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, MONITORING, AND PROTECTION PROTOCOLS FOR COLONIALLY NESTING WATERBIRDS AT CAPE HATTERAS NATIONAL SEASHORE, NORTH CAROLINA

MANAGEMENT, MONITORING, AND PROTECTION PROTOCOLS FOR COLONIALLY NESTING WATERBIRDS AT CAPE HATTERAS NATIONAL SEASHORE, NORTH CAROLINA

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September 12, 2005

Introduction

The Outer Banks region of North Carolina supports a large number of colonial waterbird species that depend upon its extensive sounds and the near-ocean waters for feeding, and relatively undisturbed islands (or portions thereof) for nesting (for example, see Parnell and Soots 1979 for one of the pioneering atlas projects on waterbirds in North Carolina). Many species of waterbirds are in jeopardy in the State, however (Parnell et al. 1977). Reasons for this are many: predation increases by mammals, competition with, and predation by, large gulls, especially herring gulls, *Larus argentatus,* human development, beach stabilization, and recreational disturbances on the outer beaches (especially Cape Hatteras National Seashore [hereafter, CAHA] and villages north, as well as extreme southern North Carolina in the Wilmington region), and perhaps mortality on the wintering grounds (Parnell et al. 1977, 1995, Erwin 1994).

The colonially nesting species of most concern for CAHA include: gull-billed terns, *Sterna nilotica,* common terns, *S. hirundo,* least terns, *S. antillarum,* and black skimmers, *Rynchops niger*. Gull-billed terns are considered to be "Threatened" in North Carolina, while the other three are "Species of special concern" both to the North Carolina Wildlife Resources Commission (fide D. H. Allen, NCWRC) and to the National Park Service (S. Harrison, NPS, unpublished report). Numbers of most breeding birds within North Carolina have declined over the past 20-30 years for all of these species. During the period 1977 to 2004, Gull-billed terns declined from approximately 268 to only 99 pairs, common terns from 2760 to only 570 pairs, and black skimmers from 976 to 623 pairs; however, least terns increased from 1925 to 2408 pairs in the same period (NCWRC database, fide D. Allen).

At CAHA, recent nesting by these species has been rather limited relative to population levels from the 1970s (Table 1).

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.

I. Species Descriptions – Distribution and Biology

Gull-billed tern

The gull-billed tern is a medium-sized (33-38 cm long, ca. 160 – 200 g) widely distributed "seabird" that often occurs at large inland seas in Eurasia as well as along the sea coasts in the U.S., the Mediterranean, and northern Europe (Parnell et al. 1995). In the United States, it occurs as two subspecies, with the Atlantic Coast and Gulf subspecies being designated *Sterna nilotica aranea*; the *van rossemi* subspecies appears to occur from the Salton Sea in California south to western Mexico (Parnell et al. 1995). On the Atlantic Coast, spring migration occurs from April to May primarily with birds arriving in North Carolina usually by mid April. The mating system is monogamous, and like many other seabirds, gull-bills have pair bonds that are probably long lasting. Nest-site establishment and egg laying occur usually in mid to late May in the middle Atlantic region, with incubation taking 22-23 days. Birds generally fledge at 26-30 days of age. The nests consist usually of a shell-lined scrape in the sand, or rarely, on wrack in marsh colonies. Nests contain from 2 to 3 brownish-blotched eggs (in the U.S., means around 2.2 eggs per nest; Parnell et al. 1995). The chicks are also cryptic in coloration, and are somewhat more precocial than the common tern, *Sterna hirundo,* or black skimmer, *Rynchops niger*, with which it coexists. Young may leave the immediate area of the nest within a few days, especially if disturbance levels are high. Pairs may renest if a nest is lost early in the breeding season. Both members of a pair incubate the eggs, with females taking the dominant role; both parents share brooding duties and both feed the young, even for an extended period after fledging occurs. One of the more unusual aspects of this species' biology is its diet; it depends more on terrestrial prey often than on aquatic organisms. It will prey upon insects, crustaceans, small mammals, and even young birds on occasion (Parnell et al. 1995).

After the breeding season in the mid-Atlantic region, fledged young and adults usually leave the colony sites by August, moving north for a short period before turning south for the fall and winter. Little is known of concentration areas during migration or winter, although wintering birds are known from Florida and the Gulf coastal region from w. Florida all the way south to Honduras, and to Panama on the west coast (Parnell et al. 1995).

Common tern

The common tern, as the name implies, is a common and widespread species across the temperate region of the northern hemisphere. A few disjunct populations occur in Bermuda and the southern Caribbean region as well (Nisbet 2002). It is one of the medium-sized black-capped terns (31-35 cm long, 110-145 g body mass) that depends

primarily on fish for prey (Nisbet 2002). It is considered to be a focal species in the formation of mixed-species colonies of black skimmers, gull-billed terns, roseate terns, *Sterna dougallii,* and occasionally other species (Erwin 1977). In North America, it is distributed primarily along the Atlantic Coast, but significant numbers also nest along the St. Lawrence River and in most of the Great Lakes along the Canadian-U.S. border (Nisbet 2002). Birds arrive in late April to early May along the mid Atlantic, and nesting begins from mid May to early June most years (Nisbet 2002). The species is considered monogamous. Nesting habitats range from sandy-shelly beaches to salt marsh grasses and wrack to artificial sites such as navigation aides and duck blinds (Thompson et al. 1997). Clutch sizes vary but the modal size is three eggs, which are typically medium-dark brown mottled, and sometimes have a dark green background. The eggs are incubated for 22-23 days, with hatching occurring asynchronously, as in most other terns. Both sexes incubate, brood the young, and feed the brood. As in other terns, feeding of young occurs post-fledging, even until fall migration in some cases. Young remain near the nest (unless disturbed) for the entire prefledging period. Renesting may occur, sometimes into July, if early nests fail. Fledging ranges from about 25 – 30 days, depending on the order of hatching, condition, and other factors. The species seems to serve as a social locus for mixed-species colony formation, possibly because of their aggressive, protective nature (Erwin 1979, Nisbet 2002). As indicated above, gull-billed terns and black skimmers often associate with common terns in the mid- Atlantic region. This species feeds by surface plunge-diving primarily on small (< 10 cm) marine, brackish, or freshwater fishes (depending on the region) and invertebrates such as shrimp, or occasionally insects.

After breeding, common terns leave the colony sites in late July – August and often move north before staging at sandbars near inlets in September before heading south. Little information is known about winter range, but they are known from Florida south through the Caribbean to Peru and southern Brazil where tens of thousands have been recorded in late winter (see Nisbet 2002).

