Predator Management for the Protection of Threatened and Endangered Species: A Multidisciplinary Study

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Abstract

This research project examined the predator management program on Cape Hatteras National Seashore (CHNS). It used a natural science approach and a social science approach to explore the biological aspect and public perception of predators and predator management. It used this research to further explore how natural and social pressures inform management decisions and regulations made by the National Park Service (NPS) to protect threatened and endangered species on CHNS.

The natural science research objectives were to determine the most significant causes of sea turtle and piping plover mortality on CHNS, and to develop a ghost crab study to determine abundance and distribution of this unmanaged predator. Sea turtle and piping plover annual report data from CHNS were analyzed and ghost crabs were determined to be the primary predator of sea turtles, with 81% of predator-related mortality attributable to ghost crabs, and piping plovers, with 54% of predator-related mortality attributable to ghost crabs. Since ghost crabs are a primary predator of these threatened or endangered species and unmanaged by the NPS on CHNS, a research study was designed to investigate their abundance and distribution at designated off road vehicle (ORV) sites and non-ORV sites within three study locations on CHNS. Data was collected on the number of ghost crab holes, sand type, location, beach morphology and topological aspects of the beach, and presence or absence of ORVs. Numbers of ghost crab holes were not influenced by ORV presence at all beaches, contrary to the findings of many previous studies. Beach profiles and soil density did not affect the number of ghost crab holes. There was a relationship between the number of holes and beach location, with Bodie Island having significantly more ghost crab holes. Wider island widths at each beach location correlated with more ghost crab holes, which implies variables outside of the dry sand beach

impact ghost crab populations and suggests management efforts should extend beyond the dry sand beach.

The social science research objective was to evaluate Outer Banks residents' knowledge and perception of predator management on CHNS. Interviews were conducted with key CHNS stakeholders to better understand their values, beliefs, and attitudes, and these responses were analyzed to inform variables for quantitative survey questions. Surveys were deployed in mail-back, personal intercept, and Internet form, and there were 531 total recorded responses. Results showed overall knowledge of predator management is low, and not affected by demographics or level of involvement in CHNS issues. They also revealed that there may be a lack of reliable information about the predator management program from credible sources, and that online sources could be most effectively used to spread information. The majority of respondents showed negative attitudes towards predator management, specifically the killing of predators for the benefit of threatened and endangered species. These results suggest that the NPS may be able to impact public perception about predator management by supplying more information about the predator management program online and that further research could be done on why residents living south of the Bonner Bridge are less accepting of the predator management program.

Upon analysis of natural and social science findings, the predator management program on CHNS appears to be effective, yet cannot be fully attributable to management efforts due to the absence of a control study. Since ghost crabs were shown to be such a significant predator of the threatened and endangered species on CHNS, the public may be more accepting of a predator management program if ghost crabs are managed as opposed to mammalian predators. However, this cannot be fully determined from this research because social science research did not

measure attitudes towards management of ghost crabs. Additionally, it may be helpful to the NPS to improve negative public perception by lowering euthanization rates of predators through controlling predator reproduction rates or increasing transparency of the program through public education, reliable information sources, and an open dialogue between the NPS and the public.

Introduction & Background

Introduction

The Outer Banks are fundamentally dependent on Cape Hatteras National Seashore (CHNS) for both their culture and economy. Many residents have a large stake in the management of the Seashore, whether for purposes of sentiment or sustenance. Recent management decisions made by the National Park Service (NPS) in relation to threatened and endangered species on the Seashore have proven very controversial. One contentious management action relates to the management of predators on the Seashore, specifically the trapping and euthanization of those that prey on threatened and endangered species. These predators include foxes, raccoons, opossums, nutria, minks and feral cats (feral cats are transported to the local animal shelter), which prey on the five species of sea turtles and a shorebird called the piping plover, all listed as threatened or endangered under the Endangered Species Act (ESA).

The purpose of this research project is to review the predator management program on CHNS and to analyze how social and natural pressures serve to inform management decisions and regulations by the NPS. We took two complementary approaches to studying the program: a social science approach that evaluated the community's reaction to management actions and a natural science approach that focused on the ecological function and implications of those actions. We developed different objectives, research questions, and methodology for each of these approaches. The objective of the natural science research was to determine the most significant causes of endangered species mortality on CHNS and to investigate the role of predators in the ecosystem. The social science research was intended to evaluate public

knowledge and perception of predator management. By utilizing the two different approaches, we were able to improve our understanding of the role that predator management plays on CHNS and how it is viewed in the surrounding community.

Background

Geographical, Ecological, Historical, and Management Context of CHNS

Cape Hatteras National Seashore was established by Congress in 1937 as the first national seashore in the United States. At first, the creation of the Seashore primarily relied on donations of private property by landowners and residents. Because of the shifting priorities of the United States during World War II, the process of land acquisition was delayed until 1952, when contributions from the state finally allowed for the expansion and ultimate completion of the Seashore in 1953 (Legner 2003). Today, CHNS spans over 70 miles of the Atlantic Coast along the Outer Banks, a series of islands and a barrier peninsula to the east of mainland North Carolina (Binkley 2007). The Seashore is divided up by a number of villages and inlets located along the Outer Banks and encompasses over thirty thousand acres of land on Bodie, Hatteras, and Ocracoke Islands.

CHNS has unique ecology that has been heavily influenced by the presence of people. The coastline is characterized by a wide continental shelf and gently sloping coastal plain that forms a lagoon system (Inman and Dolan 1989). Traditionally, hurricanes and crashing waves washed sand over much of the island, making development difficult. To reduce the rate of inland migration and frequency of ocean overwash, a dune line running the length of the coast was constructed in the 1930s. The addition of stabilizing dunes allowed the growth of scrub vegetation and maritime forests behind the dune line, thereby allowing various organisms including foxes, raccoons, possums, and birds to live in the relatively new habitat (NPS 2013b). On the other side of the dunes, the dry sand beach provides a habitat for ghost crabs, colonial shorebirds, and nesting sea turtles. A large variety of insects, plants and other organisms are also found in the area.

The CHNS has historically been influenced by diverse groups of people brought together by their shared interest in the region's resources and culture. The area has served a range of purposes throughout its lengthy and complicated past - from a hideout for the notorious Blackbeard to a battleground during the American Civil War. Despite the existence of a series of lighthouses, hundreds of shipwrecks serve as reminders of the role that natural forces play in shaping the Outer Banks. People have, however, continued to alter the landscape over time, from the few and dispersed initial inhabitations and sailing routes to the more recent large-scale developments of resorts and vacation rentals (NPS 2013a). The Herbert C. Bonner Bridge, spanning Oregon Inlet, was opened in 1963, and since then has served as the only highway connection between Hatteras Island and the mainland (NCDOT 2013). It gives people access to the Seashore that they otherwise would not have had, causing human impact where there was little before. Due to the ease of access and seasonal influx of tourists, people play a greater role today in the shaping and development of CHNS than ever before.

The National Park Service (NPS) is a federal agency under the United States Department of the Interior that is charged with managing national parks such as CHNS. As stated in the Organic Act of 1916, the mission of the agency is to conserve "the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (U.S.C. 16 § 1). Therefore, the objective of the NPS is to preserve a site's ecological integrity, not just maintain recreational value. The Redwood Act of 1978 asserts that regardless of whether a place is granted a park title, all areas in the NPS system are to be managed according to the Organic Act. Additionally, the Redwood Act maintains that if there is a conflict between people and resources, resources should take priority and be protected. To that

effect, the NPS is responsible for developing and enforcing management actions and regulations necessary to protect wildlife within national parks. The CHNS enabling legislation states that **"**no development of the project or plan for the convenience of visitors shall be undertaken which would be incompatible with the preservation of the unique flora and fauna or the physiographic conditions now prevailing in this area" (CHNS Enabling Legislation 1937). These three legislative documents clearly assign the NPS the authority to maintain and protect the natural areas of national parks, including CHNS, and the organisms that live within them.

Regulatory Framework Guiding Natural Resource Management

The Endangered Species Act (ESA) is legislation enacted by Congress in 1973 that prohibits any action that could cause harm to species listed as endangered or threatened. It is administered by the Interior Department's U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries service (NMFS). Section 4(f) of the ESA orders the Secretaries of the Department of the Interior and the Department of Commerce to develop and implement recovery plans for all listed species in order to help these species recover to the point where they can be delisted. Species are listed as "endangered" if they are likely to become extinct in the near future or as "threatened" if they are likely to become endangered within the foreseeable future (FWS 2013). These recovery plans must include management actions to conserve the species, measurable criteria necessary for the removal of the species from the list, and estimates of the time and money needed to reach the goals stated in the recovery plan. They must be based upon the best scientific and commercial data available and be site-specific for various populations of a species (NMFS 2008). Many recovery plans are written by appointed recovery teams, which are intended to include representative stakeholders with an

interest in conserving the particular species. The responsibility for the implementation of recovery plans falls largely on federal agencies such as the NPS, but local and state agencies as well as interested organizations and individuals also hold some responsibility in ensuring that recovery plans are followed where they apply (NOAA 2012). On CHNS, the NPS must implement management actions to reach the objectives set by the recovery plans for each listed species present. The listed species on CHNS are the piping plover (threatened) and five species of sea turtle: loggerhead (threatened), green (threatened), hawksbill (endangered), Kemp's ridley (endangered) and leatherback (endangered) (NPS [date unknown]).

Each threatened and endangered species of sea turtle on the Atlantic Coast, including those on CHNS, has its own recovery plan for the region's population. Threats listed in these plans include beach driving, light pollution, natural catastrophes, commercial fisheries (bycatch), oil pollution and marine debris. All of the plans list predation as a threat to recovery, and some cite specific data emphasizing their impact. For example, the recovery plan for the green sea turtle states that raccoons are a particularly destructive predator and may take up to 96% of turtle nests on a beach (NMFS 1991). The recovery plan for the loggerhead sea turtle includes the objective of minimizing predation, both of sea turtle eggs and of recent hatchlings. To address this objective, the plan states: "Ecologically sound predator control programs are implemented to ensure that the annual rate of mammalian predation on nests (under U.S. jurisdiction) is 10% or below within each recovery unit based on standardized surveys" (NMFS 2008). The recovery plans for the four other species of sea turtles stress the importance of monitoring nest activities to assess effectiveness of nest protection measures in reducing threats such as predation (NMFS 1991; NMFS 1992a; NMFS 1992b; NMFS 1993). However, these plans lack specific management actions for reducing this threat (besides nest exclosures), suggesting that the authors

intend for each region to develop site-specific actions to meet this objective. Whether or not management actions should include predator control is left up to the federal, state and local agencies involved in the management of land inhabited by these species.

The U.S. Fish and Wildlife Service (USFWS) is responsible for the recovery plan for the Atlantic Coast population of the piping plover, which was most recently revised in 1996. The plan describes the status of the population as "sparsely distributed," requiring "an extremely intensive protection effort" (USFWS 1996). The plan identifies habitat loss due to development, human and pet disturbance, and predation as major threats to piping plovers in this region. It also says that human activities affecting predator populations and activity have exacerbated natural predation on the shorebirds. These activities include introducing nonnative species such as feral cats and leaving trash on the beach, attracting predators such as raccoons. The plan includes an objective to reduce predation by removing litter and garbage from beaches, deploying predator exclosures around nests and removing predators "where warranted and feasible and where trapping can be conducted efficiently" (USFWS 1996). The plan also stresses the importance of public information and education programs, as well as scientific investigations to assist in recovery efforts.

Natural Resource Management at CHNS

In order to implement the recovery plans created for the endangered and threatened species found on CHNS, the NPS enacts different management actions including off road vehicle (ORV) restrictions and predator management. Historically, ORVs had open access to much of the CHNS, but legal action in 2012 caused the NPS to restrict beach driving from 64.9 miles to 19.3 miles (NPS 2012). This was done to minimize human contact and protect the habitat and individual nests of sea turtles and piping plovers.

Predator management is a strategy utilized by the NPS that targets certain predators to prevent them from disrupting or killing endangered species. The NPS began monitoring turtle nests in 1987 and piping plover nests in 1985 (NPS 2006a; NPS 2006b). They found that predators were a major factor in both plover and turtle nest loss and chick mortality (Cohen 2005). Accordingly, the main focus of predator control is on predators near nests and chicks ("Northern Recovery Plan 2012). The preferred mechanisms used to manage predators on CHNS are exclosure cages and live trappings. Use of exclosure cages surrounding nests began in 1994, followed by the initiation of a trapping program in 2002 (NPS 2012).

On CHNS, exclosures are used near nesting piping plovers to prevent predators from entering the nest while eggs are exposed. Exclosure cages are circular with a diameter of about ten feet and consist of welded-wire fence topped with mesh bird netting (NPS 2012). These are installed based on guidelines established in the USFWS Piping Plover Recovery Plan, and target nests with three eggs present (USFWS 1996). Although exclosure cages have not been completely effective (reports of predator tracks in and around lost nests appear regularly), they serve as basic protection for sensitive nesting areas. However, exclosures around piping plover nests are only effective before the eggs hatch. Due to their independent nature, piping plover

chicks leave the nest within a day of hatching and cannot be protected with nest exclosures. Turtle nests have no exclosure protection, but are clearly marked to prevent human interference. After approximately 50-60 days, there is a U-shaped barrier erected around the turtle nest to help guide turtles to the sea, but this does not exclude small predators such as ghost crabs.

Trapping is currently conducted near identified nesting areas in all districts of CHNS. Intensified efforts are made in areas with confirmed evidence of predators, specifically prints and scat (NPS 2012). Targeted predators include: raccoons, opossums, mink, red foxes, feral cats, and nutria. Non-lethal traps target mammalian predators with foot clamp traps. These traps are engaged when a predator steps into them, firmly holding the trapped leg in place until a NPS employee retrieves the predator. Traps are checked on a daily basis or every other day. Predators trapped in non-lethal traps are euthanized, except for feral cats, which are brought to the local animal shelter where shelter employees determine if they are adoptable. While non-lethal foot clamp traps are the most frequently used, lethal traps have been used to trap mink.

Experimental trapping of ghost crabs began in 2013 using Sherman live traps (a box-style trap), which has proved effective based on anecdotal evidence (William R. Swilling, personal communication). Avian predators have not yet been managed other than the implementation of nest exclosures to keep them away from piping plover eggs. In 2012, 410 animals were trapped, primarily raccoons and nutria. There have been 2,213 NPS trappings on CHNS since 2007 (William R. Swilling, personal communication).

Objectives

Our overarching objective was to study the connection between the managing agency and the impact that humans and predators have on the survival and success of threatened and endangered species. In order to further investigate this, we divided our research goals to include (1) the factors contributing to threatened and endangered species mortality rates and (2) the practicality of the predator management strategy employed on CHNS. Accordingly, we developed a number of research questions, which are outlined below.

1. *What are the primary causes of mortality in endangered and threatened species at different lifecycle stages? What proportion of the mortality is due specifically to predators?*

   A review of NPS annual reports of sea turtles and piping plover management was conducted to better understand the roles of predation and human interference in overall mortality rates of monitored species and how they compare to other causes of mortality, such as storm events.

2. *What forces/characteristics drive predator abundance and distribution?*

   The predator management plan is based on the assumption that predation plays at least a relatively significant role in threatened and endangered species mortality rates. We conducted a case study centered on ghost crabs, a predator of both piping plovers and sea turtles, to determine forces influencing predator abundance. The field research was conducted in part to help us to understand whether the new policies adopted on CHNS concerning ORV use impacts ghost crab populations and, if so, how.

Ecosystem Based Management vs. Species Specific Management

An ecosystem consists of a collection of organisms and the biological, chemical, and physical environment in a geographical region, including the processes therein. Because species overlap in space and time, they compete for resources required for survival while simultaneously reacting to changing external pressures in their environment (Norman et. al 1996). The dynamics of biological pressures in an ecosystem heavily depends on the organisms of interest and the environment they live in. When resources such as proper nourishment and space become limited by any combination of factors, populations of individual species dwindle and subsequently affect other elements in the ecosystem. Factors causing change in populations include human development of critical habitat, increases in number of predators, and changes in weather and rainfall patterns.

A food web is a portrayal of the numerous relationships and connections between species of different trophic levels in an ecosystem, including predator-prey relationships. However, interactions between species are not limited to those displayed in the food web and often their synergistic relationships are unnoticed by humans until a species disappears from an ecosystem altogether (Chapin III 2000). The full extent of the benefits of having great species richness and biodiversity in an ecosystem is not easily quantifiable, even after scientific research. The potential loss of an endangered species is particularly problematic because of the uncertainty in assessing the importance of individual species within an ecosystem (Chapin III 2000; Franklin 1993).

Historically, such as with the implementation of the ESA, there has been an effort to categorize species based on the status of their populations and then tailor management strategies around those populations. This type of species-specific management aims to increase the

population and vitality of a singular species of concern as opposed to improving the environmental conditions that impact the ecosystem and the many species therein. The sheer number of species and the complex interconnections within an ecosystem has made it increasingly difficult to maintain their populations while relying solely on species-specific management. To better preserve biodiversity, an ecosystem based management approach has been advocated and continues to gain popularity (Franklin 1993; Hoagland 2010).

Ecosystem based management (EBM) is a strategy used to regulate human involvement in the biological, physical and chemical aspects of the environment. EBM "maintain[s] an ecosystem in a healthy, productive, and resilient condition so that it can provide the services humans want and need" by using adaptive management and collaborative planning with a landscape scale focus (McLeod and Leslie 2009; Layzer 2008). The landscape scale aspect of EBM focuses on the ecosystem in its entirety, a move away from the traditional species-based management programs that do not necessarily take into account all the processes and human use conflicts within an area (Layzer 2008). In order to achieve more comprehensive and maintainable management and planning, EBM encourages collaborative planning among scientists, stakeholders, and government officials to arrive at consensual management decisions and solutions (Layzer 2008). Due to the complex and uncertain nature of ecosystems and the interactions within those ecosystems, it is important for management to be highly adaptive. Furthermore, adaptive management allows for flexibility in management implementation by applying new information about the ecosystem as it becomes available (Layzer 2008). Thus, EBM provides a comprehensive framework for management of human interactions with unstable components of the ecosystem.

Implications for Management on Cape Hatteras National Seashore

Endangered species management strategies, particularly those on CHNS, are primarily species-specific. Whereas EBM aims at promoting biodiversity within an ecosystem, predator management in support of endangered species protection favors the survival of one or a few species at the expense of several others. The adoption of species-specific management on CHNS is in part due to the inflexible nature of the ESA, which requires the NPS to focus management efforts and resources on the protection of specific populations of threatened and endangered species. Even though at-risk species are being supported, the overall biodiversity of a system may not increase with such management actions because the roles of other species within an ecosystem are sometimes undervalued. It is important to note that the role that some of these predators play in the ecosystem may not be fully understood, and by removing them from the system the services they provide would also be extinguished. However, many of the predators managed on CHNS are non-native, and therefore are less likely to contribute to efficient functioning of an ecosystem. Furthermore, it is possible that some predator populations have been inflated because of favorable conditions created by human alterations to the landscape. Each management agency bases actions on its management goals. Various legal mandates and actions reveal that reducing the number of extinctions is a priority of the NPS. This goal may be better achieved using species-based management strategies, which are straightforward and better understood, over ecosystem-based management strategies, which require large amounts of research and information. We chose to investigate the extent to which one of these strategies, the use of predator management, is effective as employed on CHNS. We also explored the extent of which ecosystem scale processes and interconnections are taken into account when developing management strategies.

