

Managing for Sea Turtles within the National Park Service: Balancing federal mandates, public opinion, and best available science at Cape Hatteras National Seashore



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1 Executive Summary

While sea turtle populations are generally on the rise (Valdivia et al., 2019), it is important for resource managers to formalize a goal statement for sea turtle management. This goal statement should include justifications for a range of management actions available to all park managers. Additionally, thresholds for population numbers should be continually monitored to inform what management actions are needed and in what locations. This task is necessary to ensure that all managers are moving the sea turtle system in the same direction rather than in opposing directions. This task should be initiated with the creation of an inter-regional team to create said goal statement through a collaborative decision-making process. This process will likely include a number of stakeholder meetings bringing together the local, state, and federal stakeholders in the areas to share the best available science on the topic and individual perspectives on the issue.

Table 1: Management Actions and Recommendations

Management Action	Pros	Cons	Recommendation for Cape Hatteras
Marking off nest Locations	Avoids nest destruction while facilitating human usage	Signs can be easily ignored, misread, or not seen	Continue to mark off natural nest sites.
Relocating flood prone nests	Ensures that sea turtle nests are not totally destroyed	May have some effect on future populations of sea turtles Excavation of eggs can lower success rate	Continue to relocate flood prone nests.
Predator management for hatchlings	Raises the success rate for hatchlings	Requires more manpower than other strategies	Continue to manage predators while hatchlings attempt to reach the ocean.
Incubation of nests offsite	Can raise the hatchling success rates Opens up areas for visitor usage	Requires equipment, manpower, and storage space Excavation of eggs can lower success rate	Not recommended as this requires a large investment and could lower the overall number of sea turtle hatchlings.
Relocating all nests	Eases the manpower need for other management actions Opens up areas for visitor usage	Excavation of eggs can lower success rate Makes sea turtles more vulnerable to severe weather and flooding	Not recommended as the excavation can lower egg success without compensating it with incubation.

2 Introduction

2.1 Preface

The National Park Service is an institution that was created in 1916 to preserve ecological and historical integrity of areas it is entrusted while simultaneously making them as available to the public as is possible. A major component of the founding

legislation of this agency, the National Park Service Organic Act of 1916, is the final line of section one. It states,

“The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life 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.”

This founding principle sets the stage for the wicked problems that the agency now faces. With changes in global climate and sea level, the National Park Service’s work of balancing public use and natural and historic resource conservation has become a far more complex process than it originally seemed. To compound this, the variance in need, climate, management, and challenges between park units has led to a broad diversity in strategies to meet the complex issues faced daily. One such issue that affects nearly all parks situated on the coast – managing endangered sea turtle habitats – is a prime example of this divide in management strategies.

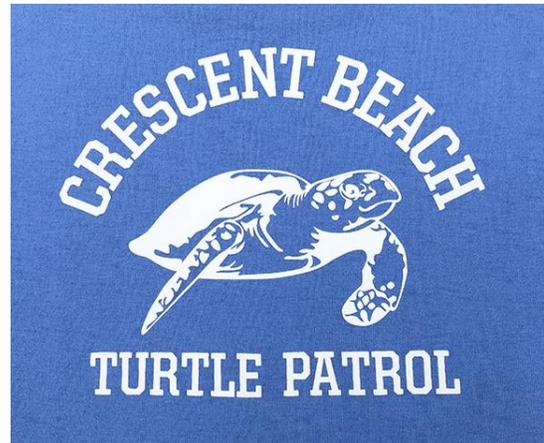


Figure 1: Logo for a sea turtle focused non-profit; Sea Turtle Image Library, c2020

2.2 Sea Turtles

Sea turtle is a term that refers to the family of marine turtles. There exist seven known species of sea turtles: green, loggerhead, kemp’s ridley, olive ridley, hawksbill, flatback, and leatherback sea turtles. These highly migratory marine turtles exist in most oceans and seas across the world. Some notable examples include the Pacific, Atlantic, and Indian oceans and the Mediterranean Sea. Most marine turtle species are omnivorous, with three notable exceptions, and feed on a wide range of ocean grasses and smaller sea life. Green sea turtles begin their lives as omnivores, but transition to an exclusively herbivorous diet as the mature. Hawksbill sea turtles primarily consume sponges which are common in their native ranges of the Caribbean. Finally, Leatherback sea turtles are known for exclusively consuming jellyfish (World Wildlife Fund, c2020).

Due to humanity's reliance on the ocean, humans have come in frequent contact with sea turtles. Many cultures relied on their meat and eggs for food both in the past and present. Another common use for sea turtles in early human societies was as decoration. The shells and leathers of specific sea turtle species were prized for their beauty and often processed into ornamental jewelry, combs, and footwear. These practices persisted in many areas up to the modern day. Due to the human impacts from over-fishing in these areas, sea turtles were labeled as an endangered species by the United States Endangered Species Act of 1973. This act prevented the intentional harvest, capture, or killing of any sea turtle, nest, or egg. While this has helped to slow the decline of sea turtle populations by criminalizing direct and intentional capture, they are still highly affected by fishing by-catch, habitat loss, and pollution. Being a large and charismatic species, many non-profit organizations exist to help rehabilitate, educate about, and lobby for sea turtles (Sea Turtle Conservancy, c2020a; World Wildlife Fund, c2020).