Least tern

The least tern, *Sterna antillarum,* is the smallest of the black-capped terns in North America. Five races are recognized in North America, although there are few differences genetically or morphologically among them (Thompson et al. 1997): *S. a. antillarum* occurs along the eastern coast of North America south through the West Indies, to Honduras and coastal Venezuela, *S. a. athalassos* (the Interior least tern) occupies the interior of the U.S. up the Mississippi River and its drainages, while *S. a. browni* is restricted to the California coast south to Baja California. In Mexico, two other subspecies are found, *S. a. mexicana* and *S. a. staebleri* along the western Mexico coast to Oaxaca, and east to Chiapas (Thompson et al. 1997). This diminutive tern weighs only about 44 g on average (Texas and Nebraska samples, Thompson et al. 1997) and is 21-23 cm in length. Spring arrival dates are from late March to mid April along the Carolinas Unlike most other North American terns, it usually nests in single-species colonies, with nests often spread out. Nesting habitats are usually open sandy-shelly beaches, with some colonies occupying rooftops in areas with heavy human disturbance on beaches

(Thompson et al. 1997). Courtship lasts for 2-3 weeks in April and May, with egg laying from late May until June. Clutch sizes range from 1 to 3 eggs, with 2 the modal size in the mid-Atlantic. Eggs are highly cryptic, with the background color beige to light olive brown. Eggs are incubated by both sexes, but females do the majority. Incubation period is on average 21-22 days. When young hatch, they are quite precocial, moving from the nest area within a few days. They are able to achieve flight at about 20 days of age and some post-fledging parental feeding occurs for several weeks away from the colony site, as with other small terns. The species feeds on very small fish, shrimp, and a few other invertebrates in shallow waters close to the nest colony.

In late July - August, after breeding, least terns also move northward into the New York – New England region, before turning south to South America and the Caribbean, however data are very limited on winter ranges (Thompson et al. 1997). Like other terns, least terns tend to congregate at staging areas along the Gulf Coast in August and then seem to disappear in the winter (Thompson et al. 1997).

Black skimmer

Rynchops niger, the black skimmer, is a unusual seabird in many respects. It is the only one of the Laridae to forage using its unusual "skimming" of the surface waters with its lower mandible, its adaptations for nocturnality (vertical pupil), and the large degree of sexual dimorphism. Morphologically, females average about 265 g, while males average 35-40% larger at about 365 g. Female length ranges from 40-50 cm, while it is 50-60 for males (Gochfeld and Burger 1994) All North American birds belong to the nominate subspecies, *R. niger niger.* There remains controversy about the systematics of races from South America (Gochfeld and Burger 1994). Birds arrive in spring in the mid Atlantic region from late April to mid May, and nest building and egg laying occur usually from late May to mid June. Nesting colonies often form within vacant areas of common tern colonies, with common terns probably acting as a potential defense against predators (Erwin 1977, Gochfeld and Burger 1994). Nesting habitat consists usually of sandy-shelly areas on barrier islands, usually among common terns, or seldom in marshes on wrack or on shell bars (Gochfeld and Burger 1994). Clutch sizes range from 2 – 4 eggs with a mean around 3.5 (Erwin 1977) in the mid Atlantic. Eggs are light buff with black blotches, and are laid (and hatch) asynchronously. Seldom do fourth-laid eggs result in fledged young. Both sexes incubate the eggs, brood and feed the young . Incubation period ranges from 22-25 days. Young remain near the nest (unless disturbed) for most of the pre-fledging period of 28- 30 days or more (Erwin 1977). If nests fail early in the season, skimmers will renest perhaps several times. They are sometimes seen incubating eggs even as late as August in the mid Atlantic region (Burger and Gochfeld 1990). As with terns, the fledged young are still fed by the parents often until the period they leave the colony site (Erwin 1977). The prey of the black skimmer consists of a variety of small estuarine and marsh fishes and shrimp (Gochfeld and Burger 1994).

In most years, by early August, adults and young leave the colonies and disperse northward from the Carolinas before heading south. Large flocks congregate at staging areas often with terns. Adults may remain with young during fall migration. Most birds

from the Atlantic region winter from southern North Carolina to Florida south to the Caribbean and into Central and South America (Gochfeld and Burger 1994).

II. Habitat Descriptions

Gull-billed tern

Breeding habitat - Gull-billed terns are usually found nesting among other tern species on open, sandy-shell beaches, either on large barrier islands or on islands created from dredged material (Parnell et al. 1995). Like piping plovers, they often occur on overwash fans that are shelly and mostly devoid of vegetation. They also occur on elevated shell ridges ("rakes") along the edges of marsh islands from Virginia to South Carolina (Erwin et al. 1998b), which they share with American oystercatchers (*Haematopus palliates*) and common terns.

Foraging habitat – Gull-billed terns are somewhat unusual among terns in not specializing on fishes. Instead, they are opportunistic, taking insects on the wing, feeding on a variety of invertebrates including fiddler crabs (*Uca pugnax*), decapods, marine worms, clams, as well as small marsh fishes (Erwin et al. 1998*b*). As a result of their opportunism, this species feeds over marshes, creeks, along the ocean and bay beach edges near its colony sites, as well as over agricultural fields sometimes several km from the nesting site.

Migration/winter roost habitat - On migration, little is known of roost habitat use, except that it generally is considered similar to those used during nesting, i.e., open beaches and sand spits along the coast (Parnell et al. 1995). Large staging concentrations have not been mentioned as for other species.

Breeding at CAHA - See Table 1 for nesting history.

Common tern

Breeding habitat – Common terns are one of the more widespread terns of the world, thus are considered generalists in many of their life history attributes, including nesting habitats. They nest mostly on open, sandy-shell beaches on ocean coastal islands, as well as at inland island sites in freshwater lakes, or in Europe, in rivers (Nisbet 2002). They are also known to nest in salt marshes along the coast, either on shell or on wrack, especially where human disturbance along the beaches is significant (Erwin 1980). They seem to tolerate sparse vegetation at nesting sites more so than do their colony associates, black skimmers and gull-billed terns (Burger and Gochfeld 1991). Nest substrates vary from sand and shell to wrack or salt marsh vegetation, and even some manmade structures such as old piers or channel markers (Burger and Gochfeld 1991).

Foraging habitat – Common terns typically prey on small fishes and shrimp, often within several km of their breeding colonies (Nisbet 2002). They feed in flocks in inlets and

where tidal convergences occur along the coast, usually < 1 km from shore, but in inland freshwater areas, may be solitary feeders (Nisbet 2002).

Migration/winter roost habitat – Common terns migrate through North Carolina in late August – October, with little information on habitat use. Most feeding continues to be close to shore, and staging areas are known at large sandy spits and bars at a number of North Atlantic sites with concentrations in thousands at some places (Nisbet 2002). In winter, birds migrate to the Caribbean and South America where they seem to concentrate in large numbers in coastal lagoons in Brazil and Argentina (Nisbet 2002).

Breeding at CAHA - See Table 1.

Least tern

Breeding habitat – Least terns are widespread in North America, and are more specialized in their nesting habitat than are common terns. Their nesting substrate is often the most bare sand-shell areas on coastal islands, or on riverine islands in the interior of the U.S. (Thompson et al. 1997). They are commonly also found nesting on dredged material islands and also on rooftops in a number of coastal areas, where pea gravel is used as part of the roofing material (Thompson et al. 1997). On coastal barrier islands, they often select colony sites either adjacent to inlets or in overwash areas, often interspersed among piping plover (*Charadrius melodus*) nests. Unlike the other Atlantic coastal tern species, least terns are usually found in monospecific colonies, often relatively small (< 100 pairs) in size. Their nests are often widely spaced as well (Thompson et al. 1997). These adaptations are probably a response to ground predation.

Foraging habitat – In a manner similar to common terns, least terns feed on small surface fishes and shrimp from estuarine marshes, in lagoons, and along the ocean coast, usually within several km of the nesting colony (Thompson et al. 1997). Unlike common terns, they seldom are found feeding in large flocks over shoals of baitfish.

