly common, with 29 to 109 sets of tracks inside closures and 4 to 146 incidents of fencing vandalism recorded/yr. ORVs drove over 4-5 nests/yr from 2000-2002, although the nests survived. Dogs disturbed or destroyed 2 nests in 2000, and 5-60 sets of tracks/yr have been recorded inside closures. Cats have not been observed to predate eggs or hatchlings, but 10 to 50 sets of tracks/yr were counted inside closures from 2000-2002. Documented beach campfires totaled 174 in 2000 and 773 in 2001. Such fires may misdirect adults and emergent hatchlings. Several cases of hatchlings being misdirected by lights from villages and other human structures were documented in 1999, 2000, and 2002.

CURRENT MONITORING AND PROTECTION AT CAHA

CAHA has been monitoring sea turtle nesting since 1988, from June 1 to September 1, although the North Carolina Wildlife Resources Commision (NCWRC) currently encourages turtle monitors to begin surveying on May 1 (M. Godfrey, NCWRC, pers. comm), and sea turtle hatching may occur through November 15. CAHA otherwise follows monitoring and management procedures outlined in the Handbook for Sea Turtle Volunteers in North Carolina (NCWRC 2002, Altman and Lyons 2003).

Since 2004, ORV traffic is restricted year-round to a 50 m-wide corridor parallel to the shoreline, bounded at one side by the average high water line. Vehicles may drive along or park within the corridor. Where there is a primary dune line, this corridor effectively extends to the dune toe in most places. Thus, little to no ocean backshore nesting habitat is free of pedestrian and ORV use except where specific areas are closed to protect sea turtle or bird nests. Pedestrians, but not pets, are permitted outside the ORV corridor on the spits, except where there are specific "resource closures."

As of 2005, monitoring to detect crawls and dig sites was conducted each day at dawn, from June 1 to September 1. When a nest was found, a buffer zone of symbolic fencline was placed around it, approximately 9 m on a side. As the hatching date approached, the buffer zone width was expanded to 23 m in low-recreation areas, 46 m adjacent to villages or areas with high day use, and 107 m in ORV zones. Furthermore, the closures were extended to the surf line to prevent further traffic between the nest and the sea, and to 15 m landward of the nest, and vehicle tracks between the nest and the sea were mechanically smoothed. Drift fences were placed behind nests to shield emerging hatchlings from headlight beams, and ORV traffic was directed landward of these fence lines. A small number of nests were relocated due to impending threat of overwash or erosion. In past years, relocations also occurred if nests were laid close to artificial light sources such as piers.

In some years prior to 2005, predator exclosure screens were placed over nests to prevent red fox predation. From 2002-2005 the NPS undertook trapping to remove mammalian predators from Bodie Island and Hatteras Island. In 2002, 12 red foxes were removed from Hatteras Island by U.S. Dept. of Agriculture (USDA) Wildlife Services personnel, and another 16 from Bodie Island. USDA officials believed there was still one fox left near South Beach, and a number of foxes on Bodie Island. In 2003, 15 foxes were removed from Bodie Island and 1 from Hatteras, as well as three opossums and one raccoon at Hatteras. CAHA staff removed one feral cat from near Hatteras Inlet. Although a number of foxes were still believed to be on Bodie Island, no fox tracks were seen in plover habitat after trapping began in 2002. Predator removal may enhance the success of exclosures.

CAHA staff proposed initiatives to use concessionaire fees to purchase turtle-friendly lighting for piers (Altman and Lyons 2003).

Effects of current management.— There is a high risk of disturbance or injury to adult females and stranded individuals due to night recreation and ORV driving, including deterrence from nesting. Starting monitoring on June 1 leads to nests laid earlier being missed, and ending on September 1 may lead to insufficient protection for hatchlings after that date. Furthermore, nests may be missed by monitors if ORV ruts obscure turtle crawls, and other nests may be missed because the amount of habitat that monitors must search at CAHA is great (55 miles/day, Altman and Lyons 2003). Unfound nests are at high risk of being crushed by ORVs or pedestrians, as are any other nests that are laid between nest surveys. The small size of the buffer zones used to protect nests leads to a risk that trespassing by people or domestic animals in protected areas will affect the nest itself. The presence of ORVs on the beach at night leads to the risk of deterred nesting and misdirection and disorientation of emerging hatchlings, which in turn leads to an increase risk of hatchling loss due to crushing by humans or becoming trapped in ruts, and due to predation and the elements. Campfires and artificial lighting on human structures, especially at the villages, may deter nesting or affect the seafinding hatchlings. The presence of ORVs 24 h/day year round may affect the beach profile and substrate characteristics in a way that reduces suitability for nesting and reduces emergence success. The use of predator screens may have attracted foxes to particular nests in 2001 and 2003, and resulted in the loss of a nest in 2003 because a screen was improperly placed (Altman and Lyons 2003). However, the screens have generally only been used when the risk of depredation by foxes was already known to be high, and in 2001 reduced the number of eggs lost even when a fox attempted to dig through a screen (Sayles 2002). Predator screens have been shown to reduce nest depredation in other places (Adamany et al. 1997, Ratnaswamy et al. 1997).