Social Science Research

Using a Cognitive Hierarchy to Understand Public Perception of Predator Management

Social science studies the relationships between people, places, and experiences. In order to examine these relationships, social science research utilizes many models and theories. The cognitive hierarchy theory is one such behavioral model (Ajzen and Fishbein 1980; Vaske and Donnelly 1999). Within the cognitive hierarchy, values are the ideas that affect beliefs, which impact attitudes and norms, which in turn influence individual behavior (Rokeach 1973; Rokeach 1979). In the simplest terms, this hierarchy is a guideline that seeks to determine how societal values are formed, and how they can be used to predict behaviors. Values can help an individual judge the appropriateness of behavior in a given social context (Rokeach 1973; Rokeach 1979). In addition to identifying the personal standard of what is "right" and "wrong," values will often aid in "personal interpretation of events and information" (Manfredo 2008).

Listening to the personal experiences of CHNS stakeholders, we gained a better understanding of individual values and beliefs. Beliefs are "judgments about what is true or false" relying strongly on values to make such delineations (Vaske and Donnelly 1999). Attitudes are associations that an individual creates within their own perceptions of concepts in their memory (Eagly and Chaiken 1993). The values we uphold as individuals predispose us to certain beliefs that ultimately shape our attitudes and behaviors. While similar values are often held by society or a group of connected persons, behaviors exhibited by individuals can vary based on individual attitudes and interpretations within their own belief system.

Research Objectives

In a preliminary study of predator management on CHNS, we chose ten questions to ask in four qualitative interviews with stakeholders. After conducting these interviews, we analyzed responses from all parties, identified conflicting attitudes and beliefs about the management of CHNS and shared values at the core of these attitudes and beliefs. We referenced this information to fine-tune our social science research questions, which were as follows:

1. *What do people know about predator management at CHNS and where do individuals get information about this and other management actions?*

   We wanted to better understand the basis for opinions related to predator management on CHNS.

2. *What are the attitudes and perceptions of predators and predator management on CHNS?*

   We sought to find out whether or not predators are valued as an important part of the ecosystem. We also hoped to determine the public perception of strategies used to protect threatened and endangered species, such as predator management. We wanted to find out whether or not people find the predator management program on CHNS acceptable, and we hoped to compare this to the level of acceptability of predator management in general.

We also hoped to find ways to improve public knowledge and perception of the management actions on CHNS and to encourage involvement of the public in management

decisions. Involving the public in this process could encourage their cooperation once management actions are put in place.

Implications for Management on Cape Hatteras National Seashore

Every individual has varying views, beliefs, and attitudes on nature and the interactions that humans can have with nature. Differences between values can affect how individuals perceive issues regarding the environment, animals, and natural resources (Vaske and Donnelly 1999). Predator management can be a contentious issue because it can be viewed through many lenses, separately influenced by the beliefs of each individual.

Better understanding of value types, attitudes, and resulting belief structures of all stakeholders on CHNS can put policy makers and enforcement officials in a better position to reflect commonly held principles in the decision making process (Manfredo 2008). Understanding stakeholder attitudes and beliefs originating in well-defined values can contribute to successful conflict resolution among dissenting parties. Though attitudes or beliefs may be conflicting, common values may be the leverage necessary for parties to compromise on contentious issues (Manfredo 2008).

Public perception of management actions includes the measure of how acceptable strategies such as trapping, sterilization and euthanization are to stakeholders. The perception of management actions blends together personal beliefs and attitudes. It also raises the question of where people get the information that they base these attitudes on, and what role public opinion should play in making policy decisions. Our research was aimed at better understanding all of these issues and hopefully contributing to possible solutions to future conflicts.

Natural Science Research

Annual Report Introduction

Piping plovers and sea turtles on CHNS are listed as threatened or endangered under the ESA. The Atlantic coast piping plover population was listed as threatened in 1986 (NPS 2008a). Leatherback, Kemp's ridley, and hawksbill turtles were listed as endangered, while green and loggerhead turtles were listed as threatened (NPS 2008b) during the 1970's (NOAA 2013). The ESA mandates that federal agencies must consult with USFWS before the authorization, funding, or conducting of any activities that may affect the listed species. Furthermore, the ESA requires federal agencies to increase conservation efforts for listed species. For example, Executive Orders for ORV use apply to lands that are under the authority of the Secretaries of Agriculture, Defense and the Interior and require administrative designation of permitted ORV areas. CHNS is under the custody of the Secretary of the Interior, and therefore must have ORV regulations. Recovery Plans were developed for the piping plover and sea turtles by USFWS in order to enforce compliance with these laws aimed at protecting threatened and endangered species. (USFWS 1996).

The NPS is expected to report annually on threatened and endangered species populations as directed by the Recovery Plans and the ESA. Executive Orders 11644 and 11989, as well as the ORV Management Plan, mandate that conservation efforts are prioritized for these species in areas on CHNS with ORV access. Resource Management Annual Reports for CHNS include information regarding management efforts for piping plovers and sea turtles, such as predator control and the monitoring, success rates, and mortalities of threatened and endangered species, in order to comply with the aforementioned laws and regulations.

The Resource Management Annual Reports made public by the NPS were used to assess the numbers and causes of sea turtle and piping plover mortalities at different life cycle stages at CHNS from 2006 through 2012. Data reported in piping plover and sea turtle annual reports prepared and made public by the CHNS was used to help answer the following research questions:

- *What are the primary causes of mortality in endangered and threatened species at different lifecycle stages at CHNS?*
- *What proportion of the mortality is due specifically to predators?*

We hypothesized that the primary cause of mortality of piping plovers and sea turtles at early life cycle stages would be predation, followed closely by storm events for sea turtles.

Annual Report Methodology

Resource Management Annual Reports from 2006 through 2012 were distributed among group members (two to three reports per person) and reviewed for instances of mortality and the cause of that mortality. In each case that a loss could be attributed, the mortality was categorized as due to one of the following reasons: predation, storms/washouts, losses due to humans, or nest abandonment (piping plovers only). Nest abandonment, for the purposes of this paper, refers to the loss of piping plover eggs or chicks due to abandonment by adult piping plovers. In instances when a cause was not attributed, the mortality was designated as unattributable. Although the NPS can usually assume the cause of death with a high degree of confidence, the cause of death cannot be officially attributed unless there is absolute certainty (William R. Swilling, personal communication). The life cycle stage during which the mortality occurred was also noted. Once the causes of mortality were categorized, the results were tallied for each year in order to quantify the total number of losses attributed to each cause of death. In the case of predation events, results were further broken down to reflect the specific predators involved.

Annual Report Results

Piping plovers

Annual report data revealed that instances of piping plover mortality could be attributed in only 32% of the overall recorded mortalities (Figure 1a). Losses were attributed to predation, storm events, abandonment, or human impact. Annual report data between 2006 and 2012 suggests that predators are the biggest threat to piping plover survival, with 56% of all attributable piping plover deaths caused by predation (Figure 2a). Nest abandonment and storm events contribute the remaining 32% and 12% of overall mortality, respectively.

Ghost crabs were the primary predator responsible for piping plover losses on CHNS from 2006 to 2012, constituting 54% of predation-related mortality (Figure 3a). Other predators contributing to piping plover mortalities include opossums or raccoons, mink, birds, and foxes. For the losses attributed to opossums or raccoons, the instances of mortality could not be reliably connected with one predator or the other. The predator involved in predation-related mortality was found to be unknown in approximately 7% of cases. Often in predation events that cannot be definitely attributed to a specific predator, tracks are found around nests. Because it cannot be stated with complete certainty which predator was responsible, the losses are categorized as due to an unknown predator.

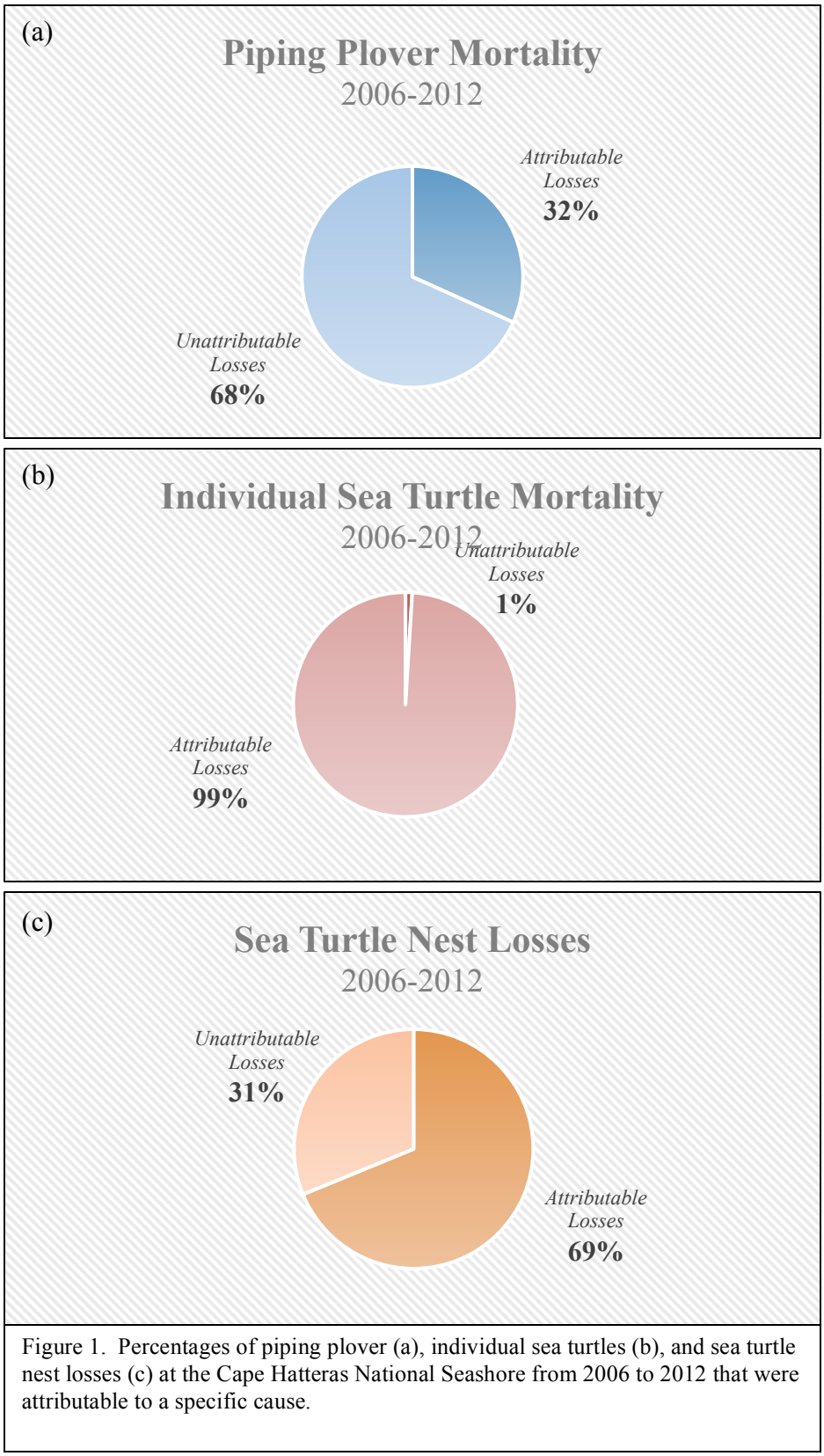
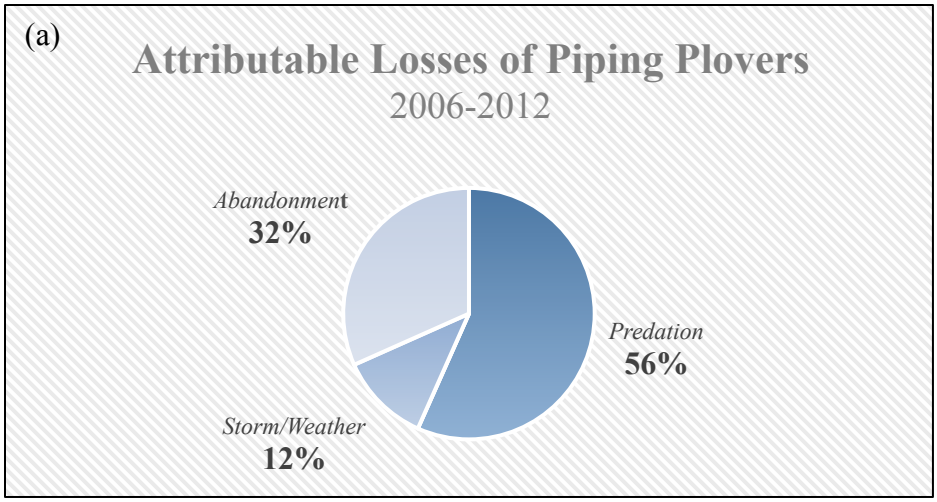
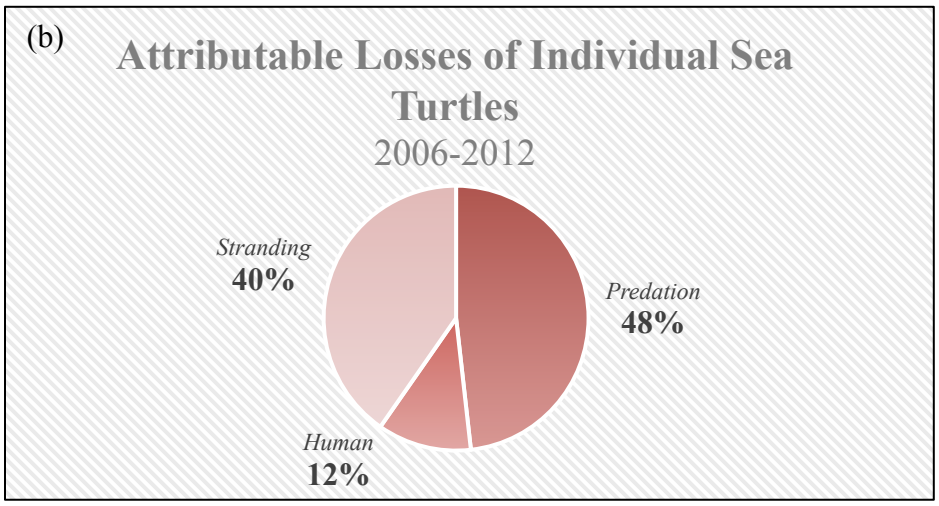


Figure 1. Percentages of piping plover (a), individual sea turtles (b), and sea turtle nest losses (c) at the Cape Hatteras National Seashore from 2006 to 2012 that were attributable to a specific cause.





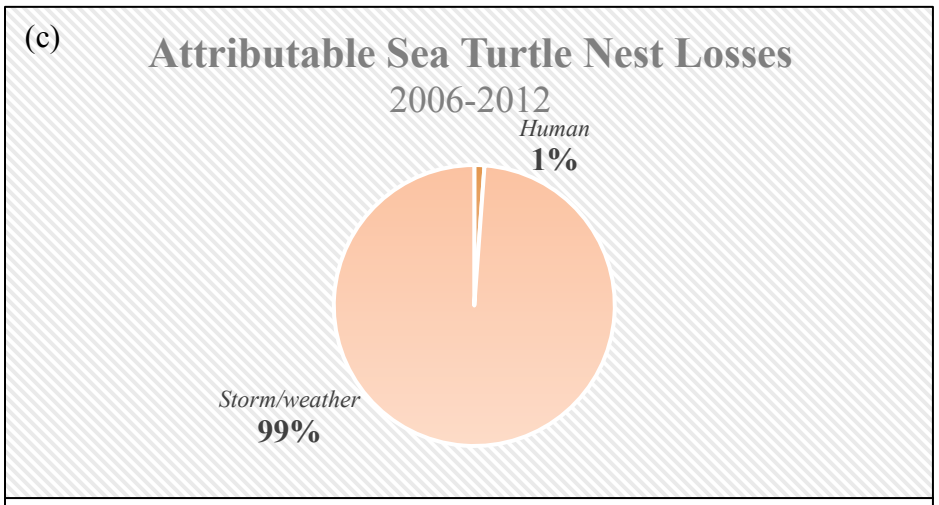


Figure 2. Percentages of piping plover (a), individual sea turtles (b), and sea turtle nest (c) losses attributable to a specific cause, including human interactions, storm events or weather, strandings, predation, or abandonment at the Cape Hatteras National Seashore from 2006 to 2012.

There were a total of 189 reported piping plover mortalities on CHNS from 2006 to 2012. The total number of piping plover mortalities fluctuated from year to year over this period of time, as did the number of attributed mortalities (Figure 4). All annual report data on piping plover mortalities is provided in Appendix A.

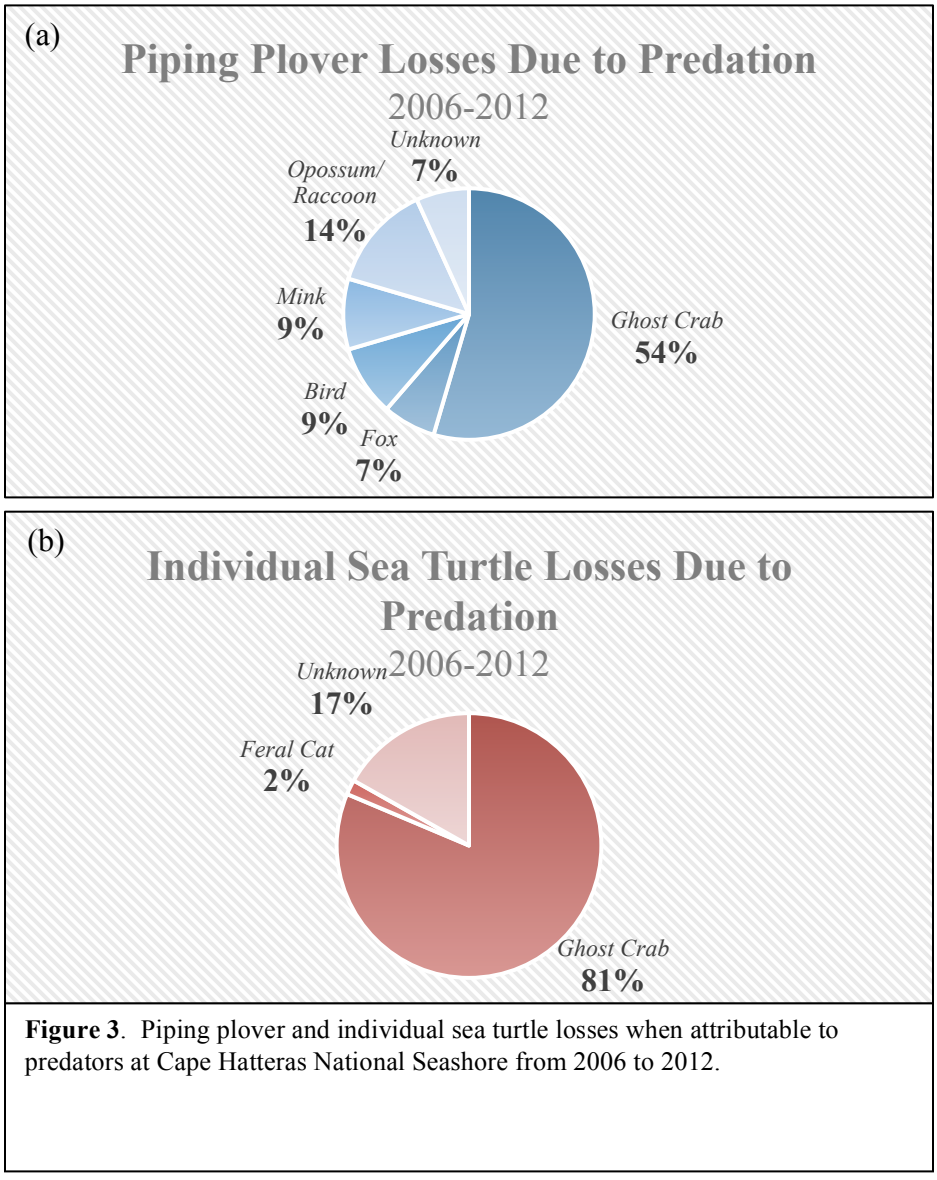


Figure 3. Piping plover and individual sea turtle losses when attributable to predators at Cape Hatteras National Seashore from 2006 to 2012.