Migration/winter roost habitat – Least terns migrate from the mid Atlantic region, usually in August or September, with distinct migration flocks forming at certain sandy island sites along the route (Thompson et al. 1997). It is unclear whether they form mixed species flocks with other terns in migration. In late July or August, remote sandbars or sandy spits serve as roost sites. Species winters from Florida through the Caribbean, and into Central and South America (Thompson et al. 1997).

Breeding at CAHA - See Table 1.

Black skimmer

Breeding habitat - Skimmers prefer open, sandy habitats on barrier islands and dredged material islands along the coasts of the U.S. (Gochfeld and Burger 1994). They may often be found in the shell-sand areas at the tips of barrier islands, or even on large shoals in inlets. They are almost always nesting in associate with other tern species along the

Atlantic Coast (Erwin 1977). With common terns, they are often found nesting in the open patches of the colony, with common tern nests more closely associated with vegetation (Erwin 1977). On occasion, skimmers may also nest on wrack or on shell ridges in lagoonal salt marsh complexes along the Atlantic and Gulf Coasts, and even on rooftops along with least terns (see above) (Gochfeld and Burger 1994).

Foraging habitat - Black skimmers usually feed very close to their nesting colonies (Erwin 1977), and prefer quiet waters in salt marsh creeks, along lagoon edges, or along barrier islands in protected coves and inlets (Gochfeld and Burger 1994). Like terns, they feed on small fishes of many species, small shrimp, and other small invertebrates that they capture by skimming the surface.

Migration/winter roost habitat – Migrate from the mid Atlantic region from September to November, with very large concentrations on sandy spits and sandbars in North Carolina in late fall some years (Gochfeld and Burger 1994). Probably roost with terns at these isolated sites, but few data are available. Birds winter from Florida through the Caribbean and South America (Erwin 1990, Gochfeld and Burger 1994).

Breeding at CAHA - See Table 1.

III. Threats to Survival and Reproduction

Direct and Indirect Effects on Populations

Weather and tides - During the breeding season, spring storms and high tides often cause flooding of nesting areas for all these ground-nesting seabirds (e.g., common terns, see Burger and Gochfeld 1991, Nisbet 2002). Further, sea-level rise threatens the long-range prospects for barrier island and marsh-nesting species (Reid and Trexler 1992, Erwin et al. in press), and some models predict more frequent and severe storms in the future along the Atlantic Coast (Intergovernmental Panel on Climate Change 2001).

Predation – Along many coastal beaches, direct effects by ground predators such as foxes (*Vulpes vulpes),* raccoons (*Procyon lotor*), rats (*Rattus norvegicus*) and feral cats (*Felis domesticus*) have increased in recent years as human populations have grown in coastal regions (Buckley and Buckley 1976, Chabreck 1988, Erwin et al. 2001). The result has been poor reproduction or major redistributions of species (Erwin et al. 2001). In addition, gulls are often predators on terns as well as competitors for nesting space (e.g., see Nisbet 2002 and references therein for common terns); this includes great black-backed gulls (*Larus marinus*), herring gulls, and the smaller laughing gull *(L. atricilla*). In addition, in certain areas, other avian species may prey on terns and skimmers (or their eggs), such as peregrine falcons (*Falco peregrinus*), great horned owls (*Bubo virginianus*), fish crows (*Corvus ossifragus*) and others.

Human activities - As ground-nesting species, these colonial species are especially vulnerable to direct human activities such as off-road vehicles, aircraft disturbances, pedestrians – beachcombers, photographers, scientists, and even poachers (Buckley and

Buckley 1976, Erwin 1980). Vandalism is rare in the United States, however, the unintentional mortality induced by off-road vehicles may be more common than realized as crushed young often go undetected (P.A. Buckley, pers. comm.., R. Cook, pers. comm., B. Blodget, pers. comm.). Indirect effects include such factors as sonic booms from nearby military operations, the presence of pets (both domestic and feral), leaving garbage as attractants (bringing in crows and gulls), and the spread of commensal predatory mammals such as raccoons and rats (see above). Even modest disturbances early in the spring when bird are first arriving and prospecting for breeding sites can be highly disruptive to colonial species (see Buckley and Buckley 1976 for a detailed list of disturbances encountered in Atlantic coastal regions).

Environmental pollutants – A number of chemicals in the environment may be detrimental to the survival and/or reproduction of seabirds. Environmental contaminants are believed to cause reproductive failure in common terns, one of the more sensitive seabirds to organochlorine chemicals (Nisbet 2002). Problem areas that have been researched in North America are mostly in the U.S. and Canadian Great Lakes region (Nisbet 2002). No evidence of any population-wide wildlife effects of agricultural contaminants have been documented for the Outer Banks region.

Foraging habitat availability - Unlike foraging habitats of shorebirds, the habitats of feeding terns and black skimmers are not contiguous with their breeding areas. Least terns, common terns, and black skimmers usually feed from 1-10 km from their nesting colonies in shallow waters (Erwin 1978, Burger and Gochfeld 1990), while gull-billed terns feed on invertebrates primarily in marshes and over upland habitats (Parnell et al. 1995). Few data are available on trends in either forage fish populations in coastal waters, or on invertebrates to indicate whether there are current threats to foraging habitats. The effects of major hurricanes (e.g., Floyd in 1999) caused major declines in water conditions and marine life throughout Pamlico Sound in North Carolina for an extended period, as numerous contained animal waste facility dikes failed (Mallin 2000).

Protection and Current Management at CAHA

Management for colonial waterbirds at CAHA has focused in the past on reducing the threats to nesting colonies. The general approach to protect all the beach-nesting birds and sea turtles has been to create a 150 ft corridor for ORV and pedestrian traffic from the high tide line landward. Vehicles may drive or park within the corridor. Pedestrians, but not pets, may cross the corridor boundary lines, except where there are specific resource closure designations. Areas with nesting birds receive resource closures using signs. When young hatch, sections of the entire beach from the water line to the dunes are closed to prevent direct mortality of chicks. In addition to management of ORVs and beach recreationists, mammalian predator control is also an ongoing management tool. Control of foxes, feral cats, raccoons, opossums, and skunks has been applied at Bodie, Hatteras, and Ocracoke islands.

In 2005, more restrictive measures were attempted in a number of areas of CAHA. At Bodie Island, there was a narrowing of the corridor near the inlet, and much of the

interior of the spit was closed including the cove area. Ponds near the inlet are important bird resource areas and were thus off limits. At Green Island, with cooperation from the NCWRC, closure signs were posted early in the season around the perimeter to protect the island for colonial waterbirds and American Oystercatchers. At Hatteras Island, an area of about 3 acres was closed around ephemeral ponds at Cape Point where terns and black skimmers nested. Along South Beach on Hatteras, the upper beach was closed for about 1.5 km to protect nesting American Oystercatchers, which could also indirectly benefit least terns. At Hatteras Spit, an experimental escort program with bird monitors was attempted, resulting in employing additional law enforcement personnel. This was enacted largely to protect piping plovers and oystercatchers nesting on the Spit. From 0700 to 1900 h, ORVs were allowed in the ORV corridor once per hour in convoys escorted by monitors. The area was closed during the night. At North Ocracoke, there was little sign of bird activity, therefore no additional closure was needed. At South Ocracoke, the vehicle corridor was narrowed in one area to protect an intertidal zone where piping plovers had been observed feeding. ORVs were permitted to drive past the protected area in the backshore, but were restricted from the shore of Pamlico Sound.