ADAPTIVE RESOURCE MANAGEMENT

Monitoring of floral and fauna over large landscapes should always include three components: a research question(s) aimed at a desired goal, a management approach or experiment to try to determine causality, and a monitoring component to determine the resultant magnitude, duration, and latency of changes associated with the management action or experiment. As monitoring results are revealed, a feedback loop allows the manager to either continue the current management practice or technique, or modify it until the desired trajectory is achieved.

CAHA is at or near the northern limit of the breeding range for all three species of sea turtle that nest there. As such, it may be difficult to manage the current populations for increased nesting density, especially for the green and leatherback turtles. For the latter two species, the primary management goals should be to accurately assess the number of nesting females and their reproductive success so that the current contribution of CAHA to regional population dynamics can be better understood, and to continue to protect adults and nests wherever they are found. Some have suggested, however, that as populations of green and leatherback turtles increase in the western Atlantic, they are expanding their range, and thus populations in North Carolina could increase in the future (M. Godfrey, NC Wildlife Resources Commision, per. comm.). For the more numerous loggerhead, factors affecting distribution and abundance, and especially the effectiveness of recreation management, can be studied and the results used to enhance management. Data collected to that end should still be collected for green and leatherback turtles, in the event that numbers of those species increase. The baseline level of recreational use of sea turtle habitat has not been quantified, and should be studied if management to reduce recreational impact is desired.

Questions to Be Addressed

1) How many nests of each species are found per year and what is their location?
2) What is the hatching success for each species?
3) What is the sea-finding success rate for hatchlings of each species?
4) What is the fate of nests that are relocated?

Adaptive Management Protocols

Objective 1: To determine the effect of management of human recreation on nesting rate, hatching success, sea-finding by hatchlings (prevalence of misorientation and trapping by obstacles), proportion of false crawls, presence of potential predators and their tracks or burrows (mammalian, avian, and ghost crabs), and nest site characteristics (intertidal zone slope, backshore slope, % vegetation in the backshore, distance from nests to tide line, distance from nest to dune, sand grain size in ITZ and backshore).

Proposal: Closure of 20 2-km beach segments to ORVs and pedestrians from April 1 (to allow the beach to return to more natural conditions before the nesting season) to November 15. Compare aforementioned variables between the treatment segments and 39 control segments that are managed according to Option B or Option C below. All segments in the experiment should be chosen in areas where turtles have nested in the last 10 years (i.e., exclude northern portions of CAHA where turtles rarely or never nest). The experiment should be replicated for several years, at least until nesting rate in the control segments equals the 10 year average of 0.7 nest/km. Improving the power of the test to detect an effect at a lower baseline nesting rate would require greatly increasing the number of beach segments that are closed to ORVs, which would likely entail collaboration with other nearby parks where ORVs are typically permitted (e.g., Cape Lookout National Seashore). Alternatively, with an increased number of beach segments (either within CAHA or with the addition of other parks), several management options could be tested simultaneously. We recommend at least 20 2-km beach segments per management option tested, with at least 39 control segments.

If a significant effect of recreation is found, recreational restrictions in the experimental and control segments can be varied systematically to distinguish the effects of pedestrians from ORVs and the effect of time of day when recreation occurs. As an example, under management Option B with no nightime pedestrian recreation as a sub-option, this experiment will be testing the combined effect of daytime ORV and pedestrian recreation. If an effect is detected, in the next round of experiments the specific effect of ORVs can be examined by allowing pedestrians into the treatment segments during the day. On the other hand, if no effect is detected then the next round of experiments could entail switching to Option C in the control areas, to determine the combined effect of 24 hour ORV and pedestrian recreation. Decrease in sea turtle protection in any portion of CAHA for purposes of management experiments should not occur without the permission of the USFWS and the North Carolina Wildlife Resources Commission (NCWRC), on a case by case basis.

Objective 2: To determine the effect of artificial light management on nesting rate and hatchling orientation.

Proposal: Compare proportion of false crawls and hatchling misorientation incidents within 500 m and 1000 m of artificial light sources on human structures before and after turtle-friendly lighting regulations or initiatives are enacted.

Additional Research to Address Management Goals

Question 1: How is the detectability of turtle nests by monitors affected by changes in observers, species, presence of vehicles, environmental conditions, and time of day?

