Biscayne National Park's Loggerhead Turtle Conservation Program in South Florida: An Analysis

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Summary

The loggerhead sea turtle (*Caretta caretta*) faces various threats throughout its life.. During nesting season, loggerhead hatchlings face obstacles such as nest predation, inundation due to erosion, recreational activities and debris entanglement; nesting females are threatened with beach armoring, nourishment, entanglement, and disturbance during nesting. Despite being given endangered status under the Endangered Species Act, and protection under various state laws and international treaties, the number of loggerhead nests in Florida has declined by 50% in the past decade. .

Biscayne National Park's sixteen year database was analyzed in order to determine its rate of hatchling success (the number of hatchlings assumed to enter the Atlantic), false crawls (when a nesting female arrives onshore with the intention of laying eggs but does not do so), and egg predation by raccoons throughout nesting years. In 2001 Biscayne National Park staff began to place wire mesh over loggerhead nests in order to prevent raccoons from predating on eggs. This paper divides nesting numbers into two groups: database logging for 1991-2001 and database logging for 2001-2008, in order to determine the efficacy of the mesh wiring intervention. Other factors are also considered, such as fluctuations in raccoon populations (due to an eradication program carried out by BNP staff) and nest inundation as a result of inclement weather.

An analysis of Biscayne National Park's (BNP) loggerhead sea turtle conservation program is important because BNP beaches are considered “transitional islands”, meaning they share characteristics of both barrier islands and hard rock coral keys. Barrier islands (and islands with barrier characteristics) are dynamic and often possess qualities that are unique and unlike mainland nesting beaches. As a result, conservation considerations on Biscayne National Park cannot be modeled after other published sites with similar data and must be analyzed on its own.

An average of 8.1 nests were laid between 2002-2008 versus a higher average of 13.7 nests

between 1991-2000. Hatchling success averaged at 58.6% and did not differ across beaches. The placement of mesh wiring was not shown to significantly reduce predation. Adelle Cove and Palm Cove beaches were shown to be more likely to be predated than others, with a 75% and 78% predation rate, respectively. These beaches were also found to have the highest number of false crawls.

Biscayne National Park staff can improve predation and false crawl rates by consistently checking nesting beaches and immediately removing debris from shores and dunes. Data logging should be consistent, and volunteer database training standardized. If the threat of predation is eliminated, inundation may become BNP's biggest problem in the future, particularly if South Florida weather patterns continue to be erratic.

Introduction

Loggerhead sea turtles (*Caretta caretta*) can be found in the temperate and tropical areas of the Atlantic, Pacific, and Indian oceans. (Bowen *et. al* 1993) Named for their relatively large heads, loggerheads can reach up to 400 lbs in weight, with a mean carapace length of 3 feet (Lutz & Musick 1997). Their powerful jaws allow them to feed on hard-shelled prey, such as conch. Loggerhead turtles are a highly migratory species--occupying terrestrial, oceanic, and neritic ecosystem zones throughout their lives--with females having been documented laying their eggs in Japan and then traveling over 7,500 miles to feed off the coast of Mexico (NMFS 2009). Loggerhead turtles do not reach sexual maturity until they are 30-35 years of age; this compounds the vulnerability of the species, as loggerhead turtles are exposed to a variety of threats before reaching reproductive age. Countries of paramount importance for loggerhead nesting are the United States and islands in the Arabian Sea off of Oman; these are the two main nesting sites for loggerhead turtles and are critical for the survival of the species. (Ross 1982, Ehrhart 1989)