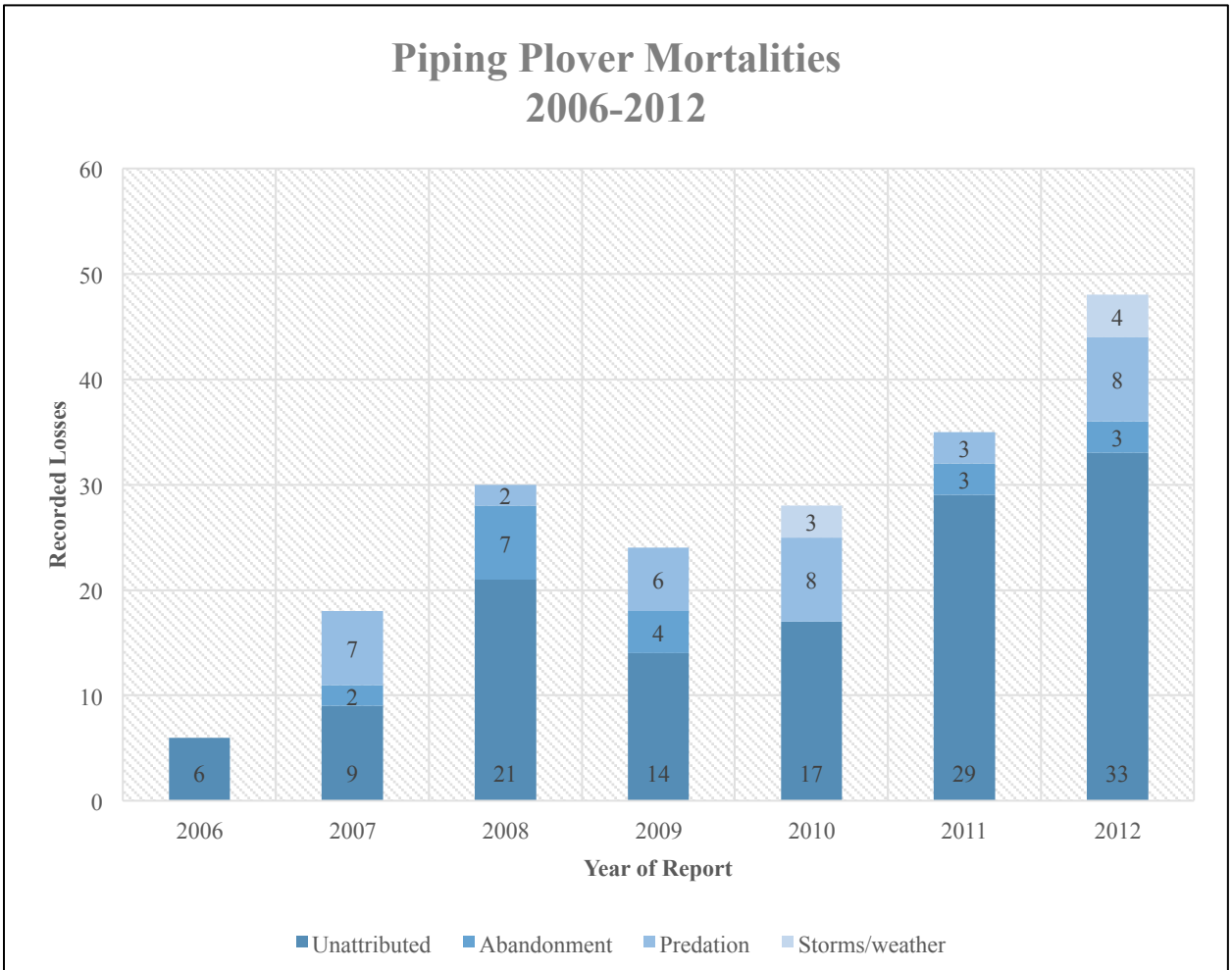


Figure 4. Total counts of 189 piping plover mortalities categorized by storms/weather, predation, abandonment, and unattributed causes in all life cycle stages at Cape Hatteras National Seashore from 2006 to 2012.

Sea Turtles

Sea turtle mortalities on CHNS were broken down into losses of individuals and losses of entire nests. Annual report data revealed that losses were attributable for 99% of individual sea turtle mortalities and 69% of nest losses (Figures 1b and 1c, respectively). Of losses that were attributable from 2006 and 2012, predation on hatchlings constituted 48% of individual sea turtle losses, followed closely by stranding-related deaths of adult sea turtles, which make up 40% (Figure 2b). Human-related sea turtle mortalities accounted for 12% of individual sea turtle losses. For sea turtle nests, weather conditions and storm activity were responsible for nearly all losses, with a negligible number of nest losses associated with human activities (Figure 2c).

Sea turtle mortality due to predation was recorded for each type of predator during the years 2006 to 2012. Comparable to the piping plover, ghost crabs were the primary predator responsible for sea turtle losses, responsible for 81% of sea turtle losses due to predation (Figure 3b). Approximately 17% of sea turtle mortalities could not be associated with a particular predator, and the remaining 2% were attributed to feral cats. As was the case with piping plovers, mortalities are classified as due to an "unknown predator" when tracks or signs of predators are found around predated nests, but the cause of mortality cannot be attributed to a specific predator.

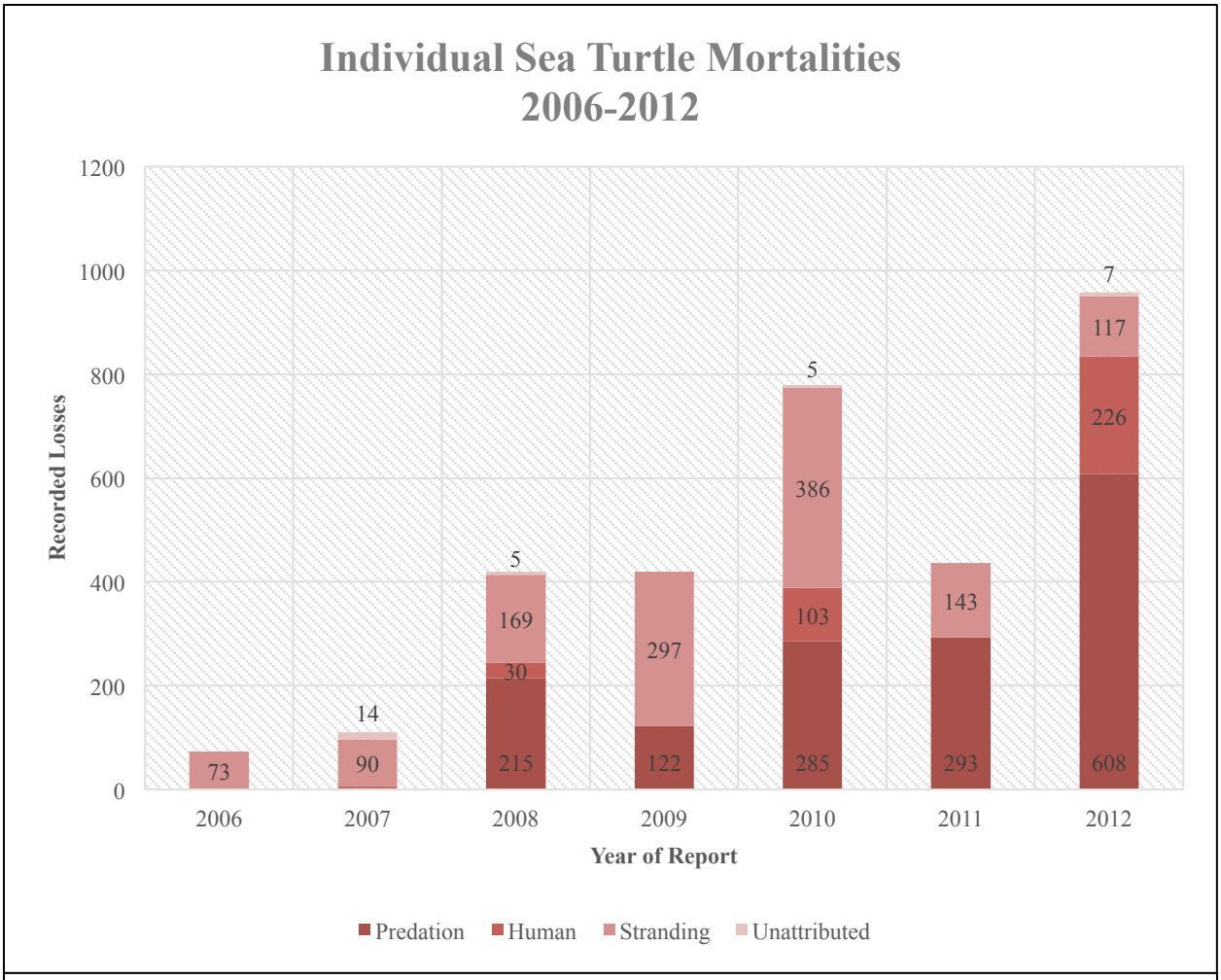


Figure 5. Total counts of the 3190 individual sea turtle mortalities for all life cycle stages categorized by strandings, predation, unattributed and human related causes at Cape Hatteras National Seashore from 2006 to 2012.
Note: year 2007 predation count needs a number on it, scale down the y axis to 1000.

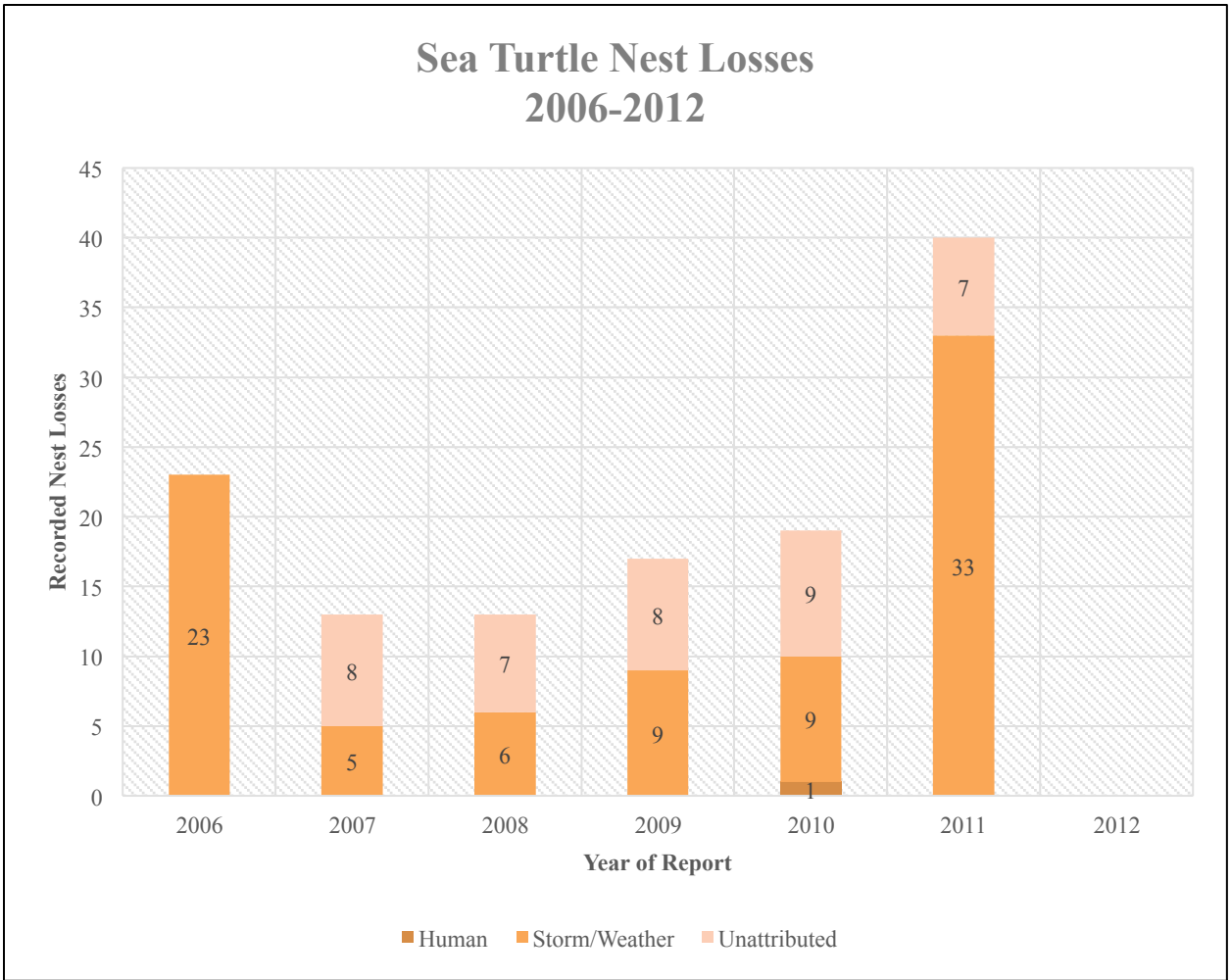


Figure 6. Total count of 125 sea turtle nest losses categorized by unattributed, storms/weather, and human related causes at Cape Hatteras National Seashore from 2006 to 2012.

There were a total of 3,190 reported individual sea turtle mortalities and 125 nest losses on CHNS from 2006 to 2012. The total number of sea turtle mortalities fluctuated from year to year over this period of time, as did the number of attributed mortalities (Figure 5). All annual report data on sea turtle mortalities is provided in Appendix B.

Annual Report Discussion

According to William Swilling, the current Natural Resource Program Manager on CHNS, differences in annual reporting from 2006 to 2008 as compared to more recent reports reveal that early annual report data may not be representative of actual mortality rates (Figures 4, 5 and 6). This potential for introduced error highlights the importance of carefully planned and implemented monitoring and reporting protocols. Consistent monitoring and reporting protocols allow for assessment of the success of natural resource management actions and subsequent adaptation as well as transparency for the benefit of the public's understanding.

Piping plovers

Based on the data collected, it was determined that a larger portion of piping plover mortalities were due to unattributable causes than to attributable ones (Figure 1a). This was, to an extent, expected due to the guidelines for reporting that must be followed by the NPS. These guidelines suggest that mortality events can only be categorized as attributable if there is absolute certainty, usually through observation. This implies that the NPS likely had a good idea of what caused piping plover mortality in a significant portion of unattributed cases.

Furthermore, of the attributed causes of piping plover mortality, the most significant known cause of death was predation (Figure 2a). In developing our research questions, we hypothesized that this would be the case. The predominance of piping plover mortalities attributed to predators explains the NPS's desire to pursue predator control as a management strategy on CHNS.

The data further suggests that ghost crabs were the main predator of piping plovers on CHNS (Figure 3a). We expected there to be a more even distribution of mortalities due to specific predators. However, following ghost crabs, the predator responsible for the second

greatest number of deaths accounted for only 14% of overall predator-related losses. This data ultimately has one of two possible explanations, or a combined explanation. The first is that on CHNS, ghost crabs would constitute the most significant predator of piping plovers with or without the current predator management program in place. The second explanation is that the predator management program, which does not presently manage for ghost crabs, is effective at reducing piping plover mortality caused by other predators. Inevitably, a program that successfully removes certain predators would allow for non-managed predators to constitute a greater proportion of overall mortalities.

Sea turtles

Initial predictions had suggested that the bulk of nest losses and a small percentage of individual sea turtle losses would be attributable. However, following annual report data analysis, individual sea turtle losses were attributed in almost all instances of mortality and in the majority of sea turtle nest losses (Figures 1b and 1c, respectively). The disparity between expectations and results regarding nest losses can be traced to the methods by which the NPS categorized certain loss events. For example, entire nests were sometimes lost because individual eggs were broken, allowing for the growth of fungus and/or bacteria. In many cases, this infection spread throughout all or many of the eggs within that particular nest. The NPS, however, categorized these nest losses as unattributed despite having evidence of a fungus and/or bacteria (NPS 2001). In reference to individual losses, it was assumed that unattributable losses would constitute the majority of recorded mortalities because only losses that were directly observed by the NPS staff could be attributed.

Predation and stranding events resulted in comparable numbers of deaths of individual sea turtles (Figure 2b). Predation, however, was the leading cause of attributable individual sea

turtle mortality. Although data regarding sea turtle strandings was recorded in our figures and graphs, it cannot be concluded with certainty that the cause of death (which resulted in strandings) actually occurred on CHNS. It is possible that there were cases where a sea turtle was injured outside of CHNS but the NPS was required to report it as a mortality within NPS annual reports because it was found on CHNS beaches. Strandings appear to be a significant portion of sea turtle mortalities, warranting future studies, but they do not inform the research questions in this report. No conclusions can be drawn from this information because it is unknown what the actual cause of death was that resulted in a stranding on CHNS.

As expected, storms were responsible for almost all instances of attributable sea turtle nest losses (Figure 2c). However, it is difficult to compare between entire nest losses and individual losses in order to assess the most significant source of sea turtle losses on CHNS. It is also important to address the apparent discrepancy that exists between the primary forces driving individual sea turtle mortality versus entire nest losses. Entire nest losses are usually attributable to storm events; in almost all instances, storm activity was found to destroy entire nests due to their low-lying positions along the beach. Turtle nests are especially vulnerable to environmental conditions causing losses of all individuals within the nest, which can explain the discrepancy between the major factors influencing mortality for individual sea turtles and nests. For example, although predation was observed at a significant number of sea turtle nests along the Seashore, the loss of entire nests can rarely be attributed to predation as only a small number of eggs were predated upon within each nest. The extent to which storm events and predation contribute to sea turtle mortality is likely comparable, but as we do not know exact numbers of individual losses resulting from storm events, we cannot say with any certainty.

Of predator-related mortality, ghost crabs caused the most deaths of individual sea turtles (Figure 3b). As previously mentioned in the piping plover discussion above, this finding is interesting because ghost crabs are one of the few predators not currently being managed by the NPS. However, results differ from those found in the Green Sea Turtle Recovery Plan. The studies within the plan, which were not necessarily specific to CHNS, stated that raccoons posed the greatest threat to sea turtle survival at the time (NMFS 1991).