Proposal: Lay down artificial tracks for each species from May 15 to September 1 at a rate and density similar to the nesting rate of each species at CAHA (for loggerheads, 1 nest/1.2 days spaced at 1 nest/1.4 km, perhaps varying the rate somewhat to mimic peak nesting). Lay the artificial tracks at randomly selected times between sunset and sunrise. Record species mimicked, sunset and sunrise time, time tracks are laid, whether there is ORV access, wind speed and direction, and indicators of precipitation (yes or no, heavy or light, proportion of the night that it rained). Record the locations of each artificial crawl with a GPS unit so they can be reliably distinguished from true nest attempts or crawls. Compare detection rates of artificial crawls on morning surveys, between ORV and no ORV areas, including the effect of hours after sunset that an artificial crawl was made, species, weather variables, and observer.

Question 2: What proportion of closure violations by pedestrians and ORVs occurs between sundown and sunrise?

Proposal: In 25 randomly chosen nest closures in the ORV areas, smooth over the sand at dawn. Survey these closures just before sundown for the presence of human, ORV, and predator tracks, and vandalism of fencing and signs. Smooth the sand again and repeat the survey during the dawn monitoring on the following day. Replicate the survey 10 times during the nesting season, including Memorial Day and July 4th weekend. Estimate the proportion of violation events that occur at night.

Question 3: How much ORV and pedestrian traffic occurs in turtle nesting habitat at CAHA, and how does this differ between day and night?

Proposal: Once/3 hrs for 10 minutes, count the number of ORVs driving through and stopping in the 59 1-km beach segments designated in the protocol for adaptive management objective 1, and the number of people seen in each segment, recording the time of day, length of stay of each ORV and whether ORVs were seen in intertidal, backshore, or dune zones, so that the "total ORV hours" can be calculated for both driving and stationary vehicles in major beach habitat types. Perform these surveys one weekday and one weekend day/month from May 15 to September 1, plus once on each major holiday. If possible, perform the survey a second time each month, such that one fair weather day and one foul weather day is surveyed each month.

Question 4: How does nest relocation affect hatching success and sex ratio, and how do the results vary by location and crew member?

Proposal: Compare hatching success and incubation time between relocated nests and natural nests that were laid at the same time. Incubation time, like sex ratio, is directly related to nest temperature (Godfrey and Mrosovsky 1997). Therefore, sex ratio is correlated with incubation time. Record the identity of all staff involved in disturbing and relocating each nest, and the geographic coordinates of the original and new nest location.

PROTECTION RECOMMENDATIONS

We provide three management options for sea turtles and their nesting habitat, presented in order of increasing predicted negative effect on sea turtles. Since the sea turtle habitat at

CAHA is dynamic and subject to change given weather, tides, and the continuous coastal processes of sediment erosion and accretion, some of the recommendations may become inapplicable for certain sites, or new sites may form that provide suitable sea turtle habitat. CAHA may modify the recommendations below based on expert knowledge of current field conditions, provided the modified protection meets or exceeds the spirit of the protocols. Once protections are put in place, we recommend that they not be later reduced without first consulting with the USFWS and NCWRC.

Option A: Highest Degree of Protection

Recommendations:

1) Close all potential sea turtle nesting habitat (ocean intertidal zone, ocean backshore and dunes) to all recreational activites, 24 h/day, year round at the option of CAHA but at least from April 1 to November 15 or until the hatchlings from the last known sea turtle nest have emerged and entered the sea (whichever is later), wherever sea turtles nested, left false crawls, or otherwise attempted to nest from 1995-2005.
2) A 10-m buffer zone of signed, stringed symbolic fencing should be placed around all nests to reduce the risk of damage by essential vehicles or monitors.
3) Essential vehicles should drive in the intertidal zone at speeds not to exceed 10 mph, whenever possible. Essential vehicles should avoid driving in sea turtle

habitat from sundown to sunrise unless absolutely necessary, and when driving in sea turtle habitat should be accompanied by a sea turtle monitor whenever possible.