The modern trends for sea turtle populations are, generally, optimistic. Nearly all sea turtle species have shown a steady upward trend in estimated populations and number of nests since the institution of the endangered species act except for loggerhead turtles (Figure 2) (Valdivia et al., 2019). Loggerhead turtles saw an initial increase then their population numbers dipped sharply starting in 2000. They subsequently hit their lowest point around 2006 and then, due to a combination of management efforts, they rebounded quickly and continue to see an upward trajectory.

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2.3 Area of Focus

A specific area of focus for this case study will be on Cape Hatteras National Seashore. This park unit encompasses the coastline from Rodanthe, North Carolina to Hatteras Village, North Carolina and nearly all the public coast on Ocracoke Island just south of Hatteras. The beaches under this park's management provide a vital habitat for nesting sea turtles at their northernmost permanent range. This federal area was

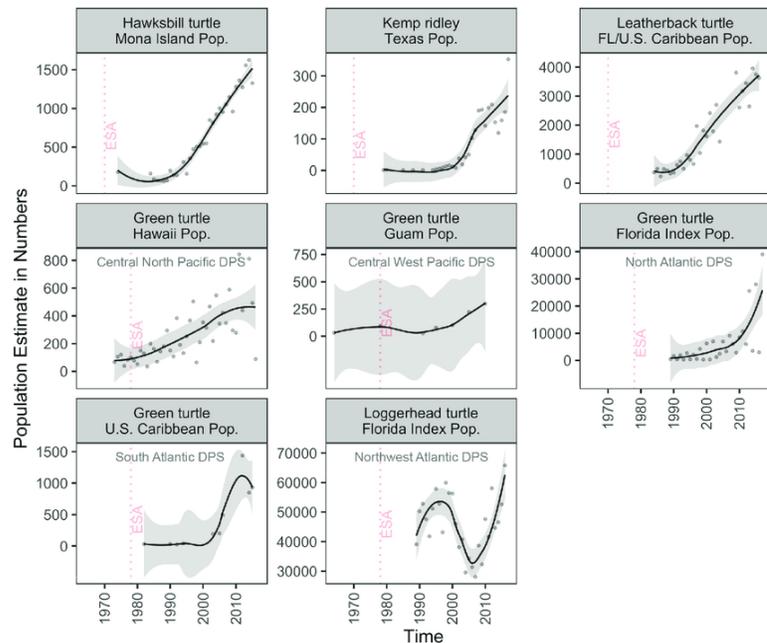


Figure 2: Sea turtle population trajectories since the US Endanger species Act of 1973; Valdivia et al., 2019

originally established in 1937 under the title Cape Hatteras National Seashore Recreation Area. This name was specifically chosen to allow hunting on park lands, a special allowance that was uncommon at the time. Along with the natural resources this park holds, the area has rich historical significance. Maritime history remembers the shoals and sand bars of Cape Hatteras as the graveyard of the Atlantic, a name the area earned with over 600 shipwrecks recorded (Thompson et al., 2019). The Outer Banks has been a focal point for environmental changes since the 1800s. Some of the earliest environmental movement here began as a result of the living dunes. These living dunes are large sand formations that slowly move in the direction of the wind; often covering vegetation and trees thereafter referred to as ghost forests. At the time, these movements say the moving dunes as a sign that man had too greedily harvested lumber from the island causing the soil to come unrooted; However, modern science has shown that these dunes are a natural part of the Outer Banks ecosystem (Senter, 2003). Regardless of the veracity of the claims, the Outer Banks was and continues to be a center piece in the discussion of climate change and ecosystem alteration.

One of the major modern issues facing this area is erosion as much of the land area here is coastal. To date, roughly \$63.8 million has been spent on beach nourishment which is the dredging of sand from offshore to replenish the sand lost to erosion. Over 6,700,000 cubic meters (8,800,000 cubic yards) of sand have been moved for this purpose since 2014 (Dare County North Carolina, c2020). Due to the proximity of Cape Hatteras National Seashore to the general population and the impact its natural resources have on the economy of the area, beach nourishment is accomplished on park lands through a series of natural resource impact assessments (National Park Service, c2020a). When beach nourishment takes place, land managers seek to improve the storm resilience of the area through the recreation of dunes and increasing buffer zones between ocean and human lands (Dare County North Carolina, c2020).

2.4 Management Strategies

The management of sea turtles and sea turtle nesting areas can take many forms. At Cape Hatteras National Seashore, there are two points of intervention in the lives of sea turtles for which the park has jurisdiction. First, because their prime nesting sites are on the beaches maintained by the park service, managers can take a wide range of actions to manage and maintain these habitats and nests. This avenue of management can help to bolster sea turtle populations through ensuring the success of eggs and nests and survival of juvenile turtles. This park chooses to rope off sea turtle nests, excavate and move nests at risk for flooding, and manage nest predators. The second point of intervention is stranded or beached turtles. This avenue of management can help rehabilitate injured or otherwise terminal adult turtles. This park chooses to

attempt to rehabilitate any turtle found stranded and still alive regardless of the cause of stranding (Thompson et al., 2019; Moore et al., 2010).