The effects of the current management are that vehicles and recreationists may still gain access to more than 90% of the open beach habitats. Little management is done during the critical stages of colony site prospecting and establishment, a sensitive period for colonial species as well as all bird species. Restrictions apply only when a colony is established. CAHA has a leash law for dogs but it is loosely enforced. There are no regulations regarding kite flying. With more than 100 km of beach to patrol, 24-hour access for recreation, no ORV permit system, and limited enforcement and resource management personnel, effective monitoring of important biological resources is strongly compromised.

IV. Adaptive Resource Management (ARM)

It has long been recognized that many traditional wildlife monitoring programs involving simply counting animals or plants over time without a clear conceptual model can be wasteful of resources and devoid of linking cause and effect (see Walters 1986, Wilson et al. 1996 as examples). Because ecological systems are very complex, there will generally be some level of imprecision or uncertainty as to causal effects, and some factors may change through time (Walters 1986). Animal populations often differ from region to region in their responses to humans, predators, or other limiting factors (e.g., Erwin 1980, therefore good monitoring programs of floral and fauna over large landscapes should always include three components: A research question(s) should be aimed at a desired goal, a management approach or experiment to try to determine causality, and a monitoring component established 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.

1. Framework for ARM

1. Questions to be addressed

A. What is the location and abundance of nests by species within CAHA? What is the hatching and fledging success of each species in each colony?
B. How does each tern-skimmer species use nesting habitat each year, and how site faithful is each species?
C. How consistent is roost habitat by species for migrants?
D. What factors limit nesting success?
E. What are the survival rates of young, post-fledglings, immatures (fledglings to first breeders), and adults? What are sources of mortality?
F. How significant is the CAHA population of each species to the State, mid Atlantic region, or Atlantic coast population?

2. ARM – Some examples

A. Predator removal (Item 1. A and D above) - A common research question is: How does predator A affect the breeding success of Species B? In the context of Cape Hatteras, larger mammalian predators such as foxes, raccoons, and cats should be removed at all potential breeding areas (Ocracoke Spit, Hatteras Spit, Cape Point, Bodie Island Spit) as an ongoing management activity. Many examples exist at other national seashores and coastal refuges to demonstrate that meso-predator removal is essential for maintaining quality nesting habitat for colonial species without the need for further experimentation. Research questions that will require additional "fine-tuning" concern the most effective trapping mechanisms and timing for each species, however this is beyond the purview of these protocols.

   At many national seashores and wildlife refuges, avian predators such as crows and gulls have been seen preying on eggs or young of a number of colonial waterbird species. In some cases, only a few individual predators may have learned to specialize on tern or skimmer colonies. Removal of selected individuals by shooting has proven to be effective at Chincoteague National Wildlife Refuge, Virginia (D. Stotts, USFWS, pers. comm.), S. B. McKinney NWR (Falkner Island), Connecticut (Dr. J. Spendelow, USGS, pers. comm..), and at Bird Island, Massachusetts (Dr. I.C.T. Nisbet, pers. comm..). Where the problem may be more systemic, we commend field experimental approaches. It cannot simply be assumed that "all gulls are predators" as has been the case in some areas (Erwin, pers. observ., P.A. Buckley, in litt.). Research is needed to document the degree of the problem. An example of how one could go about testing the question of gull effects on nest success in the following way: First, setting up observation posts to observe the frequency and activity of gulls and other potential predators around the colony. If it appears that gulls are preying on nests, set up plots in tern colonies where 5-10 thirty-cm-high poultry wire exclosures containing 3-5 tern and/or skimmer nests could be randomly placed with a similar number of control plots. Placing monofilament line on poles spaced

about 1.5 - 2 m apart and 2 m high deters gulls, but allows terns to fly into and out of the area (Blokpoel and Tessier 1983, Quinn et al. 1996). Chi-square analyses of the number of hatched young could be conducted in each colony where there were sufficient numbers of nests. Following the fate of young would prove much more difficult, since the control (non-enclosed) chicks often move considerable distances from their nests. The results of the tests, including GPS locations of the exclosures, and individual nest results can be provided in the form of Excel spreadsheets to the NPS data manager within CAHA.

B. Effects of human disturbance (Item 1. D above) - In coastal areas, human recreation in the form of pedestrian and vehicular (ORV) traffic can be disruptive. A null hypothesis is that disturbance frequency (and intensity) has no effect on nesting success of Species X. Conducting experiments on one or both aspects in the coastal seashore environment may not be feasible, as the unit of observation is the colony, not the individual nest (usually the case for all colonial species). Observations of nests are seldom statistically independent. With least terns, however, colonies are often scattered in small subgroups, such that it may be possible to set up a design where 3-4 colonies are identified as Controls (with minimum number of perhaps 3 visits during the nesting period), and an equal number of Treatments, with perhaps 3-5 visits per week. Each "visit" in a Treatment could be a human approaching and walking through the nesting area. The parameters measured could simply be the number of nests hatching at least one young, or the number of young fledged (very difficult for least terns). As above, the results could be analyzed by either Chi Square or Fishers Exact Test analysis, and data provided in the form of Excel spreadsheets to the NPS data manager.

3. *Research Needs*

A. Research is still needed to determine how indices of nesting success (e.g., ratios of young-of-year, prior to fledging, to breeding adults estimated at peak incubation) compare with more precise (e.g., Mayfield method) analyses of nest success. What are the trade-offs of nest visitation frequency and survival? (1 A above).

B. How site faithful are nesting colonies of each species, and how specific are migrant terns and skimmers to using the same beach segment (see 1 B and C above). These questions can be addressed simply by monitoring use of locations using GPS devices and applying modifications of Markov models (see Erwin et al. 1998b).

C. How do survival rates differ among young of the year, immatures, and adults? (see 1 E above). This question goes well beyond the usual needs of NPS management, but is an essential piece of information for developing Population Viability Analyses. We recommend that, where resources allow, the NPS provide support to researchers to address this question at least for species that are identified as high-priority species by the NPS, State of North Carolina, or Partners in Flight program.

2. Management Recommendations

Here we provide three management options for colonial waterbirds and their habitats presented in order from the most conservative (least probability of adverse effects) to those considered more liberal (increasing probabilities of "take"). Because of the dynamic nature of the CAHA beaches and inlets, the management may change by location and time, and new sites (bars, islands) may require additional management. Management actions undertaken by CAHA relative to colonial waterbirds should be proposed and discussed with both the USFWS and the NCWRC, and other expert consultants as appropriate.

Option A: Highest Degree of Protection

1. Completely close all waterbird nesting, foraging (ponds, pools) and roosting habitat that has been used in the past decade to all recreational activities from 15 April to 30 September. This will allow protection to areas recently used by waterbirds as well as providing the potential for future expansion of populations that have declined in the region in recent years. Thus, the Bodie Island Spit, Green Island, Hatteras Island (Cape Point, South Beach, and Hatteras Inlet), and North and South Ocracoke Island should all be posted with area closure signs with the dates posted.
2. Essential vehicles (law enforcement, NPS personnel, approved researchers) should only enter restricted areas subject to the guidelines in the Essential Vehicles section of Appendix G of the Revised Recovery Plan for the piping plover (USFWS 1996). Vehicles should not exceed 10 mph.
3. In the spring (15 April to late May) and fall migration (August to 30 September) periods, all vehicles and personnel (NPS, researchers) should try to avoid tips of spits and inlet areas where colonial species often stage, or court (spring migration).
4. Continue current management practices of trapping potential mammalian predators, to include foxes, raccoons, feral cats, skunks, and opossums, especially on Hatteras and Bodie islands. Trapping should be performed either by the USDA Wildlife Services or those with professional experience in wildlife trapping, approved by USDA and in accordance with Department of Interior animal care and use guidelines.
5. Erect signs around the perimeter of nesting colonies. Although the areas will be closed to land-based recreation, boaters may come ashore, especially at inlets, and cause disturbance unless colonies are clearly marked. See B.4 below for details on signage.