4) Sea turtle monitors may conduct their activities by ORV. Whenever possible, they should drive only in the ocean intertidal zone, but avoid the wrack line, at speeds not to exceed 10 mph, to reduce potential effects on protected avian species. If monitoring must occur when the intertidal zone is not available, sea turtle monitors should consult with piping plover, colonial waterbird, oystercatcher, and seabeach amaranth monitors prior to entering the field to reduce the risk of harm to these species (hereafter "other protected species").
5) For all nests > 50 days into incubation, all vehicle tracks should be smoothed nightly between the nest and the sea. Essential vehicles should make extra effort to not drive in the vicinity of a nest from 50 days until hatch, but if it is necessary they should not drive between the nest and the sea, and should consult with monitors for other protected species.
6) Continue trapping of potential nest and brood predators prior to the onset of the nesting season with the goal of removing all potential mammalian predators from the site, including the removal of all foxes from Hatteras Island and the prevention of their spread to Ocracoke Island. Removal of avian predators should be done by targeting problem individuals observed near sea turtle nests (Boarman 2003), in the presence of a trained monitor. Avian predation can be further controlled by enforcing proper trash disposal and anti-wildlife feeding regulations (Boarman 2003) throughout CAHA. Consult with a sea turtle monitor familiar

with nest locations when trapping during the nesting period, to avoid disturbing nests. Trapping should be done by a trained professional with experience removing the species in question.

7) Protect nests with predator exclosures if nest predation becomes prevalent in a particular area. Monitor the exclosures for signs that predators are attracted to them.

8) Enact turtle-friendly lighting regulations for CAHA structures, and conduct outreach with adjacent communties toward the aim of enacting lighting regulations there. Examples of turtle-friendly lighting can be found in Witherington and Martin (1996). The goal of light management should be no artificial lights directly visible continuously in areas of the beach where adult turtles lay their eggs and hatchlings emerge. The Parks should follow through in its initiative to use concessionaire fees to purchase turtle-friendly lighting for fishing piers (Altman and Lyons 2003) and also to identify problem lights in the beach communities and provide the homeowners with alternatives.

9) Relocate nests imperiled by impending erosion or flooding, according to guidelines in Handbook for Sea Turtle Volunteers in North Carolina (North Carolina Wildlife Resources Commission 2002).

10) Assist stranded turtles according to the guidelines in the Handbook for Sea Turtle Volunteers in North Carolina (North Carolina Wildlife Resources Commission 2002).

11) Outside of the restricted period detailed in Option A, Item 1, closures may be lifted unless doing so would conflict with protocols for other protected species in a particular area.

Predicted effects:

There will be almost no risk of direct recreation-related injury, mortality, or disturbance to sea turtles within the boundaries of CAHA, and no recreation-related habitat alteration during the nesting season itself. Outside of the nesting season, ORV traffic may alter the beach profile and sediment characteristics and lead to decreased nesting rates or emergence rates, if CAHA opts not to enact year round closure. Visitation to other areas of CAHA may attract potential predators such as raccoons that may then enter sea turtle habitat. Essential vehicle use of sea turtle habitat and ORV-based monitoring entail slight risks of a nest or hatchlings being crushed, and of disturbance to nesting females. Predator trapping may result in disturbance to females or hatchlings, or nest or hatchling loss if the trappers are not cognizant of the location of the nests. Nest exclosures entail a slight risk of damaging eggs during placement, and may result in full or partial nest losses if a predator learns to hunt at them. If made of metal, nest exclosures can alter the magnetic field of sea turtle hatchlings, with unknown consequences (Irwin et al. 2004). Nest relocation entails disturbance of an existing nest, and may result in the loss of eggs or entire nests. Nest relocation may also results in decreased incubation periods that likely indicate an increased female bias in the sex ratio of the hatchlings produced by the relocated clutch (Rush 2003).

Option B: Moderate Protection

Recommendations:

1) Close all potential sea turtle nesting habitat (ocean intertidal zone, ocean backshore and dunes) at CAHA to ORV traffic from sunset to sunrise (or until the morning sea turtle monitoring in a particular area has occurred for the day, whichever is later) from April 1 to November 15 or until the hatchlings from the last known sea turtle nest have emerged and entered the sea (whichever is later) wherever sea turtles nested, left false crawls, or otherwise attempted to nest from 1995-2005. Pedestrians may be allowed in sea turtle habitat at night at the option of CAHA, but pets should be prohibited at night (and during the day, at the option of CAHA). Pedestrians should be prohibited from sea turtle habitat at night in any area where nighttime closure is recommended in the protocols of other protected species.
2) Prohibit wildlife feeding and trash disposal in sea turtle habitat, 24 h/day, year-round.
3) If pedestrians are allowed on the beach at night, they should first be required to participate in an educational program on proper conduct in the habitat of protected species.
4) Close segments of sea turtle habitat to recreation 24 h/day during the period detailed in Option B, Item 1, as per adaptive management protocol objective 1.