Ghost Crab Study Introduction/Background

As is evident in the NPS annual reports on piping plovers and sea turtles at CHNS, predation by ghost crabs contributes significantly to overall mortality rates for these threatened and endangered species. We therefore designed and conducted a field study intended provide information about the factors that influence the abundance and distribution of ghost crab populations. Specifically, we set out to investigate how distribution and abundance of ghost crab burrows are impacted by location along the beaches of the CHNS, presence of ORVs, beach morphology and topography, sand characteristics, and presence of a wrack line. It is important to point out, however, that forces driving ghost crab abundance and distribution do not necessarily correlate with forces driving that of other predators in the area. It is also essential to highlight the fact that the NPS is not currently managing ghost crabs; although they plan to incorporate ghost crabs into predator management practices in the future (Swilling, William R. 2013).

Ghost crab burrows were used as a proxy for the presence and abundance of ghost crabs because it would have been nearly impossible to get an accurate count of ghost crabs by attempting to catch and release ghost crabs, largely due to time limitations and problems associated with double-counting (or not counting) individual ghost crabs. Based on previous research, it was concluded that the distribution and abundance of these predators could be estimated by measuring the diameter and quantity of crab burrows along a portion of the beach (Lucrezi et. al 2008). Although it is possible for multiple crabs to occupy the same burrow at any one time, ghost crab burrows provide a fairly accurate representation of the size and age of the inhabiting ghost crab populations (Valero-Pacheco et. al 2007; Lucrezi et. al 2008). Moss and McPhee (2006) state, “burrow counts are suitable as an indirect population assessment tool provided the burrows of a species are clearly distinguishable from any other species and there is

a known relationship between the number of individuals present in a burrow." The purpose of our study was to assess the factors influencing ghost crab distribution and abundance, which have the potential to indirectly impact survival rates of piping plovers and sea turtles at the Seashore.

Tureli et. al (2009) conducted a study in Turkey that established a distinct correlation between ghost crab burrow density and distance to the swash zone. The researchers stated that the likelihood that this relationship exists, at least in part, is because of the differences in sand composition - specifically, grain size and soil moisture - within different zones of the beach. To that effect, our study further investigated the extent to which this was true at CHNS. In addition, this case study was aimed at determining whether differences in the topography of beaches throughout CHNS influenced the distribution, abundance and density of ghost crab burrows. Prior to data collection, we established that the beach berm may be divided into three definitive "zones":

1. The dry sand beach, which lies between the first line of stable vegetation on the dunes and the storm wrack line. If there was no wrack line present, the two of the dunes marked the transition point.
2. The supertidal zone, which is considered to be above the mean high water mark, below the dry sand beach, and is often subjected to overwash during storm events.
3. The intertidal zone, or the zone that exists between the mean high water mark and the mean low water mark.

When planning for the investigation of possible variables affecting ghost crab density and abundance, several previously published works were determined to be of use. A study by Lucrezi et. al. (2008) evaluated how beach biota responded to human influences by measuring ghost crab population density on Mooloolaba Beach in Australia. The project focused on how human trampling affected ghost crab densities. Researchers found that burrow densities decreased at sites during periods of heavy beach use and remained low even after significant drops in visitation. Highly impacted areas supported only half the number of ghost crabs that were found in the least disturbed areas. Lucrezi et. al. (2008) concluded that this human impact lowered the densities of ghost crab burrows and affected the location of their distribution across the beach.

Studies by Schlacher et. al., (2007) as well as Moss and McPhee (2006), examined how ORVs impact ghost crabs on North Stradbroke Island in Australia. They addressed how ghost crabs respond to traffic intensity, the degree to which burrows protect crabs from ORVs, and if mortalities caused by ORVs contribute to declines in ghost crab populations. They found that crab densities were lower in areas with heavy ORV use. Declines in ghost crab abundance by ORV use occurred in several ways, including direct crushing, changes in habitat suitability (i.e., when ORVs loosen sand and hinder burrow construction), interference with reproduction and recruitment, reduction of food supplies by crushing prey, and via light pollution (Schlacher et. al. 2007). We expected to find that ORV presence would drive ghost crab abundance and distribution by finding significantly fewer ghost crab burrows and lower burrow density on beaches with high human presence.

Briefly, we investigated the influence of these factors on ghost crab abundance and distribution as follows:

1. ***Location***

   Three sample sites were selected at random along 30 miles of CHNS and were intended to capture the variability in beach characteristics and ghost crab populations among different areas of CHNS beaches. The geographical locations of the three transects at each beach (including ORV and non-ORV areas) were intended to reflect and account for some of the variation in ghost crab populations within an area of beach at CHNS.

2. ***Open or Closed to Beach Driving***

   Data was collected from designated ORV access sites and non-ORV access sites at each beach location. The sites were paired - each location in an ORV access zone corresponded to a nearby location in a non-ORV access zone. Pairing them in such a way allowed for comparison between the two areas, with non-access areas acting as a control in determining the impact that ORVs have on ghost crab populations. Previous studies have found differences in ghost crab burrow abundances and density between beaches where driving was allowed and restricted.

4. ***Beach topography, morphology, sediment type and structure, and presence of wrack line***

   At each location, we assessed the proximity of ghost crab burrows to the dunes/vegetation and to the swash zone (the zone affected by wave breaking and runup that shifts with changing tides). We also compared the widths of the island,

beach slope, sand bulk density, sand texture, and the presence or absence of a wrack line to ghost crab burrow abundance and distribution. The geographical locations of the transects were intended to reflect and account for some of the variation in ghost crab populations between beaches at CHNS.

Materials & Methods

Site Description and Study Design

In preparation for data collection, specific time frames were chosen to reflect the variation in burrow density over the course of a single day. We selected three sites open to ORV access in Little Kinnakeet, Salvo, and Bodie Island (Ramp 27, Ramp 22, and Oregon Inlet), and three open to pedestrians only (Ramp 27, Salvo Day Use Access, Coquina Beach Access) at CHNS.

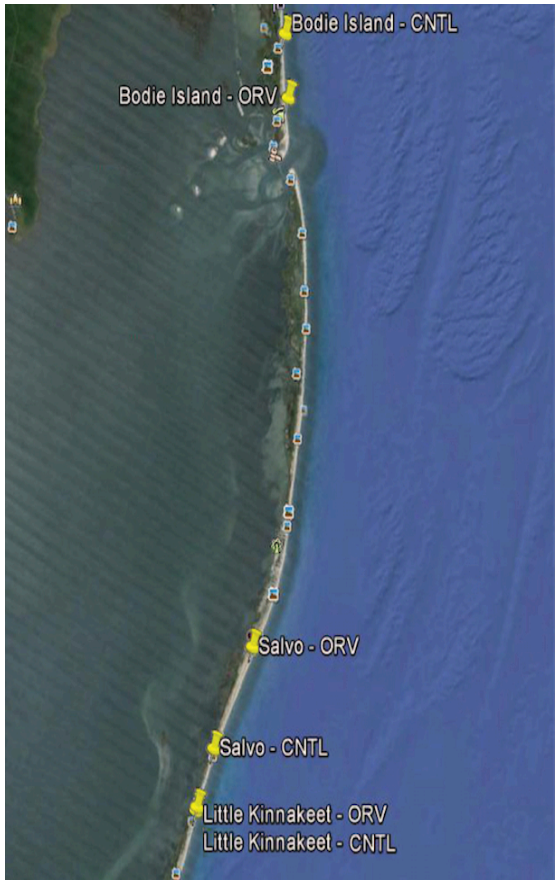


Figure 7: Map of sites chosen for study

Island widths at these locations were determined using ArcGIS software. Due to the government shut-down, all beaches at CHNS were closed to beach driving until October 17; data collection took place on October 21 at the Little Kinnakeet and Salvo transect sites and on October 22 at the Bodie Island data collection sites. We originally chose to begin field days at sunrise to minimize new human impacts on burrow densities but also added afternoon sampling events to assess the variation in burrow density over the course of a single day. A summary of environmental conditions at the time of sampling is presented in Appendix C, Table 1.

Transect Selection and Zonation

To create a transect along the beach, a 50 meter measuring tape was laid perpendicular to the shoreline starting at the first line of vegetation on the dune line and ending in the swash zone. Transects were divided into three zones: the foredunes (Zone 1), the dry sand beach (Zone 2), and the wet sand beach (Zone 3). Zone 1 began at the stable vegetation line with the beginning of the transect tape and was marked with a surveying flag. Zone 2 began at the highest wrack line, and in the absence of such a wrack line, the toe of the dunes. Zone 3 began at the start of the wet sand beach or at the point where the beach became more perceptibly sloped towards the water. The presence of a wrack line from the most recent high tide in Zone 3 was recorded. The presence of ghost crab burrows within a meter on either side of each transect was recorded along with the location of each burrow along the transect, as well as which zone the burrow was located in(Appendix C, Table 1).

Total Station

A Leica Geosystems Pinpoint R400 Total Station was used to record beach profile data for each transect. The data was obtained by aiming the station at a prism fixed on an adjustable pole. The total station was placed at a high point behind each transect, usually on top of the first seaward dune. After selecting an appropriate vantage point, the total station was leveled by adjusting the height of each leg. The station was completely rotated two times, centering the adjustment knobs on each leg to perfect the balance. Once the station was prepared, the beach profile of each transect was measured, recording the position of the prism to determine the distance, slope, and height difference from the station. The prism was moved along the transects and measurements were made at points where the slope visibly changed to record changes in elevation. Any discrepancies between initial starting points for Total Station transects and ghost crab transects were corrected for in data analysis.

Soil Cores

At a random point within each zone, along each transect, a soil core was taken using a small PVC corer of known volume (59.54 cm^3). After a burrow was dug, the corer was inserted perpendicular to the side of the burrow 5 cm below the sand surface. The corer was then removed and sediment placed in labeled bags. Samples were later analyzed for particle size distribution by first drying samples for 24 hours at 105 degrees Celsius then sieved in a RoTap machine for 15 minutes using a sieve tower varying in diameters from 4 mm to 0.063 mm. Samples were then weighed to calculate bulk density and the relative distribution of particle sizes (Appendix C, Table 2). Particle sizes were grouped as gravel (diameter >2.1 mm), very coarse to

coarse sand (0.51-2 mm), medium sand (0.26-0.5 mm), and fine sand (0.05-0.25 mm) using the Udden-Wentworth scale (Wentworth 1922).

Statistical analysis

T-tests were used to determine if the number and density of ghost crab burrows was influenced by the presence of ORVs. An unpaired t-test was used to compare differences between all sampling locations while a paired t-test was used to compare differences between sections of the same beach area that were either open or closed year-round to ORV access. An unpaired t-test was also used to determine whether or not the number and density of ghost crab burrows was influenced by the presence of a wrack line. ANOVA tests determined if location and island width affected ghost crab burrow numbers and density, and if there were differences in soil texture between beaches. T-tests and ANOVA tests were completed using SAS against using a critical value $\alpha=0.05$, which means that when tests returned p-values greater than 0.05, no correlation between the variables was found. Linear regression was used to see if soil bulk density, sand composition, and beach profile had a linear effect on the numbers and density of ghost crab burrows in a given area. R^2 values and p-values from the linear regression were used to test hypotheses.

Results

The number and density of ghost crab burrows was found to not be significantly influenced by human presence in the form of ORV access for all beaches (number of burrows p=0.4757, density of burrows p=0.71) and for individual beaches (number of burrows: Bodie Island p=0.9620, Little Kinnakeet p=0.7343, Salvo p=0.0521; density of burrows: p=0.7). Wrack line likewise did not have a significant effect on number of ghost crab burrows (p=0.14) or the density (p=0.106)

The results of linear regression analysis determined that beach profile did not influence the number of ghost crab burrows in a given location (R^2=0.0056). Bulk soil density had no significant observable effect (p-value=0.7807, R^2=0.0015). Linear regression on the influence of the mean relative density of each size category on the number of ghost crab burrows was also found to be insignificant (gravel, p-value=0,9759, coarse to very coarse sand, p-value=0.9355; medium sand, p-value=0.8970; fine sand, p-value=0.9018; R^2 for all tests was less than 0.0001).Linear regression tests on burrow density and beach profile (R^2=0.001), bulk soil density (R^2=0.065), and sand composition (R^2 values between 0.0002 and 0.046) showed no significant relationship.

Analysis revealed there were no significant differences in bulk density and mean relative density of sediment size at each beach (bulk density, p=0.3683; gravel, p=0.1697; coarse to very coarse sand, p=0.2218; medium sand, p=0.1099; fine sand, p=0.1320). There was no significant difference in beach profile slope between locations (p=0.4206). There was no observed difference in ghost crab density between zones (p<0.13) and between beaches (p=0.108). While zone had no observed influence on the number of burrows, there was a relationship between the number of burrows and beach location (zones, p=0.1907; beaches, p<0.0001; Figure 7). Bodie

Island beaches had significantly more ghost crab burrows. Mean width of the island at sample locations also influenced the number of ghost crab burrows demonstrated a positive correlation between increasing width and number of burrows ($p=0.0003$) while there was no relationship between width and density of burrows ($p=0.18$). *Raw data can be found in Appendix C.*

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Discussion/Implications

Our results were unexpected given the results from the studies that provided the basis for our methodology. Previous studies have found a negative correlation between human presence and ghost crab burrow abundance (Lucrezi 2008; Moss and McPhee 2006; Noriega and Smeunix 2008; Schlacher et al. 2007; Tureli et al. 2009;Valero-Pacheco 2007). Even though there is some question about the accuracy of estimating ghost crab populations by the number of burrows, there is well- documented evidence that the number of burrows correlates to the level of human impact on the beach (Silva and Calado 2013). We have contradictory findings indicating that human impact may not be the only driver in ghost crab populations or behavior in the on the beach berm since there was no significant difference in number of burrows between paired beaches with ORV access and pedestrian only access. We also found that sand composition, beach slope, proximity to the ocean, and wrack line presence did not influence the number of observed ghost crab burrows.

The finding that ghost crab burrow density was not significantly different between site locations and width of the island implies that the study area size is a driver of ghost crab abundance. Comparing ghost crab burrow density takes into account the differences in magnitude of the study area due to differences in the berm width and transect length. We found that ghost crabs populate CHNS at a uniform density, but because there are differences in the width of the island at different locations, we observe larger numbers of ghost crab burrows at some locations.

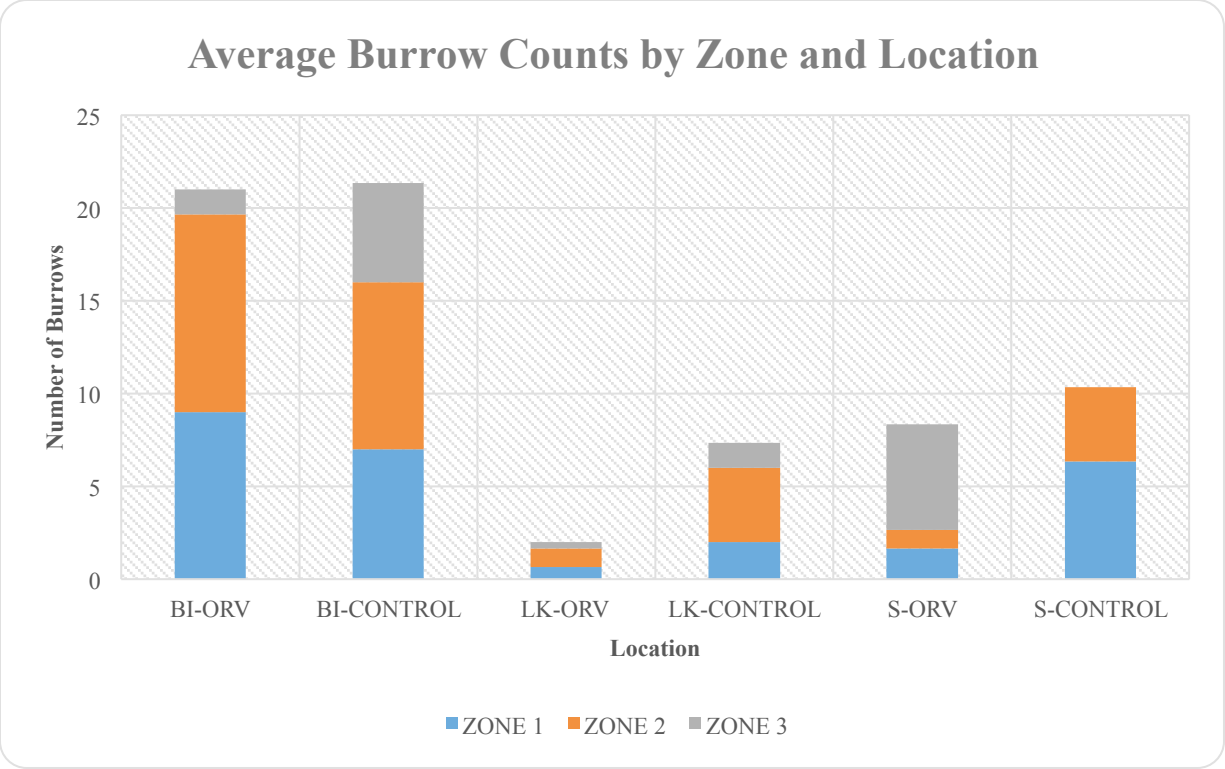

Fig 8. Bar chart showing average number of burrows rounded to nearest integer per zone at each location. Control beaches were pedestrian access only while ORV were allowed annual access. The bar graph shows significantly larger count at both Bodie Island locations compared to Salvo and Little Kinnakeet (Appendix C, Table 2).

Bodie Island had a width >2000 m and had significantly more ghost crab burrows, implying that there may be a relationship between island morphology and ghost crab populations. Finding that the width of the island where the beach is located has a role in the number of ghost crab burrows observed implies that there are variables that impact ghost crabs outside of the dry sand beach. Many of the predator control efforts have focused on the beach, where sea turtle and piping plover nests are usually found, yet our results indicate that predator populations are influenced by other larger-scale geographical factors located elsewhere. Further studies are needed to better define the relationships of ghost crab burrows with non-beach habitat areas outside of the beach berm.

A confounding factor in our study is the closure of CHNS to public driving during the government shutdown in October, 2013. It is possible that our results showing a uniform burrow density are a result of opportunistic re-population of abandoned ranges by ghost crabs in the absence of human impact during those two weeks. Since the Park Service closes beaches to public driving and pedestrian access when plovers are nesting, it would be of great interest for future research to compare changes in ghost crab burrows abundance and density before and after beach closures to driving. A study such as this will reveal whether the pattern of island width influence and location impacting ghost crab abundances that we observed was a result of the closure or if this is a permanent characteristic of CHNS.

The finding that areas outside the berm may drive predator abundance and distribution could be applicable to other predators as well. Cape Lookout National Seashore focuses predator management on mammalian predators, particularly raccoons. Researchers at NC State University have investigated geographic distribution and predation habits of raccoons on the Southern Core Banks, which is ecologically similar to CHNS and provides habitat to American oystercatchers, piping plovers, and sea turtles (Parsons 2013). In one study, researchers found that few raccoons were responsible for predation on endangered species and that the majority of raccoons who fed on birds were consuming birds endemic to marsh areas, not sandy beaches (Parsons 2013). There was no evidence of turtle or turtle egg consumption (Parsons 2013). Additionally, researchers found that raccoons spent their time primarily in salt marsh habitats but adjusted their range to environmental conditions (Parsons 2013). Information from this study and our findings support the idea that predator population and distribution is affected by factors that extend beyond the areas in immediate proximity to the endangered species' reproductive ranges and the current predator management focus.