2.5 Systemic Challenges to Management

When viewing this issue from the perspective of a federal land manager, the means and methods by which one can affect change are not entirely clear. Preeminently, the public has a broad impact on a federal manager's ability to effectively

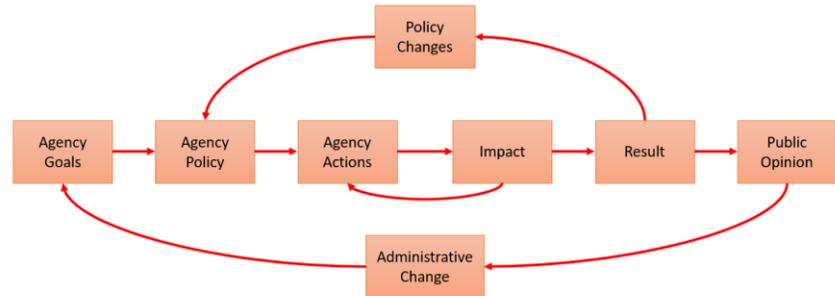


Figure 3: Conceptual model for Federal decision making

institute a policy. As shown in Figure 3, park managers can formulate a goal statement, create a policy to reach that goal, and perform actions which move the system towards a desired outcome. Throughout this process, managers can modify their actions if the impacts are not generating results or change their policies if those results do not reach the desired goal. The public's opinion comes into play when the formulated goals of a federal management agency do not align with those of their constituents. In this scenario, the public, potentially through referendum, can change the administration of these lands thereby changing that agency's goals. Considering this system is important for federal managers when creating these goal statements otherwise the changes they are hoping to implement may not be able to create lasting changes.

When considering the natural systems in conjunction with the anthropogenic, the number of problems faced by land managers increase. Especially for a charismatic species such as the sea turtle with many non-profit organizations dedicated to them and much news coverage, there is a great pressure from the public to effectively and efficiently conserve and protect (Ducarme et al., 2013). However, in the case of the sea turtle specifically, many of the hazards come from areas in which land managers do not have jurisdiction. Additionally, it is the actions of human beings, and not the natural systems these land managers regulate, that are predominantly hampering the growth of sea turtles. There is a cognitive dissonance that arises from the population where management action to conserve these species is desired but simultaneously, they desire access to the same resources for recreation.

Finally, land managers should consider the best available scientific data when formulating a goal for endangered species management. While, alone, this portion of the goal formulation would be as simple as weighing multiple peer reviewed publications, in conjunction with the public's opinion and the mandates set on managers from the agency's creation, goal statement formulation becomes a strenuous task.

Accounting for these three, at times opposing, viewpoints will ensure that a land managers goals are lasting, effective, and efficient.

3 Decision Space

3.1 Purpose of Federal Resource Managers

As discussed in section 2.5, federal land managers function based on a set of founding principles which arise both from the creation of their agency and the creation of their specific management unit. These principles determine how a manager can interact with the natural and anthropogenic environment to affect change. While this can sometimes serve to limit the scope of management actions, it more often justifies a land manager's actions and ensure that those actions are carried through. Additionally, founding principles and agency mandates, when in conflict with best available science or public opinion, can be molded to better suit the new realities that a manager faces. As a National Park Service unit, Cape Hatteras National Seashore has a limited scope of authority; their area of authority is the land and shore (Thompson et al., 2019).

3.2 State and Local Stakeholders

At Cape Hatteras, there are a large number of groups which hold a stake in the management of the coastal resources. Primarily, there are the residents who call the Outer Banks their home. Effective management of the dunes and mitigation of and adaptation to numerous threats allows these individuals to continue living on the island comfortably. Fisheries along the coast rely on the proper management of the land as well as the maintenance of the marine ecosystem to facilitate their trade. Additionally, there are a number of non-profit groups that lobby for the interests of sea turtles in the area. One such group is the Network for Endangered Sea Turtles. This group works in conjunction with local agencies and the aquarium to facilitate rescue and rehabilitation operations. Finally, there are a few important local agencies: the North Carolina Wildlife Resource Commission is primarily responsible for rule and regulations regarding the coastal fisheries, the county of Dare works closely with the National Seashore to represent the interests of the various cities along the Outer Banks, and

3.2 Public Perceptions

As mentioned previously, sea turtles are considered a charismatic species (Ducarme et al., 2013). On a five-point Likert scale, researchers in Greece found visitors ranked the importance of protecting marine turtles a 4.12 (Jones et al., 2011). However, when asked about measure to fund management, such as entrance fees and accommodation taxes, visitors generally responded negatively (Jones et al., 2011). This creates a clear paradox for land managers. Additionally, a study of visitor perception in Queensland, Australia found that ingestion of plastics and disease were some of the highest cited threats to sea turtles (Feck and Hamann, 2013). This is in contrast to a

survey of expert opinions which found disease to be a consistently low-ranked threat (Donlan et al., 2010). Education and dissemination of information will be a key factor in the collaborative process as bridging the gaps in knowledge between managers and constituent will lead to a joint goal.