5) Prohibit artificial light sources, including electric lights, campfires, and fireworks from all sea turtle nesting habitat during the restricted period described in Option B, item 1, with the following exceptions:
    i. Pedestrian recreationists in sea turtle habitat at night may use light sources with red filters (these could be rented or sold by CAHA or concessionaires).
    ii. Essential vehicles should use the bare minimum of lighting necessary for the performance of their duties, including performance of the sea turtle management activities recommended in these protocols.
6) Throughout CAHA, narrow the current 50-m ORV corridor such that a zone of ocean backshore at least 10 m wide and running the length of the site is free of ORV traffic. This zone should be adjacent to the toe of the primary dune wherever a primary dune exists (i.e., recreation should be restricted to a corridor between the mean high tide line and the edge of the zone of protected backshore).
7) A 50 m buffer zone of signed, stringed fencing should be placed around each nest in any place where recreation occurs. Random spot checks should be made at these closures during the day and at night to detect and prevent violations by recreationists. If >3 violations of the protected area around a particular nest are observed (including vandalism of the string itself), the buffer distance should be expanded to 100 m, then to 200 m if necessary. Where recreation does not occur, a 10 m buffer zone should be used to prevent harm by essential vehicles.

8) For all nests > 50 days into incubation, in areas where recreation occurs expand the buffer zone to 200 m and smooth all ORV tracks between the nest and the sea each evening.
9) Enact recommendations 3-11 under Option A above.

Predicted effects:

If pedestrians are permitted on the beach at night there will be a low risk of disturbance to nesting females, or accidental or intentional destruction of nests or hatchlings, outside of closed areas. However, in the absence of ORV access the level of pedestrian use will likely be low, especially if the lighting restrictions are enforced. During the day, there is a risk that pedestrians or ORVs will intentionally or accidentally destroy nests. The presence of recreationists outside of closed areas may attract potential sea turtle nest and hatchling predators, and if pets are not banned during the day there is a risk that they will enter closures and disturb nests if the leash law is not strictly enforced. ORV use in unprotected areas may alter the beach profile and sediment characteristics in a manner that decreases nesting rate or hinders emergence . Potential effects of essential vehicle use, monitoring, and predation control are the same as for Option A.

Option C: Minimum Protection

1) Throughout CAHA, require all recreationists (including ORV operators and passengers) that wish to enter sea turtle habitat at night to first participate in an educational program, as detailed in Option B, Item 3.
2) Throughout CAHA, prohibit pets from entering sea turtle habitat at night (and during the day, at the Park's option), and prohibit trash disposal and wildlife feeding 24 h/day year-round.

3) Throughout CAHA, for all nests > 50 days into incubation, close the beach for 1000 m on either side of the nest to ORV traffic. This will reduce the risk that headlights will affect emerging hatchlings.
4) Close segments of sea turtle habitat to recreation 24 h/day during the period detailed in Option B, Item 1, as per adaptive management protocol #1.
5) Prohibit artificial light sources, including electric lights, campfires, and fireworks from all sea turtle nesting habitat during the restricted period described in Option B, item 1, with the following exceptions:
    i. Pedestrian recreationists in sea turtle habitat at night may use light sources with red filters (these could be rented or sold by CAHA or concessionaires).
    ii. ORVs must turn off their headlights or place red filters over their headlights whenever they are parked.
    iii. Essential vehicles should use the bare minimum of lighting necessary for the performance of their duties, including performance of the sea turtle management activities recommended in these protocols.
6) Enact recommendations 6-9 under Option B above.

Predicted effects:

Outside of closed areas, there is a high risk of disturbance or injury to females emerging from the ocean, digging nests, or laying eggs. There is a high risk of destruction of nests before they are located by monitors. There is a moderate risk of injury to hatchlings and of misdirection or disorientation of hatchlings due to headlights. Daytime effects of recreation are the same as for Option B and effects of management and essential vehicles.

MONITORING

The goal of monitoring is to estimate the number, distribution, and fate of nests for each species. Continue to follow the monitoring and reporting guidlelines in the Handbook for Sea Turtle Volunteers in North Carolina (NCWRC 2002). Since some nests are missed by June 1 (Altman and Lyons 1998), we recommend starting monitoring on May 1 as encouraged by the NCWRC, and as early as April 1 if evidence for missed nests continues to be found. The following information should continue to be collected during nest checks:

1) Date and time
2) Species
3) Sequential nest number
4) Whether a nest was relocated, the original and relocation site names, and the coordinates of the original and relocation sites, in UTM coordinates.
5) Distance from the nest to the tideline, dune, nearest fixed artificial light source, nearest vegetation, in meters
6) Nest inventory data, date when an inventory is conducted
7) Dates of nest overwash
8) Sources of egg or whole nest loss, if apparent

In addition, we recommend the following data be collected:

9) Geographic coordinates of false crawls when first found
10) Recreation management strategy in area where nest was found (e.g., ORV closure)
11) Intertidal zone, backshore, and dune slope and dune elevation (where applicable) at nests and false crawls when first found

12) Percent ground cover of vegetation at nests when first found
13) Number of potential predators, including ghost crabs, and pedestrians and ORVS within 100 m of the nest, daily
14) Number of tracks of potential predators, and pedestrians and ORVs, within 100 m of the nest, including ghost crab burrows, daily
15) Sediment grain size of samples collected at nest sites and the terminus of false crawls when first found. Samples should be collected at the surface and mid-nest depth, 1 m from nest sites along a line parallel to the tide line, outside of where the turtle has disturbed the sand if possible.