The challenges faced by loggerhead turtles are vast, present throughout their entire lives, and exist across all three ecosystem zones. In the oceanic and neritic zones, the greatest threat to loggerhead turtles is entanglement in fishing nets, which leads to suffocation and subsequent death. Pelagic longline fisheries in the oceanic zone pose the greatest threat to juvenile loggerheads, while trawl bottom fisheries pose the greatest threat to juveniles and adults in the neritic zone, with trawl fisheries having been found to cause ten times more deaths than all other human-related deaths combined. (National Research Council 1990; Crouse *et al*. 1987, Crowder *et al*. 1994) In 1997, the United States required all trawling shrimping boats to attach Turtle Excluder Devices (TED) to their nets. TEDs allow for large bycatch, such as sea turtles and sharks, to escape by preventing their entry into the back of the net with a metal grid barrier and providing a small opening for escape. In 1989, the United States banned all import of shrimp from fisheries that did not use TEDs. (NMFS 2009[1]) Other threats to loggerhead turtles in the oceanic and neritic zones are entanglement in marine debris from abandoned fishing gear, entanglement in non-fishing debris (Witherington 2002), oil spills (National Research Council 1996, Viada *et al*. 2008), non-oil spill chemical pollution (Keller *et al*. 2006) and debris ingestion (Washington and Hirama 2006). Oil and gas activities, vessel strikes, dredging, cold water, and harmful algal blooms (Redlow *et al*. 2003) also pose a threat to juveniles and adults in the neritic zone.

The terrestrial zone poses a different set of threats to loggerhead turtles. Female turtles spend their entire lives in the ocean except for a short time on land when they deposit their eggs. During egg-laying, which occurs between late April and September, nesting turtles on a beach are very sensitive to stimuli; females will not lay their eggs if they are disturbed and will seek another location. Prolonged disturbances may cause a female to deposit her eggs into the ocean.(Murphy 1985; Johnson *et al*. 1996). Once a female lays her eggs she returns to the ocean, leaving her eggs vulnerable to various threats: predation, erosion and inundation, beach armoring and nourishment, coastal construction, illegal harvest, human recreational activity, beach vehicular driving, beach cleaning, and conservation/research activities (NMFS 2008; and see *Threats* below). If an egg survives the incubation period, a hatchling's biggest threat is light pollution; because they take directional cues from moon light, artificial lighting disorients them and often prevents them from reaching the water (Witherington and Martin 1996). Other threats to hatchlings are predation, beach sand placement (which prevents them from crawling out of their nests or reaching the ocean), and debris (which causes entanglement or prevents them from leaving their nest). (Tomas et al. 2002)

Legal Protection of Loggerheads

Federal Endangered Species Act

Both FWS and NMFS operate under the Endangered Species Act, which lists loggerhead turtles as a threatened as of July 28, 1978. Despite not being listed as endangered, both FWS and NMFS have given loggerheads full endangered status protection. This level of protection prevents the sale, import, export, transport, harassment, take, pursuit, shooting, wounding, killing, trapping, capturing, collecting, or attempt to do any of the above, of loggerhead turtles (ESA 1973). "Take" also includes the harming of wildlife, such as altering or degrading an animal's habitat in a way which impacts behavior patterns.

Federal protection for loggerhead sea turtles is divided between two federal agencies: US Fish and Wildlife Services (FWS), which resides under the Department of the Interior, and the National Marine Fisheries Service (NMFS), which resides under the Department of Commerce. FWS has legal jurisdiction over loggerheads on land, which means they oversee nesting females and their hatchlings; NMFS has jurisdiction over them in the ocean. In 1991, NMFS alongside FWS published the first loggerhead recovery plan, and in 2008 the agencies published a second recovery plan. The 2008 plan (NMFS & FWS 2008) listed thirteen recovery objectives, such as increasing the number of nests on recovery units that correspond to an increase in numbers of nesting females, the management of nest predation and nesting habitats, and the development and implementation of local, state, Federal and international legislation to protect terrestrial and marine habitats.

Neither the 2009 nor 1991 recovery plan designates critical habitat for loggerhead turtles. However, in July 2007 the Center for Biological Diversity and the Turtle Island Restoration Network submitted a petition to the Secretary of Commerce (through the National Marine Fisheries Service) to list a North Pacific loggerhead population segment, reclassify this population as endangered, and designate critical habitat. In the case that NMFS does not consider the North Pacific a distinct population, they are requested to reclassify the entire Pacific Ocean population. (NMFS 2007) Pressure from conservation groups resulted in NMFS assembling a biological review team (BRT) in 2008 in order to assess whether or not distinct population segments (DPS) exist for loggerhead turtles. Establishing DPSs is significant because it allows a DPS to be treated as a species and be given a specific status, one not necessarily shared by other DPSs.