Social Science Research

Introduction

This research aimed to better understand the relationship between the residents of the Outer Banks and the predator management program at CHNS. To do this, the following research questions were posed:

- What do people know about predator management?
- Where do people get their information about issues regarding CHNS?
- What are people's attitudes and beliefs about predators and predator management on CHNS?

To answer these questions, surveys were created and administered to residents of the Outer Banks. The data collected from these surveys was entered and coded into a singular database and then statistical tests were run to interpret the information and identify relationships. The goal of this research is to clarify the public's stance on predator management and factors that influence that stance.

Methods

In order to investigate public attitudes and beliefs regarding predator management on CHNS, a combination of qualitative and quantitative research methods were used. Qualitative methods (i.e., methods employing the use of open-ended or exploratory questions) were combined with quantitative methods (i.e., methods employing the use of close-ended, scaled questions) in a step-wise fashion in order to focus research on the salient aspects of the predator management issue (Creswell 2003).

Quantitative methods are useful for providing an overview of public attitudes and beliefs, and the relationship between these attitudes and beliefs and other variables such as where people get their information, how involved they are in the issue, and their level of knowledge about the issue. However, one major drawback to quantitative methods is that they are inflexible; once a survey is created and deployed the questions cannot be altered (Schaeffer and Presser 2003). For this reason, care must be taken to make sure survey questions are correctly worded and address the salient aspects of the issue.

The qualitative methods used (e.g., interviewing issue experts or key representatives) are exploratory and adaptive, thereby allowing the respondent the freedom to talk about the topics that are more interesting and significant to them personally. Combining qualitative and quantitative methods helps to formulate quantitative survey questions by reducing the initially broad range of topics to the topics of greater interest, which in this case was the relationship of attitudes and beliefs to variables such as information sources, involvement, and knowledge on the issue. Qualitative methods also provided insights into the appropriate wording for quantitative survey questions by revealing the typical language used by stakeholders.

Qualitative Research

Semi-structured personal interviews with CHNS stakeholders were conducted in order to better understand stakeholder values, beliefs, and attitudes. These interviews were conducted with representatives from the National Park Service, North Carolina Beach Buggy Association, and Southern Environmental Law Center (SELC). These groups were chosen because they represent three main aspects of all national park service policy issues: natural resource management (NPS), recreation access (NC Beach Buggy Association), and legal mandates and resource protection (SELC).

Sampling Procedure

Qualitative interviews were conducted in September 2013. A total of ten questions were asked of each interviewee. Questions focused on topics such as management of CHNS, endangered species on CHNS, and public perception of the issues regarding CHNS (Appendix D). Audio recordings were made of each interview and were later transcribed to allow for analysis and comparison.

Analysis

Using the process of grounded theory (Ezzy 2002), interviews were "coded" for further analysis. This process involved analyzing responses for similar phrases among all the respondents. Several key codes that came up in valuing the seashore were its wide-open space and its wildlife. These codes were consistent among all respondents, which indicated that similarities exist between seemingly opposing stakeholders. Additional similarities included the values of understanding the dynamic nature of the Seashore, appreciation of its wilderness, and a feeling of escape provided by the Seashore. While these values were similar among the

stakeholders, there was a clear divide in the beliefs about management of the Seashore that stemmed from these values. This presented the opportunity to inquire about the relationships between different variables that affect the beliefs of stakeholders.

Quantitative Research

Results from qualitative interviews were used to inform variables for quantitative survey questions. The variables that we selected for our survey were:

1. Information source (where do people get their information about issues regarding CHNS?)
2. Knowledge (what do people know about predator management?)
3. Acceptability (what are people's perceptions of threatened and endangered species management on CHNS and what is their level of acceptance?)
4. Involvement (do people actively seek out information or participate in discussions/forums on CHNS issues?)
5. Demographics (what is the respondent's education level and area of residence?).

Population Surveyed

The respondents for the quantitative survey were drawn from areas spanning from Nags Head to Hatteras Island, as well as a more general population with access to the web-based survey link. These areas were chosen because we were interested in comparing results from those who live on the Seashore (represented by respondents from areas south of the Bonner Bridge) and those who may access the Seashore but do not live on it (represented by respondents from areas north of the Bonner Bridge).

Sampling Procedure

Quantitative surveys were deployed using three different strategies: mail-back, personal-intercept, and the Internet. A total of 264 paper surveys were deployed on October 22nd using mail-back and personal-intercept deployment strategies. Mail-back surveys were deployed by leaving paper versions of the survey at houses in the survey area, and included an addressed and stamped envelope. Houses were chosen at random by driving through neighborhoods in the study area and selecting houses that appeared to be occupied.

Personal-intercept surveys were deployed by approaching potential respondents at public locations within the study area, such as Food-A-Rama, The Graveyard of the Atlantic Museum, and Burrus Red & White Supermarket. The primary purpose of the personal-intercept deployment strategy was to allow for researcher contact with study participants in order to better understand reactions to the survey instrument not captured by the survey questions.

A web-based version of the quantitative survey was also developed using the Qualitrics survey program. A link to the web survey was printed onto small business cards. These cards were left at various businesses north and south of the Bonner Bridge on the same day that mail and intercept surveys were distributed. The link was also posted to the online forum on the Island Free Press and the Outer Banks Voice webpages.

Analysis

Quantitative data were analyzed using Statistical Package for the Social Sciences (SPSS) version 21.0. Three basic functions were performed on the data, (1) summary statistics such as frequencies, means, and standard deviations, (2) independent sample *t*-tests testing for the differences between the means of two groups, and (3) analyses of variance (ANOVAs) comparing the differences between the means of more than two groups.

Results

Data was collected from 531 completed surveys. This data was analyzed and used to produce summary statistics and three statistical comparisons. The first was a two-tailed independent *t*-test comparing level of knowledge about predator management, attitudes towards predator management in general, and acceptability of the CHNS predator management program with whether people live or visit north or south of the Bonner Bridge (Table 1).

The second statistical comparison was a one-way analysis of variance (ANOVA) looking for differences between knowledge about the CHNS predator management program (represented as a low, medium, or high level of knowledge) and level of education, attitudes towards predator management, acceptability of the CHNS predator management program, confidence in how much they know about predator management, and level of involvement in CHNS issues (Table 2).

A second ANOVA was applied to look for differences between levels of involvement in CHNS issues (represented as a low, medium, or high level of involvement) and attitudes towards predator management, and acceptability of the CHNS predator management program (Table 3).

Table 1
Summary of differences between respondents that live or visit north of the Herbert C. Bonner Bridge and respondents that live or visit south of the Herbert C. Bonner Bridge.

	Live / Visit North		Live / Visit South		
Variable	*M*	*SD*	*M*	*SD*	*t*-value
Level of knowledge about predator management.	2.4	1.0	2.5	0.9	-0.9
Attitudes towards predator management.	-1.1	1.3	-1.4	1.2	-2.4*
Acceptability of predator management in CHNS	0.2	1.5	-0.7	1.6	3.9*

*t-value significant at p-value < 0.05

Table 1 summarizes the *t*-test comparing variables based on location (either north or south of the Bonner Bridge). This test compared three variables: level of knowledge, attitudes towards predator management, and acceptability of predator management on CHNS.

Level of knowledge was calculated after re-coding answers to survey questions 3 and 5 (Appendix E). Responses to question 3a were not used in calculating the level of knowledge. Knowledge scores ranged from 0 to 4. Those who answered two or fewer questions correct were classified as having low knowledge, three correct answers was classified as medium knowledge, and four correct answers was classified as high knowledge. Refer to Appendix F for a full summary of responses to the predator management knowledge questions (survey questions 3 and 5).

The mean (*M*) of responses to survey question 7e were used to summarize attitudes toward predator management on a scale from -2 to +2 (Appendix E). A negative score indicated a negative attitude toward predator management, whereas a positive score indicated a positive, or more accepting, attitude regarding predator management. The acceptability of predator management mean (*M*) was calculated on a -2 to +2 scale using results from survey question 7a.

A negative score indicated that respondents thought predator management was unacceptable on CHNS and a positive score indicated acceptability. If a *t*-value has a significance value (p) less than 0.05, it is considered statistically significant.

Table 2
Summary of differences between respondents with a high, medium, or low level of knowledge about predator management on CHNS.

	Low Knowledge		Medium Knowledge		High Knowledge		
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*
Level of education	4.5	1.5	4.8	1.5	4.9	1.6	2.5
Attitudes towards predator management.	-1.2	1.2	-0.9	1.5	-0.6	1.5	6.4*
Acceptability of predator management on CHNS.	-0.6	1.5	-0.2	1.6	0.1	1.5	6.0*
Confidence in knowledge about predator management.	1.5	0.8	1.4	0.8	1.3	0.8	1.4
Level of involvement in CHNS issues.	2.8	4.1	2.5	4.2	2.3	3.8	0.6

*$p < 0.05$

Table 2 summarizes one-way analysis of variance (ANOVA) comparing research variables to low, medium or high levels of knowledge. The following variables were compared: level of education, attitudes towards predator management, acceptability of the CHNS predator management program, confidence in knowledge of predator management, and level of involvement in CHNS issues.

Responses to survey question 9 were used to calculated level of education, where the mean (*M*) ranged from 1 to 7 (7 signifying the highest level of education) (Appendix E). Survey question 7d was used to summarize attitudes toward predator management on a scale from -2 to +2 (Appendix E). A negative mean (*M*) indicated a negative attitude, whereas a positive mean indicated a positive attitude toward predator management. Acceptability was measured by results from survey question 7a on a scale from -2 to +2. A negative mean (*M*) indicated the belief that

predator management on CHNS is unacceptable, whereas a positive mean indicated that respondents were more accepting of predator management on CHNS. Confidence in knowledge mean (*M*) is based on responses to survey question 4, ranging from 0 (not at all confident) to 3 (very confident) (Appendix E). Level of involvement is based on survey question 2d, with a mean (*M*) ranging from -3 to +3. A negative score indicated that respondents do not actively participate in forums regarding predator management; a positive score indicated greater involvement. A p value less than 0.05 indicates that differences in means are statistically significant.

Table 3
Summary of differences between respondents with a high, medium, or low level of involvement about predator management in CHNS.

	Low Involvement		Medium Involvement		High Involvement		
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*
Attitudes towards predator management.	-1.0	1.4	-1.2	1.3	-1.6	1.0	6.8*
Acceptability of predator management in CHNS.	-0.1	1.6	-0.3	1.6	-0.7	1.6	4.1*

*$p < 0.05$

Table 3 summarizes one-way analysis of variance (ANOVA) comparing level of involvement to attitudes of predator management and acceptability of predator management on CHNS. Involvement was measured using results from survey question 2 b, 2c, and 2d (Appendix E). Each question response scaled from -3 to +3; responses to the three questions were added together to create an involvement score that ranged from -9 to +9. Scores ranging from -9 to 0 were considered to have a low level of involvement. Scores from 1-4 were considered medium involvement. Scores from 5-9 were constituted high levels of involvement. Survey question 7e

was used to summarize attitudes toward predator management on a scale from -2 to +2 (Appendix E).

Table 4
Summary of differences regarding level of knowledge between using and not using certain information sources.

	Knowledge		
Information source	*M*	*SD*	*t*-value
OBX Voice			0.1
Used	2.5	1.0	
Did not use	2.5	0.8	
Island Free Press			2.3*
Used	2.6	0.9	
Did not use	2.4	0.9	
Social Media			-1.2
Used	2.4	0.8	
Did not use	2.5	1.0	

*t-value significant at p-value < 0.05

Table 4 summarizes knowledge based on the top three information sources identified by survey question 1 (Appendix E). Knowledge mean (*M*) ranges from 0-4, with 0 being low knowledge and 4 being high knowledge. The table compares knowledge mean for those who do and do not use the Outer Banks Voice, Island Free Press, or Social Media as their top information sources.

Research question 1: How much do people know about predator management?

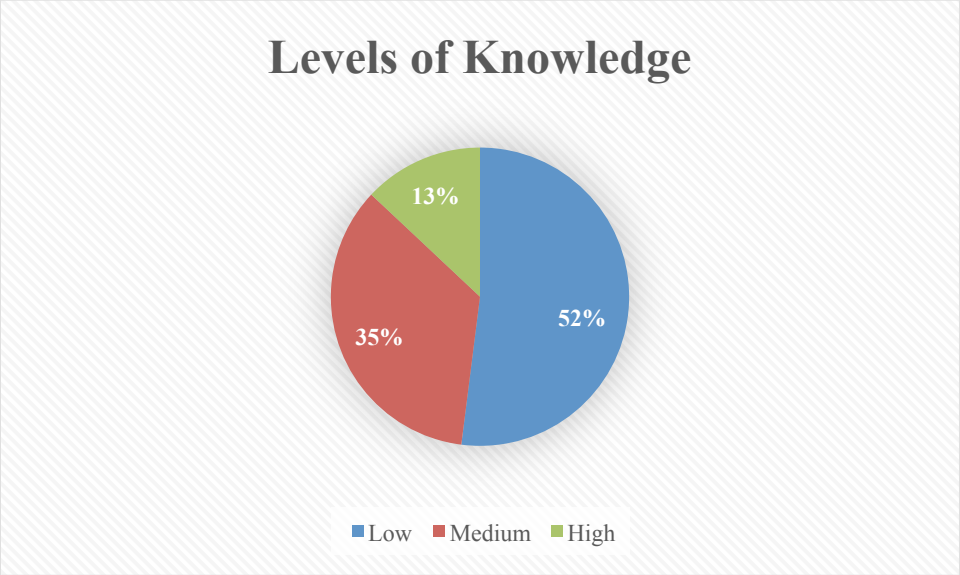

Figure 9. Summary of respondents' levels of knowledge by percentage. Low knowledge indicates that respondents answered 2 or fewer knowledge questions correctly; medium knowledge indicates that respondents answered 3 knowledge questions correctly; and high knowledge indicates that respondents answered 4 knowledge questions correctly. Knowledge questions were survey questions asking respondents about specifics of the predator management program on CHNS.

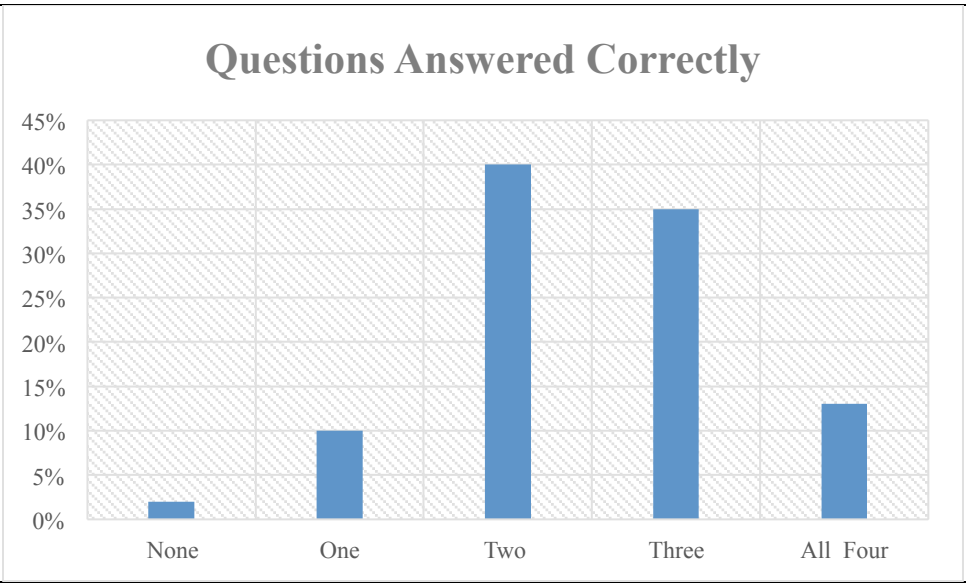

Figure 10. Summary of the number of knowledge questions answered correctly by percentage. Questions used for this data tested respondents' knowledge of the predator management program on CHNS.

Results show that almost half (48%) of respondents answered at least three question related to predator management on CHNS correctly (Figure 10). The question that most respondents answered correctly was "The National Park Service uses only lethal traps," which is false. The NPS uses nonlethal foot clamp traps to target most mammalian predators and uses lethal traps for mink. The question that most respondents answered incorrectly was "The National Park Service employs several full-time trappers on Cape Hatteras National Seashore," which is also false—the NPS only employs one full-time trapper.

As shown in Table 1, level of knowledge was not dependent on where people live or visit. On average, people that live south of the Bonner Bridge do not know more about predator management on CHNS than people who live north of the bridge.

Research question 2: Where do people get information about issues regarding CHNS?

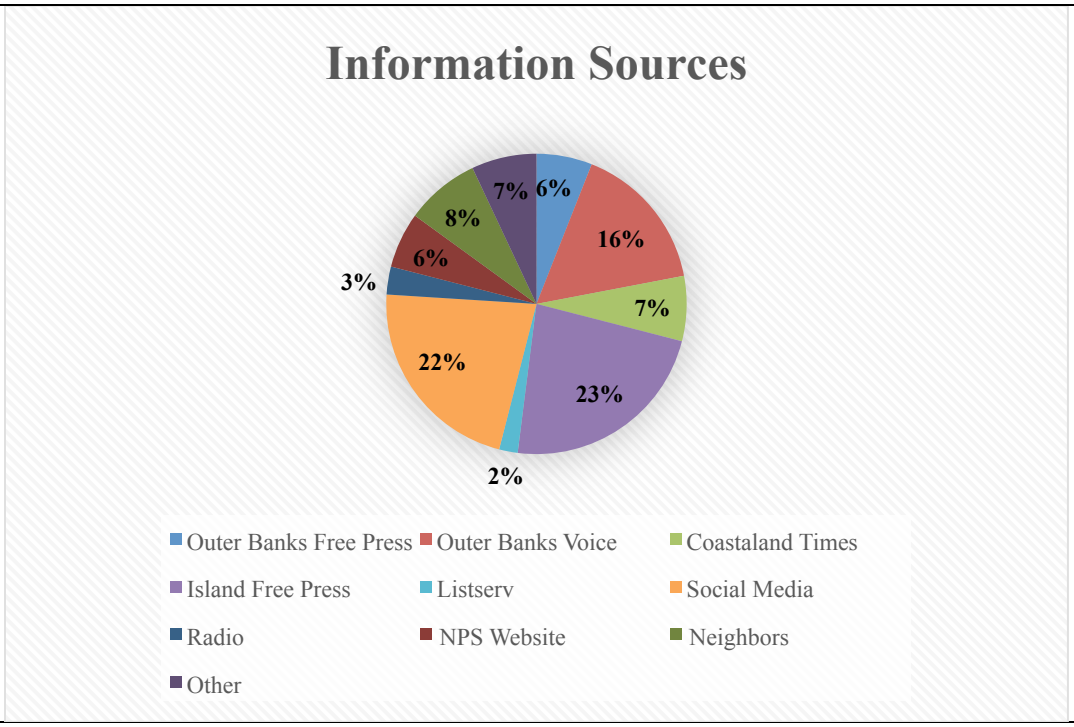

Figure 11. Summary of responses to survey question #1, "Which of the following do you rely on the most for information about issues related to Cape Hatteras National Seashore? (Check up to three)."