These additional data will assist managers in assessing potential threats to individual nests and to act before harm occurs. They will also facilitate understanding of the effects of recreation management on nesting habitat.

LAW ENFORCEMENT

If a monitor observes a potential infraction of the law that threatens a turtle adult, nest, or hatchling, the relevant law enforcement personnel should be immediately contacted from the field, if possible. Otherwise, the monitor should leave the field as soon as possible and contact law enforcement.

If the scene of a past violation is discovered (such as a nest destroyed by a pedestrian), the scene should be left intact and the following information should be recorded:

- Date and time
- Weather and tide conditions

- Location (Use a GPS unit to record the location). Plant a survey flag or other marker to assist in relocating the site. This should be a colored, easy to see marker.
- Nest number if given
- Number of adults, nests, eggs, and/or hatchlings involved
- Behavior of adult or hatchling, if relevant
- Condition of adult, nest, eggs, or hatchlings
- Hand-drawn map showing adult , nest, and/or hatchlings, symbolic fence line, predator, pedestrian, and/or ORV trails, other evidence, and nearby landscape features (e.g., tide line, dune line). If possible, use gridded paper so map scale can be indicated.
- Photographs of the evidence

The relevant law enforcement personnel should be contacted as soon as possible and provided with a copy of the incident record. While gathering of information by a lay person may compromise the scene to some degree, the ephemeral nature of evidence in beach environments requires immediate collection of some basic data.

REPORTING PROCEDURES

The data collected in the field have many potential uses and applications. For nesting location data, GPS locational information needs to be conveyed as quickly as possible to Resource Management staff in order to implement protection measures. Similarly, witnessing violations of closure areas or other illegal activities needs to be conveyed to Law Enforcement staff as soon as possible. If violations of federal or state regulations are confirmed, notification needs to be made to the U.S. Fish and Wildlife Service – Raleigh Field Office and the North Carolina Wildlife Resources Commission as appropriate.

The field data should be collected in two forms: in field books as narrative accounts, and on field data forms developed in conjunction with other partner agencies, scientists and managers. Field forms should be quality checked by an independent reader, comparing field notebooks and forms where appropriate (see section below). When verified, the data should be electronically entered, analyzed where needed, summarized in reports in text, tabular and graphic form, and submitted to both CAHA administrative personnel and other cooperating agency personnel and other scientists and managers as requested. Reports should be available both in electronic form (pdf preferred) and in limited numbers of hard copy.

DATA MANAGEMENT

Raw data collection

Field data sheets should include, at a minimum, the date, the reference location (GPS and usually a code number), a point or specific area, and observer name or initials. Because of the large amount of data included in these different data collection efforts, we strongly urge that all individuals engaged in data collection be trained in advance of the actual data collection period. Regardless of how clear a field form appears to be, questions always arise about how to record certain types of data.

Data entry

Because the National Park Service (as well as other agencies) has determined that Microsoft Access will be the official database management software in the monitoring programs, we recommend it as the primary management tool. In some cases, Excel spreadsheets may be used since this is what the cooperators/contractors often provide. However, conversion of Excel to Access is not difficult and the structure of the tables is quite similar.

One advantage of Access includes efficiency, because many fields of data (location, physical parameters) need not be reentered on each successive survey, and flexibility in presentation. Links can be made among tables of physical parameters, nesting rate estimate, hatching success, etc.

Metadata

The metadata are best structured as separate components as the resource and scientific community needing different aspects of the data are quite different.

Quality assurance and quality control are best maintained by having the field data reviewed and entered into the database on the same day it is collected. Two individuals should first review the data to reduce error propagation. Generally it is best to have the person collecting the data also doing the data entry, followed by having a second person compare the computer printout with the original field sheets. This second step can be done at a later date to reduce fatigue on field days.

Data storage

Field data sheets should be stored in a safe, low-fire-risk location in or near the NPS Headquarters in Manteo. Upon entry into a PC's electronic Access database, an extra copy of the database should be generated on a separate portable hard drive, or on CDs which then should be maintained in a separate building. If a computer network is available at the site, the files can be more easily transferred electronically to other PC sites, rather than having to physically transfer media between locations. Security demands by the NPS may require extra steps in the data management outlined here.