In August 2009, NMFS published their 2009 loggerhead status review which highlighted their biological review team's findings with regard to distinct population segments (NMFS Status Review 2009). The biological review team concluded that there exist nine distinct population segments for loggerhead sea turtles. Furthermore, all DPSs with enough data to conduct a susceptibility to quasi-extinction analysis (SQE) showed a high likelihood of quasi-extinction (the lowest population-sustaining level) in the future. A matrix model framework suggested that all DPSs may decline in numbers, particularly in Northeast Atlantic, Northwest Atlantic, North Indian, South Atlantic, and Mediterranean Sea DPSs.

On March 2010, NMFS, NOAA, and FWS issued a proposed rule to list nine DPSs that qualify as “species” under the ESA. Two segments are proposed to be listed as threatened and the remaining seven as endangered. The notice also proposes to designate critical habitat to the two population segments (Northwest Atlantic, Northeast Atlantic) that have DPSs within United States boundaries. The proposal is currently under review, with public hearings underway. (“Endangered and threatened species.... Proposed rule”, 2010)

International

Loggerhead turtles have vast international protection. They are protected under CITES, the Convention on International Trade in Endangered Species of Flora and Fauna, a 173-party international treaty established in 1975 which deals specifically with wildlife trade. CITES gives loggerhead turtles the strongest protection under the treaty, listing them under Appendix I. Species listed under Appendix I are considered to be in danger of extinction, and all international commercial trade in these species is prohibited.

Loggerhead turtles are also protected under the Convention of Migratory Species of Wild Animals (CMS), a 110-party intergovernmental treaty which seeks to protect migratory wildlife and their habitat. The CMS provides a platform for communication between governments worldwide on issues pertaining to migratory species, and has fostered regional cooperation and building capacity by partnering with the International Union for Conservation of Nature (IUCN). Their goal is to conduct "strategic planning and training" workshops around the world (including South Africa, India, United Arab Emirates, and Vietnam), where, among other things, regional workshop attendees are taught conservation techniques from marine turtle experts (Hykle 2002). Loggerhead turtles have Appendix I and Appendix II protection under the CMS, with Appendix I species offered strongest protection under the treaty, which ranges from legally binding agreements to informal understandings. Specifically, loggerhead turtles are protected under the CMS *Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia* and the *Memorandum of Understanding Concerning Conservation Measures for Marine Turtles of the Atlantic Coast of Africa* (CMS 1979). The memorandum creates a conservation and management framework for its member countries that aims at reducing direct and indirect sea turtle mortalities by identifying conservation measures and facilitating communication and necessary partnerships between governments without the oftentimes burdensome technicalities required in legally-binding treaties (Hykle 2002)

The Specially Protected Areas and Wildlife Protocol of the Cartagena Convention (SPAW) also gives loggerhead turtles protection. Loggerheads have Annex II classification, which prohibits:

> 1) The taking, possession or killing (including, to the extent possible, the incidental taking, possession or killing) or commercial trade in such species, their eggs, parts or products;
>
> 2) To the extent possible, the disturbance of such species, particularly during periods of breeding, incubation, aestivation or migration, as well as other periods of biological stress." (UNEP & CEP 1983)

Lastly, loggerhead turtles are protected under the Inter-American Convention for the Protection and Conservation of Sea Turtles (IAC), an independent, regional treaty which came into effect in 2001 and is the only internationally-binding treaty dealing solely with sea turtles. The IAC requires its parties to:

> " ...protect and conserve marine turtles and their habitats; to reduce the incidental capture, injury and mortality associated with commercial fisheries; to prohibit the intentional take of, and domestic and international trade in, marine turtles, their eggs, parts, and products; and to foster international cooperation in research and management." (Hykle, 2002; IAC 1996-1999).