Table 2: Stakeholders and Perspectives

Stakeholder	Stake in Sea Turtle Management	Possible Perspective
National Park Service (Cape Hatteras National Seashore)	Mandated to protect natural ecosystem and endangered species	Must manage a balance between visitor use and natural ecosystems.
North Carolina Wildlife Resource Conservancy	conserve North Carolina's wildlife resources and provide opportunities outdoor enthusiasts recreation	Must manage a balance between visitor use and natural ecosystems.
Marine Fisheries	Livelihood depends on ecosystem services and regulations	Depends on the marine resources being accessible for income.
Local Homeowners	Utilize the coastal resources for recreation and livelihood	Wants the coastal resources to remain open for visitors for recreation. Depends on those resources during peak season for income.
Local Businesses	Income relies on tourism to coastal resources	Depends on coastal resources being open to visitor during peak seasons.

4 Modeling and Creating a Goal Statement

4.1 Modeling Sea Turtle Systems

Much research has been done into the population dynamics of endangered species. For the sea turtle, most of this research has been into egg survivorship, fecundity, and delayed maturity (Crouse, 1999; Crouse et al., 1987). While these factors form the basis of sea turtle population growth, they are modified by a number of anthropogenic factors that will be described in greater detail in following sections. From a system thinking perspective, one must include the effects of human pollution, fisheries, and harvest on adult population numbers, the potential impact of invasive species on habitat, nests, and food, and the potential impacts of climate change and sea level rise. To model the variation in sea turtle species in a higher fidelity, these ever-changing variables must be mapped by their impact on the species. Once these impacts are mapped, a model can be created to show where the species is headed currently and what can be done to move the system into a desired trajectory.

The human systems are arguably more complicated than the natural. There exist numerous stakeholders in the oceanic and coastal ecosystems in addition to many regulating agencies. The largest stakeholder groups around Cape Hatteras National Seashore include the National Park Service, coastal homeowners, the North Carolina

Division of Coastal Fisheries, and numerous non-profit groups directed towards the conservation of wildlife on the land and sea.

4.3 Determining a Desirable Future

The National Park Service is a wide-spread federal institution with over 12,000 annual employees and maintains over 400 park units. Often, a management strategy that work for one park would not work for another. This managerial flexibility is key the continued success of the park service in its mission to constantly balance the needs of individuals with the needs of the natural ecosystems. Conversely, this phenomenon can also lead to a divide in management goals. When two individuals are working through different methods to reach the same goal, an agency thrives; however, when these goals are different, an agency will suffer. An example of this exists in the response to hazards threatening sea turtle nest. At Cape Hatteras, turtle nests are only moved when threatened by inundation; at Padre Island, all turtle nests are excavated and incubated to ensure egg success (National Park Service, c2020b). Here there is a disconnect between manager goals. To standardize the goals of the National Park Service, an inter-park team should be created to collaboratively determine what the ultimate goals of wildlife management are. What is the desired future? Here we have reached the wicked problem that Cape Hatteras National Seashore; how can a wide-ranging federal agency standardize its management goals while maintaining agency flexibility in regards to sea turtle management.

In leu of a far-reaching and time-consuming collaborative process, this study will utilize the goal statement "Managing for Sea Turtles within the National Park Service: Balancing federal mandates, public opinion, and best available science at Cape Hatteras National Seashore" to orient its findings and recommendations.

5 Sea Turtle Vulnerabilities

5.1 Injury

Sea turtles are susceptible to a wide range of injuries. While their shells have developed to withstand predation at sea, as is shown by the lack of direct predators for adult sea turtles (Sea Turtle Conservancy, c2020a), they are still highly vulnerable to anthropogenic sources of injury. A study of sea turtles in the Galapagos Marine Reserve found, of the injuries at feeding and nesting sites, boat strikes caused a majority of damage to sea turtles (Denkinger et al., 2013). Furthermore, watercraft collision consistently causes ten to fifteen percent of all sea turtle stranding worldwide (Seaturtle.org, c2020a). Another factor to consider is the incidence of entanglement among turtles. A study of turtles in



Figure 4: Sea turtle consuming marine debris; Sea Turtle Image Library, c2020

the Mediterranean Sea found anthropogenic sources caused 52% of all sea turtle stranding and, of those stranded turtles, 35% showed signs of previous capture in fishing equipment (Casale et al., 2010).

5.2 Food

Vulnerabilities exist in the food supply of sea turtles. While most sea turtle species are omnivorous and can feed on a wide range of flora and fauna, three distinct exceptions are highly vulnerable to food destabilization. The leatherback sea turtle's primary source is jellyfish; 80% of their diet consists of some type of jellyfish. This makes them highly dependent on their access to substantial populations of jellyfish. The hawksbill sea turtle, like the leatherback, has a single predominant food source in oceanic sponges. Finally, green turtles are exclusively herbivorous as adults (World Wildlife Fund, c2020). While these three species of sea turtle face a higher vulnerability than the other four, the vulnerability to loss of food source is low overall. The complex diet of sea turtles, however, does open the door to a unique vulnerability in food confusion. This food confusion can result in death due to perforation of esophagus or bowels, intoxication, and blockage of the esophagus (Mascarenhas et al., 2004). Because anthropogenic marine pollution so closely mimics prey species, sea turtles are highly vulnerable.