Predicted effects:

There should be very limited direct recreational impacts on nesting or roosting colonial waterbirds within the boundaries of CAHA, and little impact on their habitats under this management regime. Most likely affected species would be least terns, as they

sometimes establish small colonies in unexpected sites not previously used. There remains a small probability of Essential Vehicle impact on nesting waterbirds due to nests being crushed or death to young non-flying chicks as they disperse from the nesting colony.

Option B: Moderate Protection

1. Completely close all potential breeding, roosting, and foraging habitat to ORV traffic and boat landings, at all sites where any terns or black skimmers have nested in the past decade, from April 15 until September 30. Even if no colony is established early in the season, late-season nesting by least terns and skimmers is common, and renesting may occur as late as August in some years. This should include Bodie Island Spit, Green Island, Hatteras Island, including Cape Point, South Beach, and Hatteras Spit, and Ocracoke Island, including North Ocracoke (inlet area), and South Ocracoke (Fig. 1).
2. At the seven sites mentioned above, pedestrians should be allowed within a narrow walking corridor at the high tide line from sunrise to sunset. Recreation such as kite flying, frisbee and ball use, pets, and firework use should be prohibited. This corridor may have to be narrowed if it infringes upon a nesting colony (see distance guidelines below).
3. At the remaining beach habitat outside of the seven areas mentioned, the ORV corridor should allow at least 10 m of ocean beach from the toe of the primary dune seaward to remain vehicle-free during the April 15 to September 30 period. If a colony becomes established, the ORV access may need to be modified for a section of beach to allow buffer distances to be established as indicated below. Vehicle speed should be limited to 10 mph.
4. At each colony where nests are initiated (including nest scrapes), resource closure signs with string should be erected. For least terns, signs should be placed 100 m from the perimeter of the colony. For other species of terns and black skimmers, the buffer distance should be 200 m (Erwin 1989). Should a colony become established along a beach outside of a focal site, ORV access to the beach zone should be closed after young begin hatching, with the length of the beach closure depending on the dimensions of the colony. Note that these distances are less than those recommended in a National Park Service report on colonial waterbird management (Buckley and Buckley 1976); however, their recommendations were conservative estimates, not based on empirical field experiments (Erwin 1989).
5. Enact recommendations number 2-5 above under Option A.

Predicted effects:

There may be disturbance of adults at nesting colonies or staging areas at the focal sites, but with less probability of mortality of adults or nests. The risks of mortality to nests and chicks is higher in areas outside of the focal sites, however it is not highly likely that terns or skimmers will colonize these other areas. With pedestrian use of the focal sites, potential predators may be attracted to nesting colonies, but this effect is expected to be

stronger outside of the focal areas. Outside of focal areas, pets are more likely to harass or harm adults or their chicks. Chicks, especially least terns, are at risk of being crushed by pedestrians as they move closer to the water line. Potential negative effects of Essential Vehicle use (ORV use by NPS staff, monitoring personnel, trappers) are the same as in Option A.

Option C: Minimum Protection

1. Restrict all ORV and pedestrian recreation to a corridor within 50 m (ca. 150 ft) of the oceanside mean high tide line from sunrise to sunset, at all sites where colonial waterbirds have been documented in the past decade. Restrict boaters from landing at inlets where nesting colonies are within 200 m of the inlet. This should be in effect from April 15 to September 30. Even if no colony is established early in the season, late-season nesting by least terns and skimmers is common, and renesting may occur as late as August in some years. This includes the seven sites referred to in Option B # 1 above. The corridor should be narrowed (or eliminated at certain segments of beach) if the buffer distance from an active nesting colony intercepts the ORV corridor, or when young hatch from a colony. Once the zone is narrowed, it should not be widened again without consultation with colonial bird experts. Any area with nesting birds should be closed from sunset to sunrise to all recreation.
2. At the seven focal sites mentioned above, prohibit pets, kites, ball games and frisbee throwing, fireworks, and trash disposal. Vehicle speed should not exceed 10 mph.
3. Enact recommendations # 3-5 under Option B above.

Predicted effects:

Adult birds are placed at risk by pedestrians and recreational ORVs and boats at the focal sites and all other areas. Nests and/or chicks may be crushed. Enforcement requirements are higher under this option than under options A or B, thus increasing the probability of harm to nesting terns and skimmers. Activity of ORVs and pedestrians in focal areas early in the spring when colonial waterbirds are prospecting for nesting sites may be detrimental to the probability of population increases for terns or skimmers (Buckley and Buckley 1976). With more area open to recreation under this option, the potential for attracting gulls and crows is also enhanced. Effects outside of the seven focal areas and potential effects of Essential Vehicle use, and ORV monitoring are the same as under Options A and B.

3. Monitoring Protocols

A. **Breeding populations and success** (see 1A above): A fundamental question for managers concerns the location, abundance, and some assessment of reproductive success for species of management concern (see Erwin et al. 2002 for Cape Cod National Seashore). The latter issue can be very labor- and cost-intensive, however our recommendations aim to achieve a reasonable level of precision with

normal staffing. If research funding is available, even more elaborate methods should be considered, including banding and radiotelemetry applications.

Least terns: Because least terns nest on open beaches similar to piping plovers, the **locations and population sizes** of this species can be surveyed intensively each year with little extra time commitment. All beaches are surveyed during the season either by ORV or on foot, covering all beaches where nesting is possible (see piping plover protocol). The center of each tern colony should be recorded using a GPS receiver. Assign each tern colony a local name (e.g. Cape Point) to assist relocating the site. Use the same name consistently over time (if possible, use the traditional one) to preclude errors when conducting population trends through time. Nesting begins as early as late May in some years and may extend into July. The number of incubating birds (= number of nests) should be recorded during 3 surveys in each colony during the period 5-20 June (the "A count" in Blodget and Melvin 1996), then again after June 20 (the "B count") if a major change due to a storm occurs. Birds may renest until early July. Counts are best made by two independent observers. Keep these counts confidential so that individual observers can be "calibrated;" this helps in later comparing results when observers change (a common Park and Refuge situation). Observer changes can have major effects on population trend estimation (Sauer et al. 1994). A spotting scope or at least 8X binoculars should be used. A ground check is made to confirm the stage of egg laying (2-3 eggs is a full clutch). Entrance into the colony should be minimized especially during May and early June when birds are establishing nest sites and beginning egg laying. For most colonies, estimates can be made from vehicles at the periphery of the colony. On islands (e.g. Green Island), however, ground counts of nests should be made using the method outlined below for common terns, using mark-recapture methods. Avoid very warm days or rainy periods when flushing birds. Field data forms should be completed for each colony site visit. A standard colonial waterbird field data form has been developed by the NCWRC, and should be used to ensure standardization. Because least terns are notoriously unsynchronized in their nesting, numbers of nests should be estimated a minimum of three times (see above). If storms cause large-scale losses, renesting will occur; another survey should be made 2-3 weeks later. The best estimate of the number of nesting pairs in a colony is the maximum number of nests estimated among the three (or more) survey periods.