Because the IAC is a relatively new convention, it is difficult to know how effective it will be, though IAC-related literature appears predominantly hopeful. IAC ambiguities include, "the role of the Scientific Committee and the Consultative Committee, methods of financing the secretariat and for those signature countries requiring economic support to implement their programs," and, "...the inclusion of enforcement mechanisms and penalties for the non-fulfillment of the obligations the Parties assume under the Convention." (Namnum 2002)

State

The largest numbers of loggerhead nests in the North Atlantic Ocean are found in Florida (NMFS & USFWS 2008). At the same time, Florida has undergone large amounts of coastal development and has high numbers of tourists on beaches during nesting season. As a result, Florida enacted the *Marine Turtle Protection Act* (MTPA) in 1995, which among other things, requires a person to have a permit issued by the Florida Department of Environmental Protection in order to engage in any activity that affects sea turtle habitat, sea turtles themselves, and/or their nests. However, a permit cannot be denied for beach development, restoration, or nourishment if a relocation program for turtle eggs is enacted. Other legislation in the state, such as the *Coastal Zone Protection Act* and the *Beach and Shore Preservation Act* provide protection for sea turtles. The *Coastal Zone Protection Act*, which seeks to protect coastal areas from degradation of the environment, private property, and life, protects turtles by allowing the Florida Department of Environmental Protection to restrict coastal construction that interferes with sea turtle habitats as listed under the MTPA. The Beach and Shore Preservation Act regulates beach and shore construction and preservation projects such as beach nourishment and armoring by issuing permits. Sea turtle considerations must be addressed when the DEP grants these permits (Butler 1998).

The importance of terrestrial zone conservation in Florida

Appropriate conservation methods for the loggerhead turtle in Florida are of immense importance for the continuation of the species. Although Florida has the largest aggregation of loggerhead nests in the Atlantic Ocean*, there has been a 40% decline in number of nests in Florida since 1998* (NMFS & USFWS 2008). However, a decreased number of nests cannot necessarily be interpreted as a drop in the number of loggerhead turtles as a whole-- since juveniles take so long to mature, nest numbers may reflect deficiencies that occurred thirty years ago; or perhaps turtles are nesting elsewhere. Despite these limitations, nest counts continue to be the primary indicator for herpetologists who are assessing turtle populations (NMFS & USFWS 2008). If nest counts do turn out to be indicative of a species' success, then the loggerhead turtle population has significantly diminished in the past decade. Regardless, it seems clear that the conservation of remaining nests is of utmost importance, and that the best conservation approaches must be utilized in order to maximize hatchling success. These approaches will often vary when site-specific considerations are taken into account.

Threats and their Mitigation

The single biggest threat posed to loggerhead eggs in Florida and elsewhere is nest predation. The most destructive South Florida predators are, from highest to lowest: raccoons, ghost crabs, armadillos, foxes, domestic dogs, spotted skunks, and unidentified larval insects (Donlan 2004). Raccoons, which in some areas have preyed on over 90% of all nests (Bryant 1985), thrive near human environments due to unsecured trash and direct feeding. Besides the direct consumption of eggs, predators oftentimes expose nests, leaving them sensitive to changes in weather and to predation by other animals who otherwise would not have discovered the nest (Engeman et. al 2005). As a result, agencies resort to predator control measures, both lethal (removal) and non-lethal, in order to reach the 60%+ hatchling success rate mandated by the National Marine Fisheries Service and U.S. Fish and Wildlife Service's Loggerhead Turtle Recovery Plan (Stancyk 1982, NMFS & USFWS 1991).

Lethal predator control

Trapping has become a widely accepted approach for the removal of predators from loggerhead nesting sites (Barton and Roth 2008). Between 1985 and 1990, over one third of 39 important nesting beaches in the southeastern United States removed predators[1] (Ratnaswamy and Warren 1998). Various studies have been published that illustrate the effectiveness of predator removal (Engeman et. al 2005, Donlan and Eilcox 2008, Bain et al. 1997, Garmestani and Percival 2005). However, removing a native species, such as a raccoon, from a highly integrated and fragile ecosystem can have unforeseen detrimental effects in the ecological community. Barton and Roth (2008) show how removing one predator from an ecosystem can benefit secondary predators, sometimes leading to a more damaging effect for the prey species trying to be conserved. The importance of intraguild predation was seen