Data analysis techniques

The methods for analyzing the data will vary greatly depending upon the question and the level of analysis of interest. Excellent statistical support and advice is available both at the USGS Patuxent Wildlife Research Center (Drs. Jim Nichols, James Hines, John Sauer, William Kendall, Michael Runge, and Jeff Hatfield) and at NC State University (Dr. K. Pollock associated with the NC Cooperative Wildlife Research Center), and we recommend consulting with other statisticians that are familiar with sea turtle databases. Biologists at CAHA should consult with one or more statisticians whenever statistical analyses are to be conducted. Many population and metapopulation models are already available online from Patuxent (see http://www.pwrc.usgs.gov), but usually these require some discussion with statisticians beforehand.

EDUCATION AND OUTREACH

Continue posting all symbolic fence lines with signs that clearly indicate the species being protected. Post signs detailing turtle biology and the reasons for protecting the species at points where visitors are likely to first encounter restricted areas.

Provide visitors with postcards and informational brochures that contain information on turtles and the biological and legal reasons for their protection at CAHA. Interpretive walks in which visitors are guided to nest sites during the day and shown turtle crawls, and shown videos of nesting adults and hatching nests can also be a useful outreach mechanism, since untrained visitors may never otherwise see these species due to their nocturnal habits.

Advertise turtle protection efforts and management successes in local papers and magazines and write educational articles for these outlets. Gain the confidence of a skilled writer/reporter in what you are doing. Ask that all articles that reporters write be checked by a manager or biologist so that corrections can be made if errors are found.

Staff training.—Provide training to all CAHA staff including sign crew, patrol, maintenance crews, etc. on behavior and monitoring techniques for sea turtles. This training should also include turtle identification, safe vehicle operations within sea turtle habitat and limiting activities in habitat.

Turtle monitors themselves need to have a subset of skills and knowledge before entering the field independently. These ideally include:

1. Ability to identify the adults, nests, and young of all protected species by sight, sound, and track evidence
2. Ability to identify sea turtle nesting behavior by sight and by sign (e.g., crawls)
3. Familiarity with the CAHA protocols for management and protection of each species
4. Basic knowledge of the laws protecting each species
5. Understanding of the process for dealing with and reporting legal infractions and injured wildlife
6. Clear understanding of Park policies for interacting with members of the public, the press, etc., and enough basic knowledge of the biology of each species to permit such interactions to be positive and informative.

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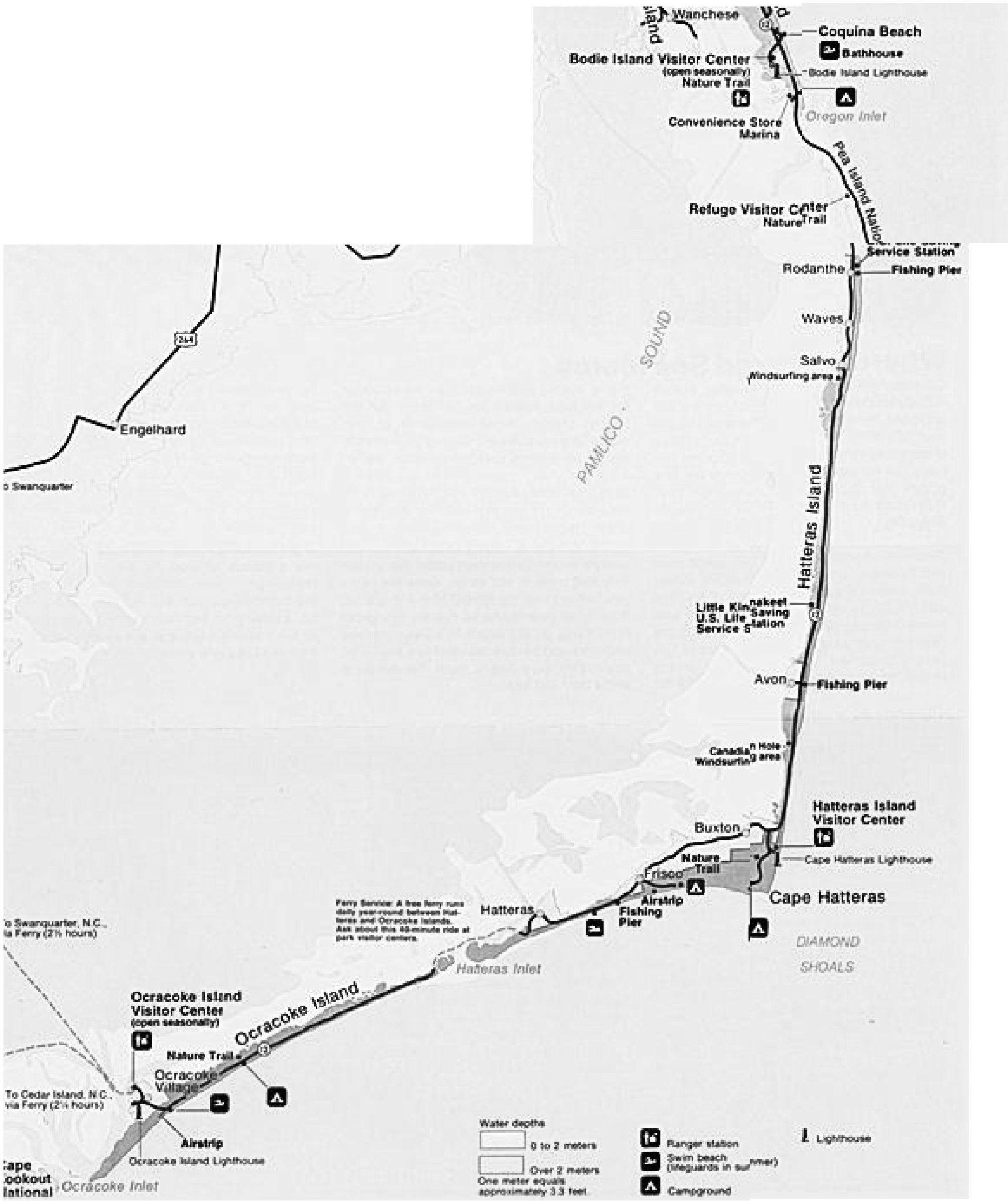