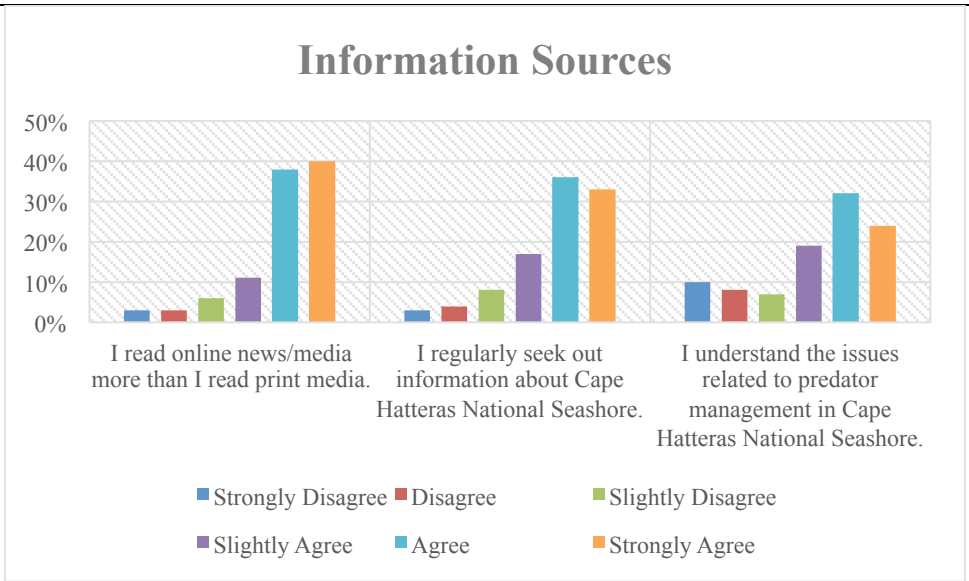

Figure 12. Summary of responses by percentage to questions regarding information sources and level of involvement in CHNS issues.

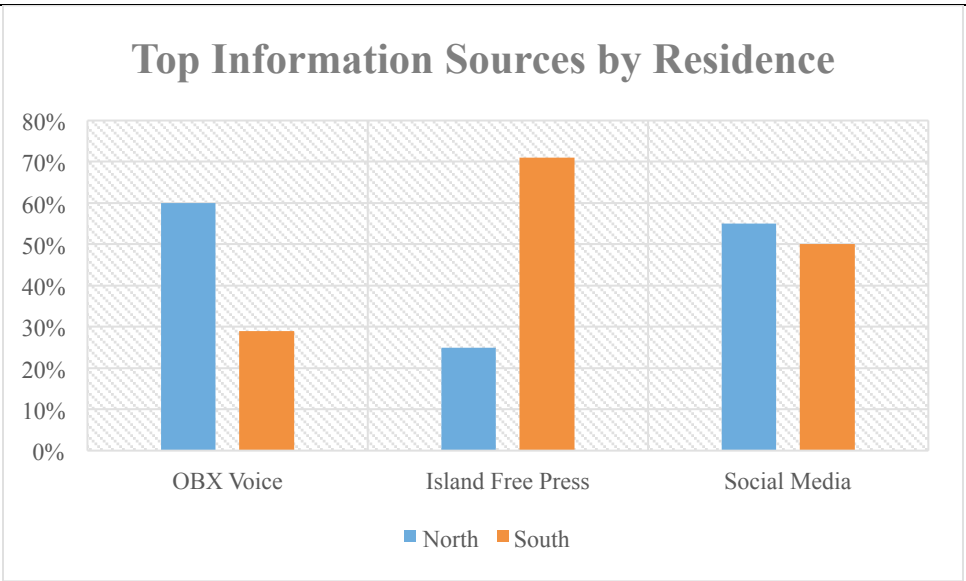

Figure 13. Comparing responses by percentage of the top 3 information sources based on residency. North is referring to living north of the Bonner Bridge and south is referring to living south of the Bonner Bridge.

Figure 11 summarizes the most chosen information sources with Island Free Press, The Outer Banks Voice, and Social Media being the most utilized. Data gathered from the summary of information sources (Figure 12) shows that the majority of people read online sources more than they do print. Information sources differed depending on where respondents live. For residents living south of the Bonner Bridge, Island Free Press was the most popular information source, but for residents living north of the Bonner Bridge, the Outer Banks Voice was the most popular news source. Social media was equally popular regardless of where respondents live (Figure 13).

In addition, it appears most people agreed that they seek out information related to CHNS. Respondents also agreed that they understand the issues dealing with predator management on CHNS. In contrast, there was some disagreement when questioned about their participation in any CHNS forums (Table 2).

Research Question 3: What are people's belief and attitudes towards predators and predator management on CHNS?

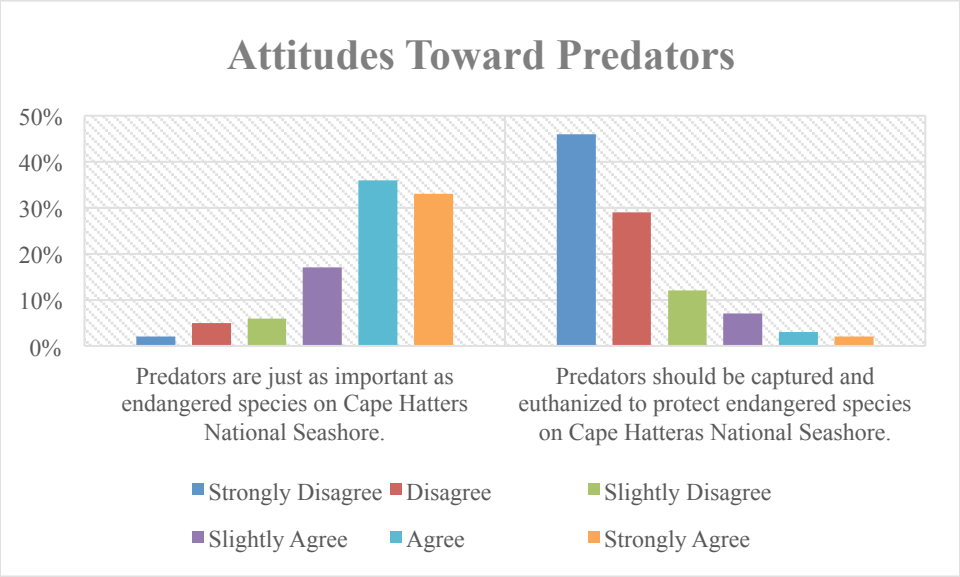

Figure 14. Summary of responses by percentage to questions evaluating attitudes towards predators. The question evaluates how respondents value predators relative to endangered species.

Figure 14 illustrates attitudes towards the value of predators relative to endangered species. The great majority of respondents believe that predators are just as important as endangered species on CHNS. The majority of respondents did not agree that predators should be euthanized to protect endangered species on CHNS, nor did they find it acceptable to kill animals at all to protect endangered species (Figure 15). Overall, people seemed to value predators as much as endangered species.

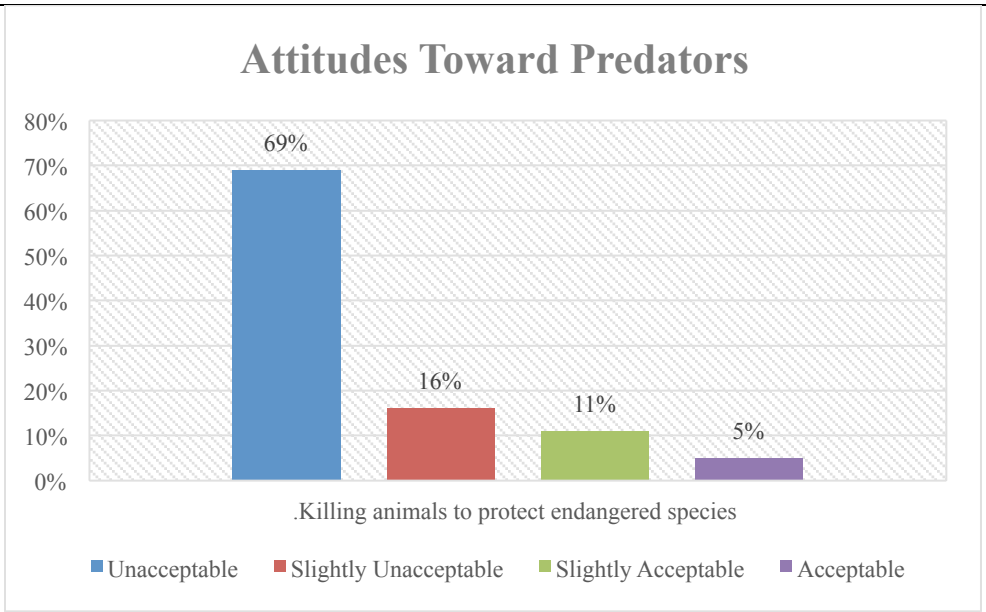

Figure 15. Summary of responses by percentage to survey question #7e, "Killing animals to protect endangered species." The question evaluates how respondents value predators relative to endangered species.

There was a significant (p=.007) relationship between residency and how people value predators in relation to endangered species. More people who live south of the Bonner Bridge agreed that predators are just as important as endangered species than people who live north of the Bonner Bridge.

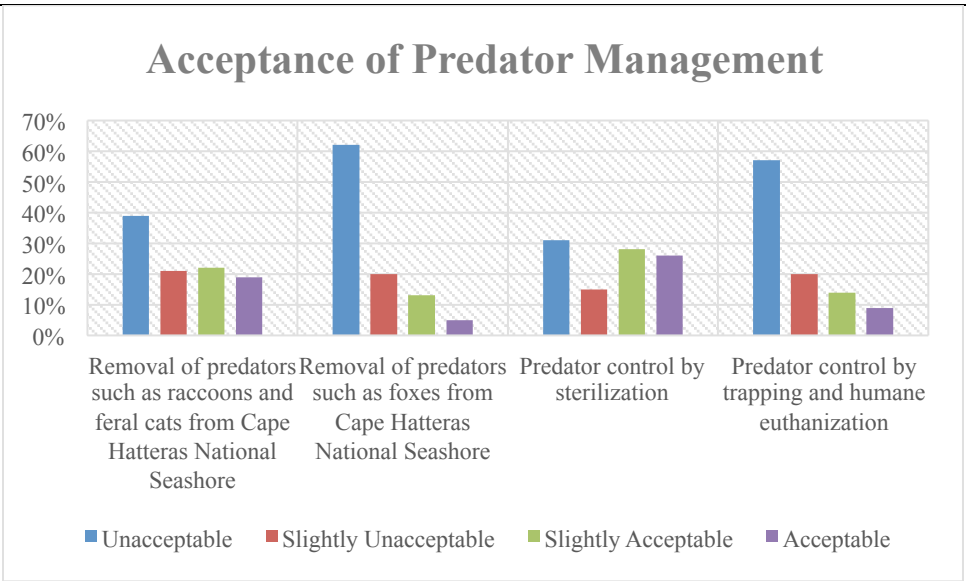

Figure 16. Summary of responses by percentage to survey question #7a-d evaluating respondents' acceptability of different predator management strategies.

To measure acceptability of predator management, respondents were asked to label several management strategies as "unacceptable", "slightly unacceptable", "slightly acceptable", or "acceptable". The most prevalent response was "unacceptable" for all management options shown in Figure 14 except "Predator control by sterilization." Sterilization was found to be slightly more acceptable than other management strategies.

When comparing involvement and acceptability (Table 3), people who are less involved in CHNS issues tend to be more accepting of the predator management program, although overall, respondents were not accepting of the program.

It was also found that those with less knowledge of the predator management program tended to view it less favorable, and those who were more knowledgeable tended to be more accepting of it. The results yielded positive means, which indicates acceptance, exclusively from respondents with medium and high levels of knowledge for the survey question that evaluated level of acceptance for predator control by sterilization. Likewise, the mean result for the question evaluating acceptance of the removal of predators such as raccoons and feral cats from

CHNS were also positive for respondents with a high level of knowledge. In short, those who knew less about the predator management program were less likely to accept it than those who knew more about the program.

Residency was also shown to have an effect on acceptability. Respondents who live south of the Bonner Bridge tended to be less accepting of predator management than people who live north of the bridge, although in both regions killing predators is unacceptable overall.

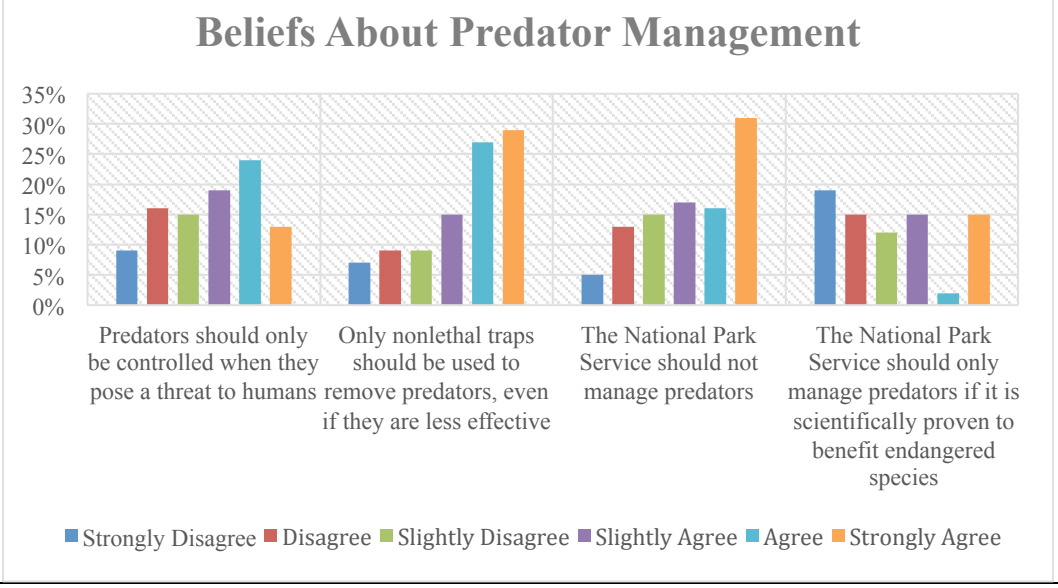

Figure 17. Summary of responses by percentage to survey questions #7c-f evaluating beliefs about predator management.

The survey data revealed that participants have negative perceptions of predator management. The majority of survey participants (about 67%) agree that the NPS should not mange predators (Figure 17). With regards to residency, residents south of the Bonner Bridge agree more than those north of the bridge that the NPS should not manage predators. Respondents were almost evenly divided about the notion that the NPS should manage predators

to benefit endangered species. It should also be noted that respondents were more likely to agree with predator management when managed predators pose a threat to humans.

Regardless of their level of knowledge about the program, a majority of respondents do not support the capture and euthanization of predators to protect endangered species. In general, respondents with all levels of knowledge agreed that only non-lethal traps should be used despite their lack of effectiveness. Overall, there were negative perceptions of predator management on CHNS.

Discussion

Through the qualitative interviews we established that while individuals on the Outer Banks have similar values regarding CHNS, beliefs and attitudes stemming from these values are very different. We developed survey questions that addressed these aspects of the cognitive hierarchy so we could better understand how similar values can still lead a diverse range of beliefs, attitudes, and behaviors. More specifically, our research questions were designed to better understand what those beliefs and attitudes are with regard to predator management. We now understand that while there is a common appreciation for wildlife on the Seashore, most people believe that predator management to protect endangered species is unacceptable. Similarly, we understand that most people have a negative attitude towards management of animals in general. We can now make better inferences about how values actually shape these beliefs and attitudes. This allows us to better understand the relationship between individual behaviors and predator management.

Research Question 1: How much do people know about predator management?

The results of the survey reveal that, based on the quantification of knowledge used in this study, overall knowledge of predator management is relatively low and level of knowledge is not affected by demographics or level of involvement. While there is no statistically significant relationship between levels of knowledge and involvement, those who have lower knowledge tend to report being more involved in CHNS issues. In theory, those who are more involved should be more likely to know more about the program because they are actively seeking out more information. However, results show that people who are more involved do not know more or less than people who are less involved. This may indicate that people who are

more involved are receiving some misinformation about the predator management program. In other words, the information that some people seek out about the program does not always increase their level of knowledge, indicating that the information they find might either be incorrect, or at least not related to the aspects of predator management asked about in the survey. The low levels of confidence that many people have in their answers to questions testing knowledge of the program suggest there might be a lack of information available from reliable sources (Table 2). The availability of more valid and less conflicting information could increase confidence levels regarding knowledge of the program. Another interesting, though not statistically significant, relationship is between the level of knowledge and confidence. Those with lower levels of knowledge tended to be more confident in the correctness of their answers than those with higher levels of knowledge (Table 2). This again points towards the possible existence of misinformation, as those who answered incorrectly were more confident in their answers than those who answered correctly.

A promising finding in these comparisons was the lack of relationship between demographic factors and knowledge. There was no statistically significant difference in levels of knowledge between, for example, those with a master's degree and those with a high school education. This suggests that knowledge can be improved in all areas, regardless of residence or education levels. It is also promising to find that across all groups, many people report that they seek out information about CHNS (Figure 12). The high level of desire to be informed on issues regarding CHNS could facilitate the distribution of accurate information by the NPS and other agencies.

Research Question 2: Where do people get information about issues regarding CHNS?

As shown above, results indicate that web sources are more popular among respondents than print sources, as 89% of people agreed that they use online more than print sources (Figure 12). This indicates that the Internet may be a better vehicle for spreading information than print sources. However, most of the people who completed the survey did so online, creating a bias for this question. Nevertheless, it is clear that many people in the area use the Internet. Data indicates that there is no significant relationship between the most popular sources of information and the level of knowledge that people using these sources displayed. Since users of all information sources show similar levels of knowledge about the predator management program, information could be distributed through all sources to increase knowledge.

Research Question 3: What are people's belief and attitudes towards predators and predator management on CHNS?

This research found that the majority of people expressed negative attitudes towards the killing of predators for the benefit of endangered species, and towards predator management in general. The data shows that most people value predators and endangered species equally and generally disagree that it is acceptable to kill animals for the protection of endangered species (Figure 14 and 15). The ESA is based on the premise that threatened and endangered species should be more protected than other species because they are at a higher risk of extinction. Our data indicates that many respondents disagree with this belief, at least to some degree. Our discussions with community members revealed that some people find killing animals for the benefit of endangered species unacceptable because they do not think humans should choose which animals live and die. Others see predator management as a "necessary evil" because it is

meant to protect endangered species and maintain biodiversity. The results from the survey indicate that most people have negative views about it, and do not believe it is necessary.

Interestingly, many respondents found it acceptable to remove raccoons and feral cats from CHNS but few found it acceptable to remove foxes (Figure 16). It is unknown as to why some predators are preferred to others, but it may have to do with how these animals interfere with the personal lives of respondents, or how natural they are to CHNS. This information is valuable because it demonstrates that some people do not find all predator management actions unacceptable. While the majority of respondents think it is wrong to kill animals to protect endangered species, some find it acceptable to kill certain animals. This indicates that the protection of endangered species may not be the only reason why some people find predator management actions acceptable.