5.3 Habitat and Nesting

Because they spend much of their lifetime at sea but return to the coast for nesting, sea turtles are vulnerable to several factors regarding habitat. Oceanic habitat changes in acidification, temperature, and currents could drastically impact sea turtles. Research has shown that temperature is a major determinant in the resulting sex ratios of juvenile turtles (Mrosovsky, 1994). These populations are moderately vulnerable to sex ratio imbalance as it can lower the ability of future generations to reproduce effectively. Additionally, these populations are moderately vulnerable to change in oceanic currents as this is thought to be the main method of long-distance migration for the species (Luschi et al., 2003). Additionally, while in oceanic habitats, sea turtles can be stunned by quick changes in temperature. Stranding data suggests this is the major factor driving sea turtle stranding and thus they are highly vulnerable to cold-stunning events (Seaturtle.org, c2020b).



Figure 5: Cold-stunned sea turtles; Sea Turtle Image Library, c2020

On land, at nesting sites, sea turtles are vulnerable to several factors, nest destruction, nest area degradation, predation, and nest area loss. Nest destruction results in the loss of a majority of eggs and reduces the already low success rate for hatchling success in sea turtles (Wyneken et al., 1988). Sea turtles are highly vulnerable to nest destruction as they possess little defense and the nests are buried but close to the surface (Cox et al., 1994). Nest area degradation results in a reduced number of nests being laid in preferred conditions and thus lowered hatchling success; sea turtles are highly vulnerable to this factor (Garcia, Ceballos, & Adava, 2003). Hatchlings and eggs are highly vulnerable to predation because adult sea turtles leave nest unguarded over the duration of the nesting season; hatchling predation is the major factor reducing hatchling success (Wyneken et al., 1988). Finally, nest area loss results in a complete loss of nesting area and significantly less eggs being laid in a nesting season. Sea turtles are highly vulnerable to this as the availability of nest areas is shrinking worldwide (Fuentes et al., 2012).

5.4 Disease

While diseases and parasites are a common occurrence among adult sea turtles, they are only mildly vulnerable to their effects (Sea Turtle Conservancy, c2020a). A small portion of stranded sea turtles annually are reported as disease afflicted (Seaturtle.org, c2020b). Parasites and diseases can hamper the ability of sea turtles to maneuver or reproduce, but only moderately (Sea Turtle Conservancy, c2020a). Sea turtle eggs, conversely, may be highly impacted by parasitism and disease. A study of Mediterranean sea turtle eggs found 23% of nest to be infested with insect larva and of those nests 10% of eggs were affected (Broderick & Hancock, 1997).



Figure 6: Sea turtle hatchling predation at Cape Hatteras; Sea Turtle Image Library, c2020

Table 3: Vulnerabilities

Vulnerability	Impact	Level of Vulnerability
Injury	Debilitation or death	Highly Vulnerable
Entanglement	Debilitation, suffocation, or strangulation	Highly Vulnerable
Rapid Temperature Shifts	Cold-stunning	Highly Vulnerable
Loss of Food	Starvation or debilitation	Mildly Vulnerable
Ingesting Debris	Almost always results in death	Highly Vulnerable
Habitat Degradation	Nest success rates drop sharply	Highly Vulnerable
Habitat Loss	Loss of nesting areas	Highly Vulnerable

Disease	Low impact to adult sea turtles Potentially moderate impact to egg success rate	Moderately Vulnerable
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6 Hazards to Sea Turtles

6.1 Predation and Invasive Species

Competition for resources from other animal species and predation are the two environmental factors that contribute to the success of a species. Sea turtles, having a wide range of habitats, must compete with a variety of plants and animals for space and food. The most hazardous species to sea turtles are those that are novel, destructive actors, invasive species, in the ecosystem. One emerging example of this is the interaction of wild boar species in coastal ecosystems. These opportunistic predators will often capitalize on the unattended sea turtle nests resulting in total or partial destruction. Furthermore, the tenacity with which these invasive predators adapt to environmental conditions make management an arduous task (Engeman et al., 2019). In areas where wild boars were initially left to populate, an example being parts of the southern mid-west, they now require intense management. In addition to their predation of eggs, wild boars also have a habitat degrading effect. Their tendency to turn through the ground for roots and other sustenance can exacerbate erosion in sensitive areas. At Cape Hatteras National Seashore, this could lead to loss of dune structure and increased erosion of the shoreline further reducing the quality of available sea turtle habitats (Engeman et al., 2019). Management of this invasive species is not impossible, however. Natural resource managers who saw the negative effects of wild boars early, such as Back Bay National Wildlife Refuge, were able to effectively prevent them from becoming entrenched in the ecosystem (Virginia Department of Game and Inland Fisheries, c2020). Because sea turtles are highly vulnerable to ecosystem degradation and nest destruction, invasive predator species such as wild boar pose a tremendous threat.

Another emerging hazard to sea turtles from invasive species comes from the appearance of large sargassum blooms. In these areas where sargassum has seen a population explosion, beaches become covered in the seaweed. Researchers have already seen the degrading effect this has had on sea turtle nesting habitats (Maurer et al., 2015). While areas as far north as Cape Hatteras National Seashore have not seen as much impact from sargassum inundation, the degradation of sea turtle habitats around the globe can have a negative effect on all sea turtle groups due to their propensity for long distance migration (Luschi et al., 2003). Because sea turtles are highly vulnerable to nest habitat loss, this hazard poses a serious threat.