Fig. 1. Map of Cape Hatteras National Seashore.

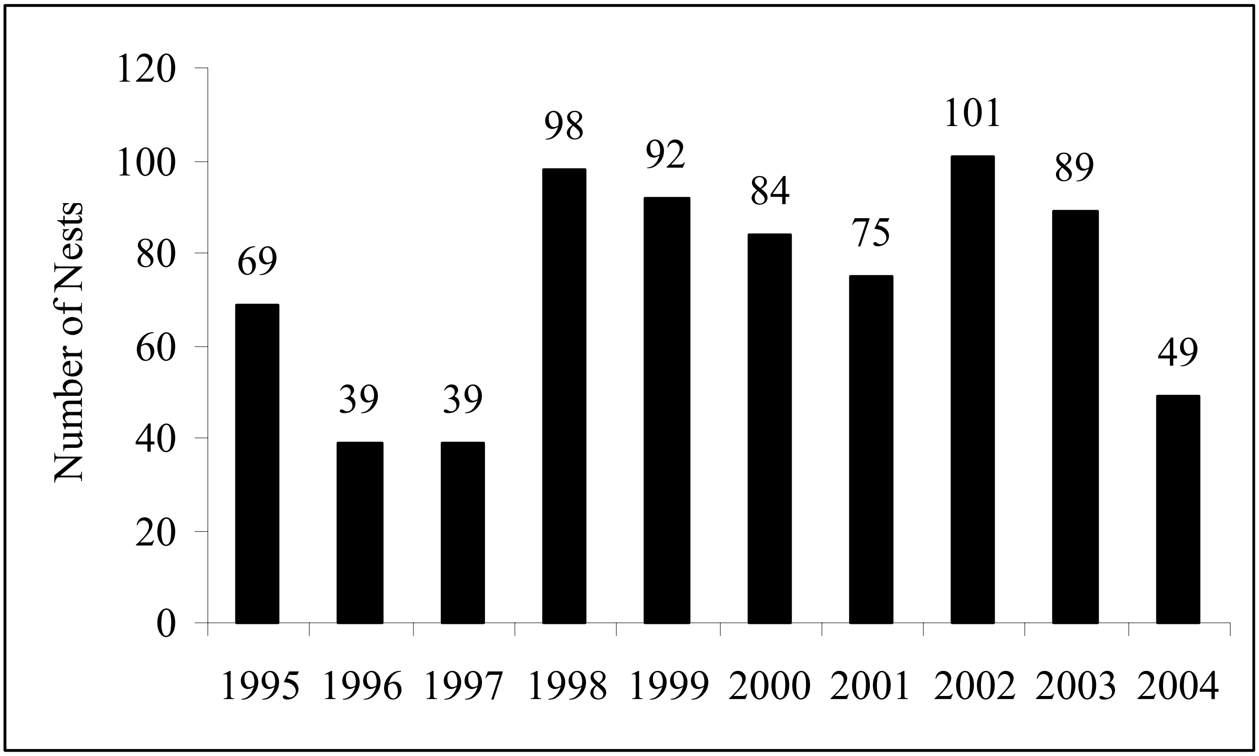

Fig. 2. Number of sea turtle nests at Cape Hatteras National Seashore, NC, 1995-2004.