Estimating the **breeding success, or annual fecundity**, of species that nest on open beaches is somewhat easier than for species that nest in vegetation (see below). With least terns, eggs typically hatch after a 3-week incubation period; after this, observers should estimate the number of chicks at least three times in each colony. The first survey for chicks should be made 10-14 d after hatching begins, normally around the end of June. Second and third checks should be made in subsequent weeks (5-8 d apart). Nest surveys should be done using a spotting scope with 15X or more, if possible from a vehicle. The final check(s) should be conducted when the oldest chicks in the colony are 21-24 days (fledging about 24-27 d). On these late-stage surveys, observers should count from the vehicle the number of large chicks in attendance for the entire colony (while not precise, young-to-adult ratios provide an index of annual fecundity). This may require taking several counts from different vantage points. This estimate can then be

compared with the estimated number of nesting adults determined at the peak of the nesting season to determine the index. (Note: elsewhere it has been suggested that the number of immatures should simply be compared with the number of attending adults; however this would result in an overestimate of nesting success, since unsuccessful nesters may have already left the colony area). Then an average can be calculated, and a "colony productivity estimate" can be derived. For example, if the ratio is 30 large fledglings to 30 nests counted earlier (i.e., 60 adults) that translates to 1 chick per nesting pair (2 adults = 1 pair). If dead chicks are spotted, they should be examined for evidence of predation (e.g. missing head usually means owl predation). This information also is recorded on the colony data forms. To evaluate detection differences between observers, independent counts of adults and young should be conducted by the observers.

Without individually-marked young followed daily, precise estimates of survival will not be possible; instead the above method will only provide an index of annual fecundity. The value of the index can only be determined by conducting both types of studies simultaneously; this should be done at a sample of colonies every few years.

Common terns-gull-billed terns-black skimmers : For **locations and population sizes** of all colonies, observers should conduct ground counts using ORVs and on foot to estimate the number of nests. Green Island needs to be visited by boat in late May for nesting colonial species (and in early April for plovers and oystercatchers). As with least tern colonies, a GPS location should be taken in the center of each tern or skimmer colony. Timing of nesting is variable, depending upon year and species, therefore some annual adjustment of survey timing may be necessary. In general, for terns it is usually late May- early June in North Carolina. A nesting population estimate is conducted with a minimum of three observers using a mark-recapture method (Erwin et al. 2002). For small colonies (< 500 nests), the entire colony can be covered by the 3 (or more) observers. If colonies exceed ca. 1000 pairs, a sample of 20-40% is recommended. After establishing a line along the long axis of the colony perimeter, a series of perpendicular transects is covered. The team walks in tandem through the colony during mid-to late incubation if possible (ca. early June for terns) counting and marking (dot of spray paint or water soluble marker on the nest edge) on 1-2 transects, or passes. Afterwards, they repeat the transects in reverse, with observers changing path positions, recording separately the number counted the second time that are marked versus unmarked (Lincoln-Petersen Index, see Smith 1966). This allows one to estimate detection probabilities associated with the transect survey, i.e. the efficiency of the count (assuming a sample of at least 50 nests). After two transects of marking and recounting, the team can simply continue the count without further marking until the colony count is complete. Care should be taken however for the crew to stay abreast of each other to insure that they are not double counting nests as they walk. Observers should ensure that the entire colony area has been surveyed. At the completion of the survey, the total number of nests in the colony is estimated by converting the total count by applying the Lincoln correction as outlined as follows:

The equation in its simplest form is:

$$N = (M * C) / R$$

Where N = the total estimate of the number of nests in the colony; M = the total number of nests observed and marked during the first pass through the survey area; C = the total number of nests observed on the second pass through the survey area: and R = the number of nests counted on the second pass that were already marked on the first pass.

As an example, if our Lincoln marking on two transects showed that we observed and marked 107 nests during the first survey (M), then counted a total of 102 on the second pass (C) of which 97 nests were already marked (R), our N, the estimated total number of nests, is 113. Thus, our first count of 107 was a 5.3% underestimate of the total. We then apply this 5.3 % correction to the remaining counts for the colony for an overall corrected total estimate.

Precise estimates of **reproductive success or annual fecundity** for species such as common terns and black skimmers are difficult to obtain without a lot of effort and disturbance to the colony (Nisbet and Drury 1972, Erwin and Smith 1985). When young are large, they may run long distances from their nests upon disturbance; this exposes them to higher levels of predation (both intra- and interspecific). Therefore, observers should estimate annual fecundity using 4-6 randomly-located enclosed plots in different parts of the colony marked with wooden stakes ca. 60 cm long to demark corners of ca. 5 x 5 m quadrats (if nest density is fewer than 7 nests per plot, the plot may have to be larger). Poultry wire fencing (2.5 cm mesh, > 40 cm high) should then be buried in the soil around the periphery of each plot. If possible, a sample of at least 10% of the colony is desired, with 20% being ideal, based on the estimated nest count made earlier. Each quadrat should be labeled and total number of nests should be counted in each plot during early (5-10) June. Plots should be set up within a few days after the nest count is done.

After hatching begins (often the end of June), two visits are to be made. One is to be conducted about two weeks after hatching when numbers of chicks are counted in each quadrat. If the nests are visible from outside the colony, a scope should be used to count young from a distance to reduce disturbance. If vegetation is dense, observers will need to enter the quadrat to do the count. It is best for two people to do this. A second count should be made the same way about 8-10 days later (common terns fledge at about 24-26 d). The total number of young surviving in each quadrat divided by the number of nests in each will provide an estimate of "colony success." Variance among quadrats will be used to adjust the number of sample plots needed to accurately estimate the number of young fledged per colony in future years. After most of the young have fledged in the colony, at least one more late-season count should be made of the ratio of adults to young around the perimeter of the colony, preferably from a boat. This final count should be timed about 10 d after the last visit to count numbers of chicks.

As with least tern estimates, these estimates of annual fecundity will also not be as precise as if each nest were monitored, chicks marked, and followed every 1-3 days (see Eyler et al. 1999). Instead, nest group (= plot), or "composite fecundity," estimates are obtained which represent an average number of fledglings per nest for the sample plot, or

quadrat. This is still far superior to the frequent qualitative manner that is reported by Park and Refuge biologists (e.g. “poor", "average", or "good” success). As in other cases, the trade-off is accuracy versus time and colony disturbance.

If personnel limitations do not allow for establishing nesting enclosures as specified above, we suggest that at a minimum, a visit be made initially to determine when peak egg laying occurs, a second visit be made at about hatching time (3 weeks after egg laying), and at least two visits be made ca. 30-35 days after hatching to estimate the number of fledglings (the ratio of number of young: number of breeding pairs estimated, as above). To estimate this value, follow the procedure outlined above (3A) for least terns.