6.2 Temperature Changes

Oceanic temperature changes have several effects on sea turtle populations. Primarily, it can extend the available range of sea turtles. Research has found this to have a major positive effect on the number of cold-stunning events. The temperatures in these areas tend to drop rapidly causing these cold stunning events. Data suggests that there has been an increase in numbers of cold-stunning events over the last ten years (Figure 7) (Fuentes et al., 2012). Another impact of oceanic temperature change is its effect on the sex ratios of juvenile sea turtles. Because sea turtles are highly vulnerable to cold-stunning and moderately vulnerable to altered sex ratios, Oceanic temperature change can be considered a threat (Mrosovky, 1994; Griffin et al., 2019).

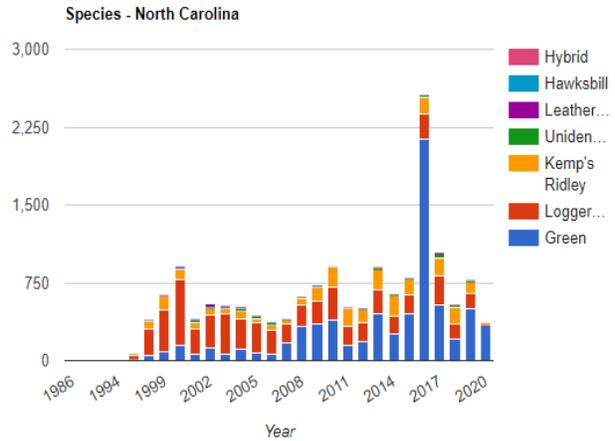


Figure 7: Annual cold stunning numbers for Cape Hatteras NS; Sea Turtle Rehabilitation and Necropsy Database, c2020

6.3 Sea Level Rise and Erosion

Sea level rise has a number of negative effects on sea turtles and their habitats. In Cape Hatteras National Seashore, sea level rise has shown to positively effect erosion on the island. The erosion of coastal habitats reduces the access of sea turtles to viable habitat and in increases the incidence of nest flooding. Additionally, sea level rise can result in the construction of sea walls and other flood mitigation devices in areas of high human development; these constructions also reduce the access to viable nesting habitats (Figure 8) (katselidis et al., 2014; Moore et al., 2010). This flood mitigation map of Eastern North Carolina, of which Cape Hatteras NS constitutes much of the coastline, shows the areas most likely to receive funds to construct flood mitigation projects. Cape Hatteras NS will be highly affected by sea level rise through both flooding and erosion (Thompson et al., 2019) and, because they are highly vulnerable to habitat loss, habitat degradation, and nest destruction from flooding, this poses a serious threat to sea turtle populations therein (Walters et al., 2014).



Figure 8: Shore hardening structures preventing sea turtle nesting; Sea Turtle Image Library, c2020

6.4 Fisheries

Unintentional catching, or by-catch, of sea turtles is a frequent occurrence for marine fishery operations. Long lines, nets, and other methods are notorious for their rate of capture for sea turtles. In a study of expert opinions on threats, fishery by-catch was consistently rated as one of the top threats to sea turtles (Donlan et al., 2010). Estimates vary for the annual impact of by-catch on sea turtle populations. Many sources claim trawl lines kill at least 150,000 turtles a year. Longlines are known to cause the deaths of roughly 200,000 loggerhead sea turtles and 50,000 leatherback turtles every year. The greatest uncertainty comes from the use of gill nets as they are widely used by non-commercial and small-scale fisheries around the world with little oversight (Sea Turtle Conservancy, c2020b). Their impact to sea turtles is expected to be comparable to that of trawl lines. These numbers alone show the severity of the impact that fishery by-catch has on sea turtles.

There currently exist a few alternative technologies which can minimize the impact to sea turtles and reduce the rate of by-catch. The introduction of circle hooks in numerous marine fishery operations has shown a notable reduction of bycatch rates, 90% in some cases (Reducing sea turtle mortality & bycatch in fisheries, c2020). The total adoption of these technologies, however, will require either some regulation or commercial advantage to institute.

6.5 Pollution

Anthropogenic pollution in relation to sea turtles has become a widespread topic in recent years. A number of groups has pushed for the elimination of plastic straws specifically due to their impact on marine turtles. Not only can sea turtles become entangled in a number of plastic product floating through the ocean, they can mistake them for a common food source – the jelly fish (Sea Turtle Conservancy, c2020a). Because they are vulnerable to food confusion, this hazard proves a serious threat to sea turtles.

6.6 Habitat Loss and Degradation

As sea turtles utilize coastal areas for nesting, the result of years of coastal development has been devastating. Development has pushed sea turtle nesting areas closer to the shoreline, increasing the risk of nest inundation (Thompson et al., 2019). Additionally, the impacts from sea level rise have led to many developed coastal areas to construct shore hardening devices, such as sea walls. These constructs further reduce the nesting areas and in extreme cases can eliminate them altogether. Artificial lighting from these developed areas can also discourage turtles from nesting in these preferred areas in favor of riskier, flood-prone sites. Juvenile sea turtles can also be disoriented by artificial lights in these areas increasing the possibility of predation (Sea Turtle Conservancy, c2020a). The vulnerability of sea turtles to habitat loss and degradation makes coastal development and sea level rise severe hazards.