Based on the general public perception of predators, it is unsurprising that the majority of people find it unacceptable for the NPS to trap and euthanize predators (Figure 16). On average, people who live south of the Bonner Bridge are more likely to believe that the NPS should not manage predators at all, even if it is proven to benefit endangered species, than people who live north of the bridge. This may indicate that people who live closer to CHNS are more affected by consequences of management actions. Strategies to improve acceptability could focus on residents living south of the Bonner Bridge since they are less accepting of the program. Likewise, since the most popular information source for residents living South of the Bonner Bridge is Island Free Press, information could be most effectively distributed through this source.

Results also showed that people who reported being more involved in the issues relating to CHNS were less accepting of predator management in practice (Table 3). This could indicate

that people who dislike predator management are more involved because they feel strongly about their views, or that higher involvement causes lower acceptability. Since there was no relationship between level of involvement and level of knowledge, those who are highly involved are not necessarily highly knowledgeable on the issue. Highly involved people who are not highly knowledgeable on the issue may be spreading inaccurate information and contributing to misinformation regarding the predator management program. Strategies to quell misinformation and increase acceptance could target people who are very involved and have a relatively large influence on overall support of the program.

Higher levels of knowledge regarding predator management related to more acceptance of the program (Table 2). Likewise, results show that all groups tend to agree to some extent that predators should not be managed, but groups with a higher level of knowledge agree less (Appendix F). This may come from a better understanding of the extent of the program. If the NPS is interested in increasing acceptability, education is a strategy they might pursue.

It is important to note that the survey did not explicitly test for why people do not approve of the predator management program; it only tested for whether or not they approve. The public's overall disagreement of predator management could be partially a reflection of negative attitudes towards the NPS and towards preferential treatment of endangered species. This negative perception is likely rooted in the recent implementation of ORV regulations and other management actions. The belief that these NPS management actions restrict the rights of Outer Banks residents and visitors could influence their perception of the predator management program, which is another management action. Also, the frustration that many people feel about the measures taken to protect endangered species has resulted in a disdain for protected species

in general. This could be a reason for why they are not valued more than other species, and why protective measures are found to be unacceptable by the majority of the public.

Assumptions & Limitations

Since we are students living in the Outer Banks for one semester, we had a short amount of time to complete our research. Due to time restrictions, we were not able to pre-test the survey before we deployed it to the selected populations. Pre-testing the survey, or administering it to a small sample size before deployment, would have allowed us to identify parts that needed clarification or further editing. When we did administer the survey, much of our sample size came from online respondents. This could have distorted the results of the question asking if the respondent relies more on print or online news sources, because those who rely more on online sources were probably over represented. The distribution of information sources most frequently used also could have been distorted since we posted the link on OBX Voice and Island Free Press. Those who use these two sources were probably over represented, while those who use other sources such as print newspapers or social media could have been underrepresented. With more time, we could have made our survey available on every type of information source so that results were better distributed.

Another limitation relates to how the questions were written. A question is only valid if respondents answered the question we intended for them to answer. The wording of some of the survey questions may have allowed for various interpretations, and responses may have varied accordingly. For example, respondents may have interpreted the statement "The NPS should not manage predators" as asking if they think the NPS should be the agency that manages predators, or if they think that *any* agency should manage predators. Likewise, the statement "Removal of

predators such as raccoons and feral cats from Cape Hatteras National Seashore" could have prompted inconsistent responses. Since respondents can be opposed to removing one of these animals but not the other, they may have struggled to answer the question truthfully. This makes it difficult to ensure an accurate interpretation of the data.

Other limitations are based on the way response options were presented. In the knowledge section we did not include a "don't know" category, so respondents had to choose either true or false. Therefore, people who did not know the answer had to guess. We then measured levels of knowledge, and found that knowledge regarding predator management is relatively low. We inferred from this finding that people are misinformed about the topic. However, since some people guessed and do not actually believe the statement is true or false, some of the perceived misinformation may actually be instances of people guessing. We also never defined predator management because we wanted to test people's knowledge of it. By not defining the term, respondents may have answered some questions differently than they would have if they understood what we were referring to when we said predator management.

Implications

The NPS is a federal agency with goals and purposes set at the national level. While the implementation of recovery plans for endangered species can be tailored to best fit the regions in which they apply, the overarching goals of the NPS and the ESA are meant to apply to all regions. Creating a principal framework for management is logical considering how difficult it would be to have separate regulations and governing agencies for each region of the United States. However, federal legislation does not necessarily provide specific strategies to ease the

tension among the local communities that depend on natural resources and endangered species habitat for their culture and economy.

The Outer Banks depends on the recreational use of the beach for both cultural and economic reasons, and the actions of the NPS can often seem to interfere with the ability to take full advantage of its resources. While the local branch of the NPS is required to meet national goals, community members feel like their opinions and rights are neglected in the process. The goal of this research was to explore public opinions, attitudes and beliefs regarding the predator management program, provide insight into the relationship between CHNS management and the public, and identify possible strategies for improving this relationship.

Research results provide insight into the public view that the predator management program is seen as a "necessary evil." Those who are supportive of the program do not necessarily find killing animals to be acceptable, but they do recognize that it is an effort to protect endangered species. They may also understand that this protection is legally required by the ESA and recovery plans, as previously discussed. Future research could focus on finding other ways to protect endangered species that are less controversial, yet still effective. However, many possibly protective measures seem to restrict the ability of the public to use the beach, and would likely be equally or more controversial than predator management.

The survey data showed that knowledge about the CHNS predator management program tested by the survey is generally low, indicating that the information providing such knowledge may be lacking from frequently used information sources. Results also indicate that when people know more about the predator management program, their acceptability of it is higher (Table 2). This suggests that the NPS might be able to positively affect public perception simply by supplying more information and increasing transparency of the predator management program.

Education may be a viable strategy to address low knowledge and disapproval at the same time. Results from this study suggest the most effective method for distributing information to the most people would be to use online sources including social media and web-based newspapers (Figure 11).

While results indicate trends in some attitudes and perceptions, the format of the survey instrument prevented us from gaining a deep understanding of the reasons for these trends. Others could use our findings to inform future research investigating reasons behind these opinions, attitudes and beliefs. These findings could then be incorporated into the decision making process of the NPS on a local and national level. Future research in this community could focus on determining the values that underlie negative attitudes and beliefs about the predator management program. There are many reasons why people may feel this way: personal morals, pre-existing perception of the NPS, general disagreement with management of the Seashore, or belief that the land should be left in its natural state. It is possible that the reasons for disagreement are a combination of these or include other reasons than those listed here.

Understanding the reasons for negative feelings towards the program could be very useful in the decision-making process and conflict resolution.

A common trend of low acceptability and a negative perception was especially seen among those who live or visit south of the Bonner Bridge. A future study might narrow the focus on this area to identify why many people there are less accepting, specifically focusing on how the predator management program impacts residents. Given the findings of the natural science research, it could also be valuable to conduct research evaluating the public perception of management of ghost crabs, a major predator of threatened and endangered species on CHNS.

Conducting this research could help the NPS predict how the public will respond if ghost crab management is implemented in the future.

Additional research could study how public support, or lack thereof, directly impacts the success of the predator management program. This could reveal the importance of public involvement, thereby informing future actions by the NPS and other managing agencies. The Outer Banks, like many communities across North Carolina and the United States, are saddled with a conflicting agenda: to balance human use of the area and the protection of natural resources, through conservation and preservation management, for generations to come. In the coming years, the need for effective management will likely increase with additional pressures on ecosystems and natural resources. The success of management programs may depend on public support. Therefore, management agencies could benefit from understanding the public's point of view towards the issue so misconceptions and concerns can be effectively addressed and resolved. This research can hopefully improve dialogue between the public and the NPS regarding predator management by increasing understanding of the public's beliefs and attitudes towards the issue.

Final Conclusions

Management Framework

Our research analyzes the predator management program on CHNS from both social science and natural science perspectives. The purpose of the project was to better understand how predator management contributes to the protection of threatened and endangered species and the community response to these management actions specifically on CHNS. Management of natural resources on CHNS attempts to strike a balance between seemingly conflicting goals to make valuable natural resources available to the public for use while still protecting and conserving national parks "in such a manner…as to leave them unimpaired for the enjoyment of future generations" (Organic Act of 1916 U.S.C. 16 § 1). The NPS is required by law to implement recovery plans for the piping plover and sea turtle populations on CHNS. Recovery plans often incorporate predator management as a strategy to reduce threatened or endangered species' mortality rates.

Legislative and legal rules, public input, and scientific research all inform how the predator management program is created and implemented on CHNS. Our preliminary research reviewed the history of the policies and legal mandates which predator management acts to fulfill. The social science research addressed public knowledge and perception of the predator management program, while the natural science research tested and reviewed scientific assumptions that inform the creation and implementation of the CHNS predator management program. Future policy is more likely to be successful if it is adaptive, responding to public input and updated scientific research. Science will continue to inform policy actions and where to focus management strategies based on measurable successes or failures of programs. The ESA

requires management plans regardless of public perception of the program. It is in the NPS interest to incorporate the public's input in the management process to ensure long- term success of its mission.

Efficacy of Predator Management Program

Our research indicates the current program may be effectively managing the predators that affect threatened and endangered species. However, it is impossible to accurately measure effectiveness because the ESA prevents the NPS from having a controlled study. Without a controlled study, it is impossible to tell how abundance of predator populations has decreased because there is no baseline measure. Since the NPS cannot determine with certainty that their efforts to manage predators have been successful, they cannot inform the public with specifics regarding the results of management actions. Our research indicates that an increase in level of knowledge about the predator management program is related to an increase in acceptance. If the NPS could educate the public about the program's efficacy, overall public acceptance may improve.

The research found that the surrounding community on CHNS maintains a negative attitude towards the program and more generally towards the killing of animals to protect threatened and endangered species. This leaves the NPS facing a trade-off: continue to implement the current predator management program or gain public support of management actions. If the fate of the predator management program was solely determined by local public perception, it is likely that the program would be discontinued due to a lack of support. The NPS is legally required to enact recovery plans for each ESA listed species. If predator management were no longer an option, the NPS would be forced to rely on other strategies to reduce threatened and endangered species mortality, including increasing the frequency and scope of

beach closures. The public may not be fully aware of the trade-off between predator management and other, less popular strategies to meet recovery goals.

The direct impacts of the predator management program on plover and turtle survival does not hinge on public support, but instead on the effectiveness of the traps and where they are placed. However, if NPS cannot increase public support and cooperation, it may be more difficult to manage and maintain preservation and conservation efforts. Increased public support of natural resource management could be valuable to ensure long-term success of management goals, like biodiversity protection. Creating and implementing recovery plans for threatened and endangered species is required under the ESA, but predator management is not. Can the NPS increase public support by substituting other management actions in the place of the current predator management program? On CHNS, there are three main threats to threatened and endangered species: weather, predators, and humans. Weather cannot be controlled and the public is unaccepting of managing for predators, which would leave the NPS further managing human actions. Currently the alternatives for managing for predators would be to further regulate beach driving and increase beach closures. It is well known that the public is very unaccepting of these actions; today, predator management is the best option for threatened and endangered species management.

Diversifying Management Scope

Presently, the predator management program is focused on removing specific animals that prey on the threatened and endangered species found on CHNS. Methods of predator control are employed principally in areas within close proximity of sea turtle or piping plover nests. However, our research suggests that the abundance of predator populations may be influenced by

factors outside of the dry sand beach that have not been previously considered. Much of the habitat for NPS-managed predators, for example, lies in the shrubbery and vegetation behind the dunes. This finding suggests the possible effectiveness of different management strategies that focus on managing the factors that *support* predator population, like reproductive habitat outside of the dry sand beach, as opposed to the strict management of predator populations themselves. Predator populations may become smaller not because more are being killed, but because less are being born or surviving to adulthood. It might improve public perception if measures were taken that aim at lowering predator reproduction rates, thereby reducing the need for predator euthanization. According to the social science research, many people hold negative attitudes about the predator management program because they find it unacceptable to kill animals, even if for the benefit of threatened and endangered species. If predator populations were weakened, threatened and endangered species populations were increased, and fewer animals were harmed, public perception of predator management would likely improve.

Review of NPS records indicated that ghost crabs cause the majority of attributable predator-related deaths of sea turtles and piping plovers. This finding could indicate two things. First, ghost crabs are actually the most significant predator of these species at early life cycle stages on CHNS. The second, less direct implication is that this data could suggest that current management strategies utilized by the NPS have been successful in reducing piping plover and sea turtle mortality. If this is the case, predator management could be improved in the future to provide for the management of ghost crab populations. Our survey research aimed at community response did not include ghost crabs specifically in questions that measured attitudes or perception. The NPS does not currently have valid scientific evidence to suggest that it has been successful in improving the population abundance of sea turtles and piping plovers, but

establishing the effectiveness of the program may be crucial for improving public attitudes. There is a chance that the public might be more accepting of predator management if ghost crabs were managed rather than larger mammalian predators. Future management of ghost crabs as a main predator of threatened and endangered species could allow the NPS to evaluate the effectiveness of predator management actions on CHNS. This would be possible because the NPS would have the opportunity to develop a control study of ghost crab population abundance that would act as a baseline to compare to future ghost crab population data.

Increasing Transparency of Future Predator Management Programs

The majority of respondents in our research seem to lack an accurate understanding of the reasoning behind and the implementation of the predator management program on CHNS. Opposition may be partially due to a lack of knowledge in particular, knowledge as to how successful the strategies implemented on CHNS are in improving sea turtle and piping plover survival rates. In the past, annual reports by the NPS regarding sea turtles and piping plovers on CHNS have not been written for a public audience. Reporting styles have often been inconsistent both within and between individual reports. In addition, the reports are not widely distributed and have been difficult to find by the public. It could be useful to standardize reports to avoid confusion. It could also be helpful for the NPS to include some kind of summary table or graphic in the annual reports that briefly describes the most important findings in a way that is easy for the public to digest. Additionally, annual reports findings should be made easily accessible to all in order to promote public education.

Our research found that surrounding communities have negative perceptions of the predator management strategies implemented on CHNS. Even avid supporters of the program

deem it to be a “necessary evil” (Cyndi Holda, personal communication). Research suggests that much of the controversy surrounding predator management exists due to a lack of communication between the NPS and the public. If the NPS were to implement a predator management program for ghost crabs in the near future, it could be a great opportunity for the public to be made aware of predator management plans from the beginning. Transparency of future predator management programs is likely to increase levels of knowledge regarding all management strategies. Our research indicated that higher levels of knowledge were associated with higher levels of acceptance of predator management on CHNS. If transparent information were made readily available to the public, then the communities on CHNS may find the strategy to be more acceptable. Increased knowledge has the potential to improve the public perception of predator management, though more research could be done to better understand the reasoning behind the local community’s negative perceptions about the predator management program.

In summary, our research indicates that while public support of the predator management program is low, there are many changes that can be made to the way the program is implemented that could yield positive results in both program effectiveness and public acceptance. Ideally, such changes will ease the tension in balancing human and ecosystem demands, allowing for the best possible management actions that enable both continued protection of wildlife and recreational enjoyment of CHNS for many more generations.

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APPENDIX

Appendix A: Natural Science Piping Plover Annual Report Data

Table 1: Piping Plover Mortalities Attributable to Predators in Egg Life Cycle Stage

Year	Species	Life Stage	Ghost Crab	Feral Cat	Fox	Bird	Mink	Raccoon	Opossum/Raccoon	Opossum	Unknown
2006	Piping plover	Egg	0	0	0	0	0	0	0	0	0
2007	Piping plover	Egg	1	0	0	0	0	0	3	0	0
2008	Piping plover	Egg	0	0	0	0	0	0	0	0	0
2009	Piping plover	Egg	4	0	0	0	0	0	0	0	0
2010	Piping plover	Egg	7	0	0	0	0	0	0	0	0
2011	Piping plover	Egg	1	0	0	0	0	0	0	0	0
2012	Piping plover	Egg	10	0	3	1	4	0	0	0	0
Total			23	0	3	1	4	0	3	0	0

Table 2: Piping Plover Mortalities Attributable to Predators in Chick Life Cycle Stage

Year	Species	Life Stage	Ghost Crab	Feral Cat	Fox	Bird	Mink	Raccoon	Opossum/Raccoon	Opossum	Unknown
2006	Piping plover	Chick	0	0	0	0	0	0	0	0	0
2007	Piping plover	Chick	0	0	0	0	0	0	0	0	3
2008	Piping plover	Chick	0	0	0	2	0	0	0	0	0
2009	Piping plover	Chick	0	0	0	0	0	0	0	2	0
2010	Piping plover	Chick	1	0	0	0	0	0	0	0	0
2011	Piping plover	Chick	0	0	0	1	0	1	0	0	0
2012	Piping plover	Chick	0	0	0	0	0	0	0	0	0
Total			1	0	0	3	0	1	0	2	3

Table 3: Piping Plover Mortalities at Egg Life Cycle Stage

Year	Species	Life Stage	Predation	Human	Storm/ Weather	Abandonment	Unattributed
2006	Piping plover	Eggs	0	0	0	0	0
2007	Piping plover	Eggs	4	0	0	2	3
2008	Piping plover	Eggs	0	0	0	7	8
2009	Piping plover	Eggs	4	0	0	4	0
2010	Piping plover	Eggs	7	0	3	0	0
2011	Piping plover	Eggs	1	0	0	3	6
2012	Piping plover	Eggs	8	0	4	3	7
Total			24	0	7	19	24

Table 4: Piping Plover Mortalities at Chick Life Cycle Stage

Year	Species	Life Stage	Predation	Human	Storm/ Weather	Abandonment	Unattributed
2006	Piping plover	Chick	0	0	0	0	6
2007	Piping plover	Chick	3	0	0	0	6
2008	Piping plover	Chick	2	0	0	0	13
2009	Piping plover	Chick	2	0	0	0	14
2010	Piping plover	Chick	1	0	0	0	17
2011	Piping plover	Chick	2	0	0	0	23
2012	Piping plover	Chick	0	0	0	0	26
Total			10	0	0	0	105

Appendix B: Natural Science Sea Turtle Annual Report Data

Table 1: Sea Turtle Mortalities Attributable to Predators in Egg Life Cycle Stage

Year	Species	Life Stage	Ghost Crab	Feral Cat	Fox	Bird	Unknown
2007	Unidentified	Egg	2	0	0	0	0
2008	Unidentified	Egg	29	0	0	0	156
2009	Unidentified	Egg	122	0	0	0	122
2010	Unidentified	Egg	277	0	0	0	0
2011	Unidentified	Egg	293	0	0	0	0
2012	Unidentified	Egg	602	0	0	0	0
Total			1325	0	0	0	278

Table 2: Sea Turtle Mortalities Attributable to Predators in Hatchling Life Cycle Stage

Year	Species	Life Stage	Ghost Crab	Feral Cat	Fox	Bird	Unknown
2007	Unidentified	Hatchling	0	0	0	0	0
2008	Unidentified	Hatchling	0	30	0	0	0
2010	Unidentified	Hatchling	8	0	0	0	0
2011	Unidentified	Hatchling	5	0	0	0	0
2012	Unidentified	Hatchling	6	0	0	0	0
Total			19	30	0	0	0