B. **Migration and Wintering Populations and Habitat** (see 1C above): Managers need to know which areas or habitats are key for migration staging of colonial waterbirds and shorebirds in spring and fall, and how consistently used are these sites (site fidelity). Because of the dynamics of barrier island habitats, the specific site (few hectare parcel) is less important than the larger landscape (e.g., the tip of an island). Because few terns and skimmers winter in North Carolina, the emphasis here is on staging areas during migration. Models to assess and quantify site fidelity can be adapted from those for colonial species (see Erwin et al. 1998).

Remote surveys**:** High tide roosts are seldom well documented for waterbirds. We tested aircraft methods for large-scale surveying of waterbirds on Cape Cod National Seashore in late summer-fall 2000 and winter 2001 and concluded that using small fixed-wing aircraft on a regular periodic basis was not logistically pragmatic there (Erwin et al. 2002). The regulations required of federal biologists for aircraft operations over federal lands, the difficulty in coordinating pilot and biologists’ schedules, and inclement weather on the outer Cape all conspired to reduce our capability to survey when necessary.

In North Carolina, however, where small aircraft may be more efficiently utilized (or where federal law enforcement pilots commonly survey), we recommend use of either small helicopters (better sighting but very costly, *fide* P.A. Buckley) or small, high-wing aircraft to be flown at low altitude (300-500 ft). Low-level flying, i.e. below the 500 ft ceiling, requires filing for a Special Use permit with the Office of Aircraft Safety (OAS) and biologists need to recognize that obtaining OAS approval of private aircraft and pilots is an elaborate and time-consuming process; not many vendors are amenable to such restrictions unless there are prospects for long-term contracting. We highly recommend using federal pilots within DOI whenever possible.

Once successfully contracted, the aircraft should fly the entire beach shorelines, bays and marshes, and adjacent open sandy uplands (sand bars near inlets) and important (> 200 birds) congregations should be visually located and recorded using GIS receivers. At least 5 surveys should be flown under stable weather conditions (low winds, no precipitation) during the spring migration period of 15 April to 30 May and fall migration, 1 Aug. - September 30, for colonial bird and shorebird surveys. Copies of

topographic maps of each bay or water body should be used to circle and identify by number the roost concentrations. A portable tape recorder should be used to record estimates of numbers for species or groups for each numbered location. Data are to be transferred to field forms as soon as possible afterwards. Where species identification is problematic, guilds can be used, such as “small terns” (for least, common, Forster’s), or “small peeps” (for many of the small sandpipers such as least, semipalmated, western). One precaution should be noted however; for trend analysis, interpretation of the trends may be difficult using "group" data, e.g., “peeps”, instead of individual species. Because of the special attention now being paid to certain shorebirds, such as red knots and whimbrels, care must be taken to estimate these species. As with any aerial survey or count, each observer should keep independent count records. These can then be “calibrated” by comparing photographic counts with ocular estimates, or by comparing the observer’s accuracy to known numbers of objects using computer software programs (e.g., Wild Counts).

Five replicate aircraft surveys are considered a minimum for developing an index of consistency of site use. A major assumption here is that as species composition changes through the migration season, the preference for roosting habitat will not shift accordingly. This can be examined using the surveys conducted on the ground.

Ground Surveys: If aerial surveys cannot be used, ground surveys, combining boat, truck or ORV use will be required. We recommend that complete area surveys be performed at least twice to include all inlets, sand bars and spits, high open areas near feeding flats, and elevated areas on marsh islands be visited within the CAHA boundaries. These should be performed at or near high tide late in the day (within 3 h of sunset) to increase the probability that birds are attending roosts. Because of the longer time “window,” we suggest that roost site surveys be performed during the fall shorebird migration period, from late July to late September.

At CAHA, the following areas should be included in roost surveys and should be surveyed 3-5 times: Bodie Island south spit, Green Island and north end of Pea Island, Hatteras Island, especially from Cape Point SW to Hatteras Spit, and all of Ocracoke Island. Survey area should include both beach and marsh (bayside) areas of the islands. Counts of birds and locations using GPS receivers should be recorded on field data forms and topographic maps. Natural landmarks will be used for boundaries. A map of each roost area (bay, river, beach area) is useful to accompany the field form, with each roost location numbered to correspond to the data form entry. Because location and approximate size of roosting flocks are most important, emphasis should be on site location and obtaining an overall estimate of numbers, rather than trying to obtain a precise species estimate. When sleeping, species are difficult to identity in many cases. Limiting observations at each site to only one brief survey period will often lead to underestimates of the numerical importance of sites; however more information is gained by visiting more sites over a larger landscape, even if sacrificing some accuracy at any given site.

4. Reporting Procedures

The data collected in the field have many potential uses and applications. For nesting location data, especially for the threatened piping plover, or endangered amaranth locations, 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 the Migratory Bird Treaty Act or Marine Mammal Protection Act (and sea turtle equivalent) are confirmed, notification needs to be made to the U.S. Fish and Wildlife Service – Raleigh Field Office, the National Marine Fisheries Service, 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. The NCWRC maintains a database on colonial waterbirds and should be consulted on use of standardized data forms. 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 management 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.

5. Data Management

A. **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. In addition, where counts of birds are recorded, we strongly urge that two observers keep independent records. Variation due to observer differences has been shown to be a major source of error (Sauer et al. 1994).

B. **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. Again, consultation with the NCWRC is important here. Fortunately, the conversion of Excel tables to Access is not difficult and the structure of the tables is quite similar.

Because the Piping Plover is a Federally Threatened species, the USFWS and the North Carolina Wildlife Resources Commission have developed their own system of data

collection and management, with the State taking responsibility for data coordination and management. The data reporting requirements are outlined in the Region 5 Piping Plover recovery plan (USFWS 1996).

For the majority of the bird data sets, the data are entered directly from field forms into Microsoft Access, a relational database. 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, bird species estimates, feeding behaviors, etc.

C. **Metadata:** The metadata are best structured as separate components as the resource and scientific community needing different aspects of the data are quite different. We suggest developing metadata for the following databases within the CAHA database of natural resources: (1) piping plover database that contains breeding season, migration, and wintering data required by the USFWS Recovery Plan and State of North Carolina; (2) American oystercatcher database that includes breeding, migrating, and wintering data; (3) Colonial waterbird database that includes breeding season data on terns (especially common, least, and gull-billed) and black skimmer colonies; (4) Migrating (spring and fall) and wintering shorebirds and colonial species database, (5) a sea turtle database, including nesting and strandings, and (6) a beach amaranth database .

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.

D. **Data storage:** Data from each of the six components should be given separate code names 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.

E. **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). 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), the USGS Colorado Cooperative Fish and Wildlife Research

Unit (contact: K. Burnham), and elsewhere; however, these require some discussion with statisticians beforehand.

6. Education and Outreach

A. Public education: Although the strict protections detailed above are necessary to recover the colonial waterbird populations at CAHA, it is essential that the public be informed of management decisions and their justification as these protocols are implemented. Long-term sustainability of waterbird recovery at CAHA will depend on the cooperation of the public. Area closures and restrictions, and the reasons for each of them, need to be made clear. Continue posting all symbolic fence lines with signs that clearly indicate the species being protected. Interpretive signs with various species of waterbirds, including photos of nests and young, along with major points about their biology should help captivate the public interest and concern.