1 I was unable to find a more recent estimate.

during their study of four east-central nesting beaches, where both raccoons and ghost crabs preyed upon loggerhead nests. Because raccoons also fed on ghost crabs, their removal led to high densities of ghost crabs, who then fed on loggerhead eggs at levels higher than when both predators fed on the nests. Additionally, raccoons may serve other important roles in the ecosystem by doing things like dispersing seeds (Ratnaswamy and Warren 1998). However, in nesting sites that are inaccessible to daily or weekly non-lethal predator control measures, predator removal may be the only option. If this is the case, some suggest that an assessment of potential environmental impacts is done before the removal period. In somecases, predator removal on islands has shown to be effective in restoring ecosystems and preventing near-extinctions of species (Donlan and Wilcox 2008); however, other cases have shown predator removal to accomplish an opposite effect. LeCorre (2008) showed that when cats on an island in New Zealand were eradicated in order to preserve seabirds, the island's rat population exploded, and rats filled the predator “gap” that resulted from a lack of cats. Other studies (Boergstrom et al., 2009) have reported similar results.

Wire Screening

The most common form of non-lethal predator control is the wire screening of nests, which allows hatchlings to escape but prevents predators from digging for eggs. This method has been shown to be successful in deterring predators of turtle eggs while at the same time allowing them to continue to be part of the ecosystem (Ratnaswamy et al. 1997, Antworth et al. 2005). Ratnaswamy et al. (1997) showed that the screening of nests was more effective in reducing predation than predator removal, but that it requires a considerable amount of effort through daily nest monitoring and is more expensive than predator eradication methods. Researchers have also pointed out that metal cages distort the magnetic field surrounding the nest area. A study conducted by Irwin et. al. (2004) showed magnetic distortion rates at an average of 26% above the egg chamber and 5% at the bottom, which could affect hatchling orientation and navigational behavior, although the latter has yet to be tested. Cages constructed from magnetically neutral material would successfully address this problem. A third response to high predation rates is relocation. This approach, discussed in more detail in the next section, should almost always be a last resort.

Beach nourishment

Beach nourishment is performed when erosion has significantly decreased shorelines. Remotely-sourced sand is added to a beach in order to temporarily stabilize shorelines, or protect property, or for recreational use (Rumbold et al 2001). Although it has been argued that beach nourishment assists in restoration (Witham 1990), and can provide extra nesting habitat for sea turtles, who are particularly vulnerable to erosion (NMFS & USFWS 1991), nourished beaches can also significantly alter sand properties, moisture content, density, and resistance (Foley et al. 2006). The new qualities of nourished beaches can impair nesting sea turtle behavior by increasing abnormal nest construction and putting an energy strain on the nesting female, and can also affect hatchling success rates (Burney and Mattison 1992, Crain et al. 1995). Rumbold et al. (2001) showed that beach nourishment significantly reduced the number of nests laid on the first nesting season after nourishment, but that the second nesting season showed much improvement. However, due to continued erosion, nourishment must be done periodically in order to be successful. This should be taken into account when considering the start of a project. Additionally, nourishment projects should be selective in their fill material, as sand characteristics influence hatchling success; more loggerhead hatchlings reared in a laboratory survived when the size of incubating sand particles increased. Other considerations, such as the effect of nourishment on sand water salinity also need to be taken into account because hatchling success is also correlated with low levels of salinity (Foley et al. 2006).

Beach armoring

Beach armoring--or the placement of an unyielding structure (such as a jetty) parallel to the shoreline--is among the most harmful development-related factors that influence egg-laying behaviors in nesting females (NMFS & USFWS 2009). Beach armoring is done to temporarily protect property from flooding and to control eroding shorelines; however, armoring does not maintain sandy beaches, prevents long-term beach/dune recovery by altering wave and wind formations (NMFS & USFWS 1991), hastens erosion processes seaward of the structure (Pilkey et al 1984), and alters shoreline processes. Research shows that nesting grounds with beach armoring had fewer nesting attempts, and females who did appear on shore returned to the water without laying nests at average rates above those at non-armored beaches (Mosier 1998). Females who did lay nests in armored beaches did so at lower levels of the beach, which elevates the risk of egg inundation and erosion (Foley 2006). Another set of problems occur if the beach armoring itself is done during nesting season: heavy equipment can crush unmarked nests, water runoff and vibrations can damage nests, and nesting mothers and hatchlings can become entangled in construction gear. The Loggerhead Sea Turtle Recovery Plan provides a total estimated adjusted annual mortality rate of 123 loggerhead adult females due to beach armoring[2] (NMFS & USFWS 2009). Beach armoring is a serious threat to loggerhead turtles and most researchers agree that it should never be permitted in conservation areas.