Table 4: Hazard Scenarios

Hazard	Vector of Impact	Hazard Scenario
Invasive Species	Predation of adult and hatchling turtles	Invasive feral hogs destroying large numbers of nests for food and increasing erosion of dunes. Massive sargassum blooms blanketing coasts and interfering with sea turtle plantings.
Oceanic Temperature Changes	Changing sex ratios Cold-stunning events	Warming ocean temperatures lure sea turtles into northern climates where ocean temps can drop quickly.
Sea Level Rise and Erosion	Loss and degradation of habitats	In conjunction with coastal development, this can result in a total loss of shoreline. Will increase the likelihood of nest flooding.
Fisheries By-Catch	Entanglement Injury	Without introduction of new line and net technologies, will result in high volume of by-catch incidents.
Plastic Pollution	Entanglement Food confusion Injury	Plastic production still outpaces recycling and clean-up efforts. Will significantly reduce the capacity for sea turtles in oceanic habitats.
Coastal Development	Loss and degradation of habitats	Artificial lights confuse hatchling turtles increasing predation. Sea level rise mitigation in developed areas often come at the expense of coastal habitats.

7 Foresight for Sea Turtles Habitats in Cape Hatteras

7.1 Sea Level Rise and Erosion

Sea level rise will continue to be a pressing issue for both human and natural systems along the coast. For sea turtles, an increase in shore hardening along developed coasts will constitute a major threat to nesting areas. Figure 9 shows areas along the outer banks where shore hardening will be likely to take place, areas in red and brown being the most likely (Sea level rise planning maps, c2020). Cape Hatteras National Seashore will likely be faced with the issue of a shrinking park as erosion and sea level rise continue (Moore et al., 2010). Mitigating this shrinkage of the ecosystem will be Cape Hatteras National Seashore's main method of assisting in the conservation of marine turtles in the years to come.

7.2 Invasive Species

The growth of invasive species in the United States continues to present a problem for natural resource managers. Managers must determine whether novel species are truly an invasive threat or can integrate into the native ecosystem. An example of an integrated species is the coyote who, in some ecosystems, has begun to fill the role left vacant by the now endangered wolf species. Conversely, wild boars have shown to significantly degrade a number of biomes when introduced, namely wetlands (Engeman et al., 2019). Land managers will also have to contend with an expansion in plant species such as sargassum which threaten to cover sea turtle habitats making them unusable (Maurer et al., 2015). These species will be a major wild card in the effort to conserve marine turtles as their impacts are varied, meaning their impact could vary depending on the species.

7.3 Plastics and Pollution

Plastic pollution is a constantly growing concern for marine ecosystems (Mascarenhas et al., 2004). The pace at which plastic is produced significantly outpaces the pace at which it is recycled. Additionally, single-use plastics are seeing an increase in use among average consumers for its cheap production. Some movements have recently emerged to counter this increasing use. Some localities have banned the

NC SEA LEVEL RISE PLANNING MAPS
County: Dare (Hatteras)

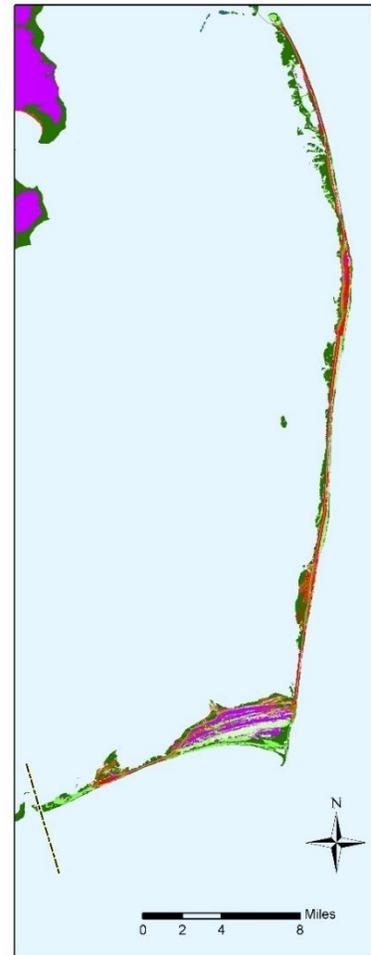


Figure 9: Projected funding for shore hardening in the Outer Banks, NC; Sea level rise planning maps, c2020

usage of plastics for items such as grocery bags. Limiting the buildup of marine debris from plastic pollution will be a major factor in the conservation of sea turtles around the world into the future.

Table 5: Future Scenarios

Hazard Scenario	Non-desirable Future	Desirable Future
Sea Level Rise, Erosion, and Coastal Development	Coastal communities sacrifice coastlines by constructing seawalls to mitigate sea level rise. Sea turtle habitats are gradually reduced to unsuitability With little to no effective nesting area left.	Sea level rise mitigation and adaptation effort focus on preserving coastal ecosystems. Sea turtle habitats are made more resilient through living coastlines and beach nourishment.
Plastics and Pollution	Plastic production is increased, recycling efforts do not match production and disposal. Sea turtle populations are debilitated by harmful marine debris.	Plastic production is reduced, plastic products are replaced with sustainable and recyclable materials. Marine debris are removed from ecosystems.
Invasive Species	Harmful endangered species are allowed to thrive in coastal and marine ecosystems. Habitats are degraded and sea turtles' abilities to reproduce are lowered significantly.	Invasive species are managed effectively allowing sea turtles to continue effective reproduction. Non-harmful species are allowed to integrate into coastal and marine ecosystems.