Provide visitors with informational brochures that contain information on terns and skimmers and the biological and legal reasons for their protection at CAHA. Indicate how closures will be used to better inform management in the future such that restrictions may possibly be eased. Interpretive walks in which visitors are guided to places to watch breeding and nonbreeding adults and broods through a spotting scope can also be a useful outreach mechanism, since untrained visitors will likely never otherwise see this species due to its cryptic coloration and inconspicuous behavior. Teaching the public to value birds as part of their beach experience is the most important management activity that CAHA can undertake.

Advertise bird protection efforts and management successes in local papers and magazines and write educational articles for these outlets. Submit public interest spots on beach wildlife on local radio stations. Ask that all articles that reporters write be checked by a manager or biologist so that corrections can be made if errors are found. Issue press releases detailing closures and other restrictions during both the breeding and nonbreeding seasons. Provide these press releases to local officials, the local press, local marinas, shops, special interest groups, etc.

B. Training: Provide training to all CAHA staff including sign crew, patrol, maintenance crews, etc. on behavior and monitoring techniques for both nesting and nonbreeding colonial waterbirds. This training should also include species identification, safe vehicle operations, and limiting activities in habitat.

Seasonal and permanent staff 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 breeding and nonbreeding behaviors by sight, sound, and other sign (e.g., nest scrapes, distraction displays)
3) Ability to observe adults, nests, and young of each species through optics and to record data without causing disturbance
4) Familiarity with the CAHA protocols for management and protection of each species
5) Basic knowledge of the laws protecting each species
6) Understanding of the process for dealing with and reporting legal infractions and injured wildlife

There should be 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

Table 1. Estimates of colonial waterbird nesting (in nesting pairs) at Cape Hatteras National Seashore from selected years, 1973 to 2003 [a]

Location	1973	1977	2001	2002	2003
Bodie Island	None noted by PAB	0	0	0	LT-10 pr
Hatteras Island	LT-20 pr CT-3-4 pr BS-6 pr "None at Cape Point even in optimal habitat" (PAB)	LT-88 pr N of Buxton (2 cols.)	LT-53 pr. in 5 cols. (11 in 2000)	LT- 5 Cols. GBT-1 col. (no counts made)	LT-100 CT-14 BS-40 (5 LT cols.)
Ocracoke Island	CT-100 pr. BS-65 pr. GBT-19 pr. LT – 0 1 PIPL nest probable (PAB); "Only site for these species nesting on mainland barrier beaches" (PAB)	LT-33 CT-802 BS-286 GBT-27	LT-210 CT-387 BS-193 GBT-108 (2 cols.)	"About same as in 2001" (no counts made)	CT-172 BS-225 GBT-8 LT-no firm counts due to many washouts

[a] **Codes**: LT-Least Tern; CT-Common Tern; BS- Black Skimmer; GBT-Gull-billed Tern; PIPL – Piping Plover.

References: For 1973, letter from Chief Scientist, NPS P.A. Buckley and F. G. Buckley to the Cape Hatteras National Park, (July 9, 1973); for 1977, Parnell and Soots (1979); for 2001-2003 date, source was Marcia Lyons, unpublished annual reports from the Cape Hatteras National Seashore.

V. Acknowledgments

We appreciate the comments and technical review of Dr. P.A. Buckley (retired, formerly NPS and USGS research biologist), D. Allen, NCWRC, S. Cameron, NCWRC, and D. Rabon, USFWS, Raleigh Field Office. Administrative review was also provided by the following NPS personnel: Sherri Fields and Steve Harrison, and by Dr. J.B. French, USGS Patuxent Wildlife Research Center.

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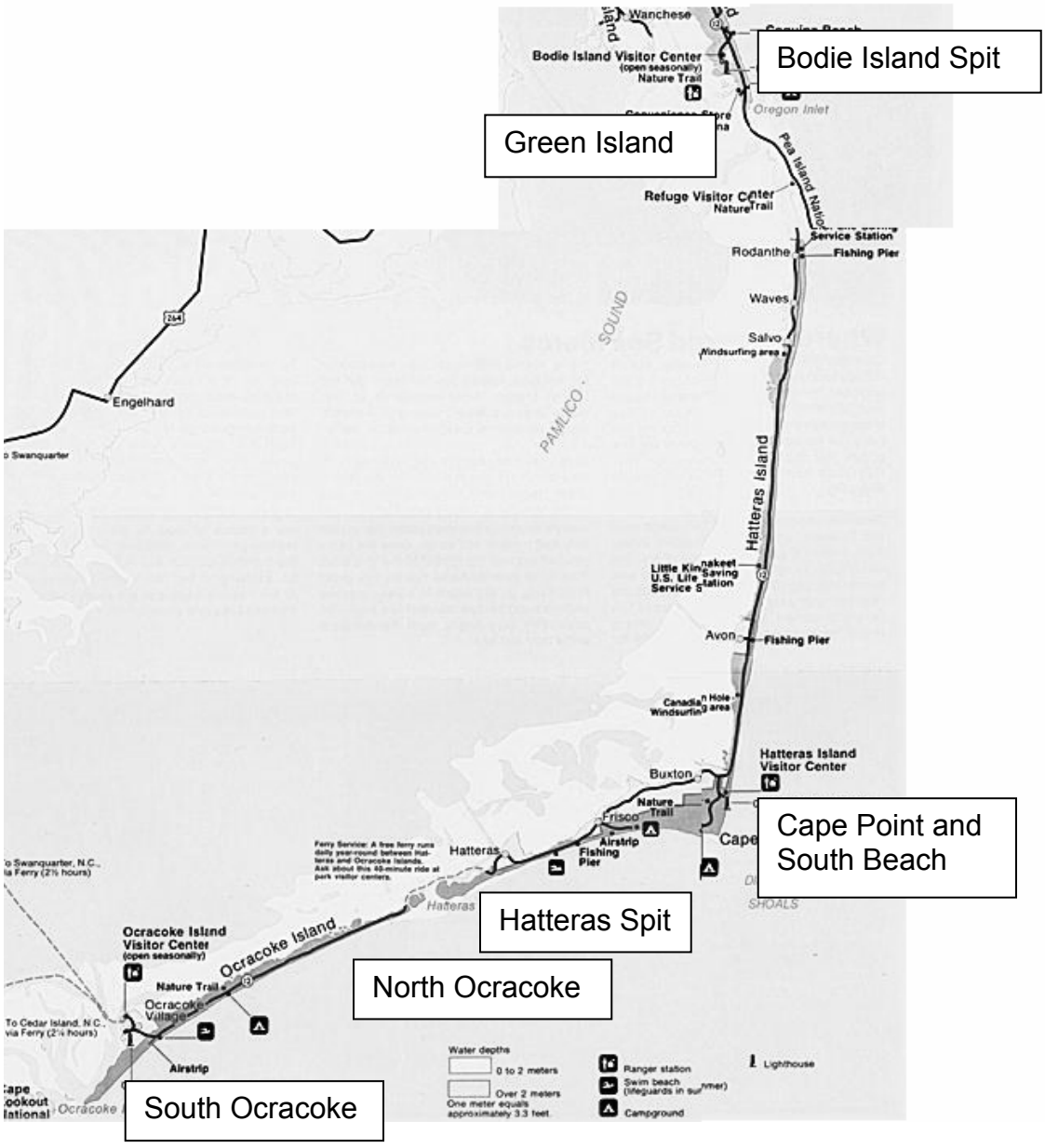

Fig. 1. Map of Cape Hatteras National Seashore indicating the seven major focal areas for colonial waterbird populations.