Table 3. All Sea Turtle Mortalities at Egg Life Cycle Stage

Year	Species	Life Stage	Predation	Human	Storm/ Weather	Stranding	Unattributed
2007	Unspecified	Eggs	2	4	0	0	0
2007	Leatherback	Eggs	0	0	0	0	14
2008	Unspecified	Eggs	185	24	0	0	0
2009	Unspecified	Eggs	122	0	0	0	0
2010	Unspecified	Eggs	277	101	0	0	0
2011	Unspecified	Eggs	293	0	0	0	0
2012	Unspecified	Eggs	602	217	0	0	3
Total			1481	346	0	0	17

Table 4. All Sea Turtle Mortalities at Hatchling Life Cycle Stage

Year	Species	Life Stage	Predation	Human	Storm/ Weather	Stranding	Unattributed
2008	Unspecified	Hatchling	30	6	0	0	5
2010	Unspecified	Hatchling	8	1	0	0	5
2012	Unspecified	Hatchling	6	9	0	0	4
Total			42	16	0	0	14

Table 5. Sea Turtle Nest Losses

Year	Species	Human	Storm/ Weather	Unattributed
2006	Unspecified	0	23	0
2007	Unspecified	0	5	8
2008	Unspecified	0	6	7
2009	Unspecified	0	9	8
2010	Unspecified	1	9	9
2011	Unspecified	0	33	7
2012	Unspecified	0	0	0
Total		1	85	39

Table 6. Sea Turtle Strandings at Adult Life Cycle Stage

Year	Species	Life Stage	Stranding
2006	Unspecified	Adult	73
2007	Green	Adult	50
2007	Kemp's Ridley	Adult	5
2007	Leatherback	Adult	1
2007	Unspecified	Adult	2
2008	Green	Adult	94
2008	Kemp's Ridley	Adult	34
2008	Leatherback	Adult	2
2008	Loggerhead	Adult	39
2009	Green	Adult	183
2009	Kemp's Ridley	Adult	57
2009	Leatherback	Adult	2
2009	Loggerhead	Adult	53
2009	Unspecified	Adult	2
2010	Green	Adult	220
2010	Kemp's Ridley	Adult	92
2010	Loggerhead	Adult	74
2010	Unspecified	Adult	1
2011	Green	Adult	48
2011	Loggerhead	Adult	46
2011	Unspecified	Adult	49
2012	Green	Adult	44
2012	Kemp's Ridley	Adult	30
2012	Leatherback	Adult	2
2012	Loggerhead	Adult	33
2012	Unspecified	Adult	8

Appendix C: Natural Science Ghost Crab Study Data

Table 1. Environmental conditions of three study site beaches Salvo (S), Little Kinnakeet (LK), and Bodie Island (BI)

Beach	ORV (1 or 0)	Transect	GPS N	GPS W	Temp. (ºF)	Windspeed (MPH)	Wind Direction	Sampling date and time	Approximate width of barrier island (m)
S	0	1	35º 31.624'	75º 28.187'	63	11-13mph	ENE	10/21/13 10:30	1500
S	0	2	35º 31.606'	75º 28.198'	63	11-13mph	ENE	10/21/13 10:30	1500
S	0	3	35º 31.652'	75º 28.18'	63	11-13mph	ENE	10/21/13 10:30	1500
S	1	1	35º 28.209'	75º 28.907	68.1	8	E	10/21/13 12:30	500
S	1	2	35º 28.223'	75º 28.913'	68.1	8	E	10/22/13 12:30	500
S	1	3	35º 28.241'	75º 28.902'	68.1	8	E	10/23/13 12:30	500
LK	0	1	35º 26.337'	75º 29.051	62.2	7-9mph	ENE	10/21/13 7:50	500
LK	0	2	35º 26.353'	75º 29.057	62.2	7-9mph	ENE	10/21/13 7:50	500
LK	0	3	35º 26.376'	75º 29.052	62.2	7-9mph	ENE	10/21/13 7:50	500
LK	1	1	35º 26.230'	75º 29.063'	62.2	7-9mph	ENE	10/21/13 6:30	500
LK	1	2	35º 26.214'	75º 29.066	62.2	7-9mph	ENE	10/21/13 6:30	500
LK	1	3	35º 26.206'	75º 29.063	62.2	7-9mph	ENE	10/21/13 6:30	500
BI	0	1	35º49.807	75º33.398	-	0.5-1mph	ENE	10/22/13 7:10	2000
BI	0	2	35º49.797	75º33.392	-	0.5-1mph	ENE	10/22/13 7:10	2000
BI	0	3	35º49.786	75º33.384	-	0.5-1mph	ENE	10/22/13 7:10	2000
BI	1	1	35º47.962	75º32.531	-	1.5-2mph	ENE	10/22/13 9:10	2000
BI	1	2	35º47.976	75º32.538	-	1.5-2mph	ENE	10/22/13 9:10	2000
BI	1	3	35º47.988	75º32.546	-	1.5-2mph	ENE	10/22/13 9:10	2000

Table 2. Soil characteristics of Salvo (S) beaches

Beach	ORV (1 or 0)	Transect	Zone	Hole Number (n)	Gravel relative density (% of total mass)	Very coarse to coarse relative density (% of total mass)	Medium sand relative density (% of total mass)	Fine sand relative density (% of total mass)	Bulk density (g/cm3; dry mass/volume)	Slope of beach face
S	0	1	1	2	0	1	15	82	2.02	-0.09
S	0	1	2	3	0	4	21	74	1.8	-0.01
S	0	1	3	4	0	6	31	61	1.56	-0.06
S	0	2	1	4	0	0	7	93	1.58	-0.1
S	0	2	2	1	0	4	32	64	1.49	-0.02
S	0	2	3	1	0	0	1	93	1.39	-0.07
S	0	3	1	0	0	0	13	85	1.65	-0.1
S	0	3	2	7	0	1	31	67	1.42	-0.01
S	0	3	3	0	0	1	17	81	1.4	-0.08
S	1	1	1	1	0	1	32	66	1.8	-0.07
S	1	1	2	0	4	11	19	65	1.78	0
S	1	1	3	1	0	25	49	25	1.72	-0.1
S	1	2	1	2	0	1	38	60	1.89	-0.02
S	1	2	2	0	0	12	26	61	1.74	-0.04
S	1	2	3	0	0	10	66	22	1.72	-0.11
S	1	3	1	1	0	4	50	45	1.89	0.34
S	1	3	2	1	0	1	11	87	1.72	-0.05
S	1	3	3	0	0	7	51	40	1.54	-0.1

Table 3. Soil characteristics of Little Kinnakeet (LK) beaches

Beach	ORV (1 or 0)	Transect	Zone	Hole Number (n)	Gravel relative density (% of total mass)	Very coarse to coarse relative density (% of total mass)	Medium sand relative density (% of total mass)	Fine sand relative density (% of total mass)	Bulk density (g/cm3; dry mass/volume)	Slope of beach face
LK	0	1	1	6	2	21	44	34	1.72	-0.08
LK	0	1	2	0	0	1	26	72	1.5	-0.02
LK	0	1	3	0	0	5	25	67	1.62	-0.11
LK	0	2	1	5	0	1	26	72	1.5	-0.06
LK	0	2	2	12	0	1	26	72	1.5	-0.02
LK	0	2	3	0	0	25	41	33	1.83	-0.11
LK	0	3	1	8	0	5	25	67	1.62	-0.06
LK	0	3	2	0	0	2	30	68	1.5	-0.04
LK	0	3	3	0	0	26	51	23	1.64	-0.08
LK	1	1	1	1	0	7	53	41	1.74	-0.05
LK	1	1	2	1	0	14	34	52	1.78	-0.01
LK	1	1	3	4	0	6	28	65	1.7	-0.1
LK	1	2	1	2	0	7	55	38	1.87	-0.03
LK	1	2	2	2	1	22	41	36	1.82	-0.02
LK	1	2	3	1	0	4	33	63	1.75	-0.11
LK	1	3	1	2	0	5	42	53	1.71	-0.03
LK	1	3	2	0	0	9	34	57	1.48	-0.02
LK	1	3	3	12	0	35	50	14	1.76	-0.11

Table 4. Soil characteristics of Bodie Island (BI) beaches

Beach	ORV (1 or 0)	Transect	Zone	Hole Number (n)	Gravel relative density (% of total mass)	Very coarse to coarse relative density (% of total mass)	Medium sand relative density (% of total mass)	Fine sand relative density (% of total mass)	Bulk density (g/cm3; dry mass/volume)	Slope of beach face
BI	0	1	1	5	0	0.15	18.68	81.05	1.72	-0.08
BI	0	1	2	3	0	26.13	43.91	29.8	1.72	0.01
BI	0	1	3	6	0	13.14	46.86	39.76	1.72	-0.1
BI	0	2	1	5	0	0.39	30.09	69.26	1.72	-0.09
BI	0	2	2	12	0	0.78	40.18	58.82	1.72	0.01
BI	0	2	3	7	12.56	36.28	11.99	38.97	1.72	-0.11
BI	0	3	1	11	0	5.68	74.98	18.66	1.72	-0.11
BI	0	3	2	12	0	23.01	53.46	22.45	1.72	0.01
BI	0	3	3	3	0	34.42	39.55	26.34	1.72	-0.12
BI	1	1	1	12	0	2.09	40.23	62.13	1.72	-0.2
BI	1	1	2	3	0	0.78	1.32	100.1	1.72	-0.06
BI	1	1	3	0	1.72	1.33	9.25	89.53	1.72	-0.02
BI	1	2	1	6	0	0.35	9.66	89.82	1.72	-0.09
BI	1	2	2	17	0	0.31	0.54	97.63	1.72	0.01
BI	1	2	3	2	9.87	1.3	11.25	77.81	1.72	-0.11
BI	1	3	1	9	0	0.45	13.36	84.9	1.72	-0.12
BI	1	3	2	12	0	0.54	2.86	96.95	1.72	-0.05
BI	1	3	3	2	1.1	0	0.27	97.05	1.72	-0.04

Appendix D: Social Science Qualitative Interview Questions

1. What do you believe to be the most significant threat to endangered species within the Cape Hatteras National Seashore? Do you think humans or predators play a larger role? Or, do you believe there is a combined effect? Why?

2. What do you think most affects public perception of endangered species at Cape Hatteras National Seashore and the management actions taken to protect those endangered species?

3. What laws/policies are in place that directly affect recreational use of endangered habitats?

4. What is the biggest public misconception about biodiversity conservation, the ESA or ESA recovery plans?

5. If you could enact any law or policy regarding biodiversity protection and conservation, effective today, what would you it be?

6. What do you believe is the relationship between public perception and conservation efforts?

7. What is your favorite aspect of visiting CHNS?

8. What role do you think the National Park Service should play in preserving public lands?

9. What factors do you/your organization view as most important for maintaining habitat quality?

10. Do you think predator control should play a role in protecting biodiversity?

Appendix E: Social Science Quantitative Survey

Thank you for taking the time to complete this survey. Your opinions are important to us. This survey asks about your personal beliefs and opinions related to the management of Cape Hatteras National Seashore. Please understand that this survey is voluntary and anonymous. Also, you are free to not answer any question for any reason.

1. Which of the following do you rely on **the most** for information about issues related to Cape Hatteras National Seashore? (Check up to three)

- ¨ Outer Banks Free Press
- ¨ Outer Banks Voice
- ¨ Coastland Times
- ¨ Island Free Press
- ¨ Non-profit listserv or publications (e.g., Nature Conservancy, NC Coastal Federation)
- ¨ Social media (e.g., Facebook, Twitter)
- ¨ Radio (NPR, local stations, XM)
- ¨ National Park Service Cape Hatteras National Seashore website
- ¨ Conversations with neighbors
- ¨ Other (please specify): _____

2. The following statements relate to your attitudes and preferences related to sources of information for Cape Hatteras National Seashore. Please indicate the extent to which you agree or disagree with the following statements.

	Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
a. I read online news/media sources more than I read print media.	¨	¨	¨	¨	¨	¨
b. I regularly seek out information about Cape Hatteras National Seashore.	¨	¨	¨	¨	¨	¨
c. I understand the issues related to predator management in Cape Hatteras National Seashore.	¨	¨	¨	¨	¨	¨
d. I am an active participant in forums about Cape Hatteras National Seashore.	¨	¨	¨	¨	¨	¨

3. The following statements are about predator management in Cape Hatteras National Seashore. If you believe the statement is true, please indicate "True." If you believe the statement is false, please indicate "False."

		True	False
a.	The National Park Service removes ghost crabs and seagulls to protect colonial shorebirds.	¨	¨
b.	The National Park Service employs several full time trappers at Cape Hatteras National Seashore.	¨	¨
c.	Other national parks trap and remove predators to protect endangered species.	¨	¨
d.	The National Park Service uses only lethal traps.	¨	¨

4. How confident are you in your answers to the previous question (Question #3)?

Not at all Confident	Slightly Confident	Confident	Very Confident
¨	¨	¨	¨

5. In an average year, how many animals do you think the National Parks Service traps within Cape Hatteras National Seashore?

¨ Less than 100 animals
¨ Between 100 and 500 animals
¨ Between 500 and 1000 animals
¨ More than 1000 animals

6. The following statements relate to your beliefs about predator management. Please indicate the extent to which you agree or disagree with the following statements.

		Strongly Disagree	Disagree	Slightly Disagree	Slightly Agree	Agree	Strongly Agree
a.	Predators are just as important as endangered species at Cape Hatteras National Seashore.	¨	¨	¨	¨	¨	¨
b.	Predators should be captured and euthanized to protect endangered species at Cape Hatteras National Seashore.	¨	¨	¨	¨	¨	¨
c.	Predators should only be controlled when they pose a threat to humans.	¨	¨	¨	¨	¨	¨

d.	Only nonlethal traps should be used to remove predators, even if they are less effective.	..	..	..	..	..	..
e.	The National Park Service should not manage predators.	..	..	..	..	..	..
f.	The National Park Service should only manage predators if it is scientifically proven to benefit endangered species.	..	..	..	..	..	..
g.	The presence of wildlife on the seashore is important to my enjoyment of the beach.	..	..	..	..	..	..

7. The following statements relate to your personal attitudes and beliefs about predator management within Cape Hatteras National Seashore. Please indicate the extent to which you accept the following scenarios.

		Unacceptable	Slightly Unacceptable	Slightly Acceptable	Acceptable
a.	Removal of predators such as raccoons and feral cats from Cape Hatteras National Seashore.	..	..	..	..
b.	Removal of predators such as foxes from Cape Hatteras National Seashore.	..	..	..	..
c.	Predator control by sterilization.	..	..	..	..
d.	Predator control by trapping and humane euthanization.	..	..	..	..
e.	Killing animals to protect endangered species.	..	..	..	..

8. Do you live north or south of the Herbert C. Bonner bridge? – OR – When you visit the Outer Banks do you typically stay north or south of the Herbert C. Bonner Bridge?

¨ I live or stay north of the Herbert C. Bonner bridge.

¨ I live or stay south of the Herbert C. Bonner bridge.

¨ Other (please specify): _____

9. Which of the following represents your highest level of education? (Check one)

- ¨ Some High School
- ¨ High School
- ¨ Associates Degree
- ¨ Some Four Year College courses
- ¨ Bachelor's Degree
- ¨ Some Graduate Level Courses
- ¨ Graduate Degree
- ¨ Other (please specify): _____

Appendix F: Summary Tables of Responses to Survey Questions

Table 1. Question 1: Summary of Information Source Preferences

	Percent
Outer Banks Free Press	0%
Outer Banks Voice	39%
Coastland Times	16%
Island Free Press	55%
Listserv	4%
Social Media	51%
Radio	8%
National Park Service Cape Hatteras National Seashore Website	15%
Conversation	20%
Other	16%

Table 2. Question 2: Summary of Information Source Preferences and Attitudes

	Disagree			Agree				
Statement	-3	-2	-1	1	2	3	*M*	*SD*
I read online news/media more than I read print media.	3%	3%	6%	11%	38%	40%	1.850	1.48
I regularly seek out information about Cape Hatteras National Seashore.	3%	4%	8%	17%	36%	33%	1.657	1.52
I understand the issues related to predator management in Cape Hatteras National Seashore.	10%	8%	7%	19%	32%	24%	1.083	1.96
I am an active participant in forums about Cape Hatteras National Seashore.	14%	28%	13%	18%	15%	12%	-0.244	2.07

Table 3. Question 3: Summary of predator management knowledge.

Statement	*n*	True	False
The National Park Service removes ghost crabs and seagulls to protect colonial shorebirds.	503	16%	84%
The National Park Service employs several full-time trappers at Cape Hatteras National Seashore.	503	62%	38%
Other national parks trap and remove predators to protect endangered species.	494	78%	22%
The National Park Service uses only nonlethal traps.	496	21%	78%

Table 4. Question 4: Summary of Animals Trapped Annually

Statement	Not at all confident	Slightly Confident	Confident	Very Confident
How confident are you in your answers to the previous question?	28%	45%	19%	8%

Table 5. Question 5: Summary of Animals Trapped Annually

Statement	<100	100-500	500-1000	>1000
How many animals on average does the National Parks Service trap within Cape Hatteras National Seashore?	28%	45%	19%	8%

Table 6. Question 6: Summary of beliefs about predator management

Statement	Disagree			Agree			*M*	*SD*
	-3	-2	-1	1	2	3		
a. Predators are just as important as endangered species at Cape Hatteras National Seashore	2%	4.7%	6%	17%	35%	33%	1.69	1.51
b. Predators should be captured and euthanized to protect endangered species at Cape Hatteras National Seashore	45%	29%	12%	7%	3%	2%	1.90	1.50
c. Predators should only be controlled when they pose a threat to humans	9%	16%	15%	19%	24%	13%	.32	2.00
d. Only nonlethal traps should be used to remove predators, even if they are less effective	7%	9%	9%	15%	27%	29%	1.10	1.98
e. The National Park Service should not manage predators	5%	13%	15%	18%	16%	31%	.89	2.01
f. The National Park Service should only manage predators if it is scientifically proven to benefit endangered species	19%	15%	12%	15%	21%	15%	.03	2.23
g. The presence of wildlife on the seashore is important to my enjoyment of the beach	1%	3%	3%	12%	29%	51%	2.13	1.28

Table 7. Question 7: Summary of personal beliefs and attitudes about predator management within Cape Hatteras National Seashore.

	Unacceptable			Acceptable		
Statement	-2	-1	1	2	*M*	*SD*
Removal of predators such as raccoons and feral cats from Cape Hatteras National Seashore	39%	21%	22%	19%	-.40	1.60
Removal of predators such as foxes from Cape Hatteras National Seashore	62%	21%	13%	5%	-1.21	1.23
Predator control by sterilization	31%	15%	28%	26%	.03	1.64
Predator control by trapping and humane euthanization	57%	20%	14%	9%	-1.02	1.39
Killing animals to protect endangered species	69%	16%	11%	5%	-1.33	1.20

Table 8. Question 8: Do you live north or south of the Herbert C. Bonner bridge? – OR – When you visit the Outer Banks do you typically stay north or south of the Herbert C. Bonner bridge?

	N	Percent
I live or stay north of the Herbert C. Bonner bridge.	185	31.5%
I live or stay south of the Herbert C. Bonner bridge.	347	66.3%
Other (please specify):	11	2%

Table 9. Question 9: Which of the following represents your highest level of education? (Check one)

	Percent
Some High School	0%
High School	13%
Associates Degree	12%
Some Four Year College	20%
Bachelor's Degree	28%
Some Graduate Level Courses	11%
Graduate Degree	16%
Other (please specify)	1%