8 Points of Intervention

Cape Hatteras National Seashore can directly intervene in this system in three major points – nesting, egg success, and juvenile survival. Strategies for ensuring the access of sea turtles to suitable nesting sites are paramount to continued protection. These strategies include the use of living shoreline rather than shore hardening, nest relocation for nests placed in unsuitable locations, and beach nourishment for areas significantly affected by erosion. These strategies will help to mitigate the impacts of habitat degrading hazards such as coastal development and sea level rise (Ashley et al., 2003). To counteract the impacts from hazards such as nest destruction and predation, managers can implement nest incubation strategies utilized in some park service units. This strategy fully excavates an impacted nest and incubates the eggs to ensure successful hatching (Kornaraki et al., 2006). Other strategies include marking off nesting site to prevent destruction from anthropogenic sources and closing off heavily used nesting areas to the public. Finally, to ensure a higher rate of juvenile success, many locations already practice predator management strategies to assist turtles to the

ocean. The optimal strategy for ensuring a healthy population of marine turtles will be in the combination of one or more of these strategies with partnerships and education programs to promote buy-in among constituents (Ashley et al., 2003; Baskale and Kaska, 2005).

Cape Hatteras National Seashore can also work together with local agencies who have more control and less boundaries to management. A prime example would be the North Carolina Wildlife Resource Conservancy. Because they regulate coastal fishing, they are an important gatekeeper to affect changes in critical areas of sea turtle habitats. A partnership here would help both prevent sea turtle losses and gather valuable data for managers in both agencies. Mandatory reporting for sea turtle by-catch would help facilitate knowledge of the issue off the coast of Cape Hatteras. Next, regulating fisheries to utilize new hook technologies would decrease the by-catch rate by a significant amount (Sea Turtle Conservancy, c2020b). Finally, Cape Hatteras National Seashore could utilize the inroads that state and local agencies have with local schools, businesses, and communities to facilitate information sessions and educational experiences.

9 Discussion and Conclusions

Organizing the operations of a large federal agency will not be a simple task. This task will require a protracted series of meetings and discussion to come to a conclusion. Once a goal statement is reached there will be further discussions as to the methods to reach it. Despite these challenges, it is imperative that this is done. Effective management for sea turtles will require a concerted effort of park managers modifying the system toward the same goal rather than toward potentially opposing goals. Furthermore, managers must be aware of the ever-changing environment in which sea turtles reside. Sea level rise, coastal development, invasive species, and marine debris being the most important factors to constantly monitor. Finally, it should be recognized that the public desires that measures be taken to preserve this charismatic species, but often does not connect manager's actions to the goal.

10 Recommendations for Management

10.1 Recommendations for Participatory Decision Making

Recognizing that ...

- Human use is often in conflict with the needs of natural system to function sustainably;
- Resource managers within the National Park Service lack a cohesive, agency-wide goal for management of sea turtles.

Understanding that ...

- Sea turtles are a charismatic species with high popular support for conservation;
- Sea turtles are threatened by more hazards than just those the National Park Service can control;
- Sea turtles are an endangered species subject to the Endangered Species Act of 1973

Acknowledging that ...

- The National Park Service is a federal agency bound by a federal mandate for action;
- The National Park Service often has limited resources at its disposal relative to the tasks it must accomplish.

It is recommended that the National Park Service ...

- Create an inter-regional collaborative decision-making task force to determine the desired future that can be used to create a goal statement;
- Perform a park-wide survey to understand the various methods used by each park unit and their justification for its use;
- Hold stakeholder meetings to discuss this issue with local fisheries, homeowners, and government agencies to discover their perspectives and inform them of the vulnerabilities of and hazards to the system;
- Create a management guideline that maintains the high level of agency flexibility while formalizing management goals to mitigate and adapt to the hazards to sea turtles;

10.2 Recommendations for Sea Turtle Management Strategies

Recognizing That ...

- Cape Hatteras National Seashore has a responsibility to protect the natural resources and wildlife within park boundaries;
- Invasive species present a novel challenge to land managers in a number of areas;
- Sea level rise and erosion are increasing threats to shoreline habitats.

Understanding That ...

- Sea turtles naturally have a low hatchling success rate;

- Sea turtle reproduction is struggling to match the rate at which they are removed from the ecosystem.
- The marine ecosystems around Cape Hatteras are managed in part by the NC Wildlife Resource Conservancy

Acknowledging That ...

- Sea turtle nest excavations can lower natural egg success ratios;
- No participatory model has been made for the National Park Service;
- Any collaborative decision-making process takes precious time;
- Any direct management of sea turtles will take place only within the park unit.

It is recommended that Cape Hatteras National Seashore ...

- Continue to mark off natural sea turtle nest locations to avoid destruction from human recreational activities;
- Close down sections of beach that have a high volume of sea turtle nests;
- Continue to excavate and relocate sea turtle nests that are placed in flood prone areas;
- Perform beach nourishment when erosion presents a clear and present danger to sea turtle habitats;
- Construct living coastlines along the most vulnerable areas of sea turtle habitat;
- Work in concert with the NC Wildlife Resource Conservancy to limit the use of long-line, trawl-line, and gill nets to reduce the impact of fishery by-catch;
- Perform educational sessions to promote the spread of best available science to local businesses, homeowners, and fisheries.

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