Relocation

The relocation of nests, usually to a higher elevation on the beach, is often done to combat nest inundation as a result of erosion (Marcovaldi et al. 1997). Nests placed low on the beach have a lower hatchling success rates than those placed high on the beach, and conservation strategies striving to maximize hatchling success relocate nests for this reason (Dutton and Whitmore 1983, Wyneken et al 1988). However, because the gender of loggerhead turtle hatchlings is determined by nest temperatures,

[2] It is not clear whether this estimate accounts for the number of eggs that would have hatched if females had not been deterred and/or laid their eggs too low on the beach and that the adjustment represents the number of these hatchling females that would have made it to adulthood, or if it is only the mortality rate for nesting "mothers". If the adjustment is the former, it is also not clear whether it takes into account a female depositing her eggs into another beach or counts the deterrence as a total nest loss.

and low temperatures produce males, the relocation of nests from low to high elevation significantly skews sex ratios, producing more females than males since temperatures are higher farther away from the shoreline (Foley et al. 2000). Nesting sites in the Southern half of Florida are believed to produce predominantly female hatchlings. Because of this, nests laid near the shoreline are particularly important, since they have the greatest probability of producing much-needed males. Although lower nest sites have less hatchling success, Foley (2000) argues that it may be more important in Florida for a nest to produce a small number of males rather than be relocated and produce a higher number of females. Other researchers have questioned whether relocation of nests that would otherwise be inundated alters the selection process by preserving the gene pool of females who are unsuccessful nesters; however, further research has shown that female loggerheads scatter their nests, exposing them to a variety of incubation temperatures in both high and low areas, and that the overwhelming majority of loggerhead females (97%) have at least one unsuccessful nest (Pfaller et al. 2008).

Furthermore, Foley et al. (2000) showed that loggerhead clutches can withstand a considerable amount of inundation, more so than previously thought; one successful clutch withstood full inundation at least twice, was half inundated at least four times, and lower-half inundation occurred at least four other times. However, inundation, particularly in prolonged amounts, generally inhibits nest success. Nest relocation, then, should be a matter of last resort, done only when there is a good amount of certainty that very few to no eggs will hatch. In areas that are highly skewed towards female hatchlings, even a very small number of potential males may justify not relocating the nest.

Other problems associated with nest relocation are movement-induced mortality as a result of handling and transporting eggs (Witherington 1999).

Oftentimes, eggs are relocated to a hatchery. Hatcheries have serious drawbacks; they are expensive, require constant monitoring, require proper training which often does not occur due to funding restraints, have lower hatchling success rates, skew sex ratios, and exhaust hatchlings and create “fish feeding stations” when improperly released. Predation of loggerhead eggs is highest at hatchery sites, likely die to the high density of eggs in a single location (Whelan and Wyneken, 2007) Additionally, the creation of hatcheries accommodates the destruction of natural habitat and creates a dependence of human intervention by the natural world (Mortimer 1999).

Other threats

Other common threats to nesting sea turtles, their nests, and hatchlings are light pollution, debris entanglement, recreational activities, beach cleaning, illegal harvest, beach vehicular driving, and research/conservation efforts. Light pollution as a result of coastal development poses a particularly big threat to hatchlings. Each of these events has a surrounding set of issues and solutions, but addressing them all is beyond the scope of this paper because they generally pose little threat to site being examined by the author.

Site Specific Considerations

The qualities of the nesting site being examined by the author are unique and important. Elliott Key is a barrier island off the coast of Miami and lies at the northernmost part of Biscayne National Park (BNP). Loggerhead turtles nest on five of the beaches on the island. The interplay between loggerhead nesting success, conservation approaches, and barrier islands is not as well researched as mainland nesting sites, yet these sites are frequented by nesting females. Because barrier islands are dynamic and prone to constant erosion and inundation, they pose considerable challenges to nesting females (Lamont and Carthy 2007).

Biscayne National Park

Biscayne National Park is a 173,000 acre marine park in South Florida, nestled between the waters south of Key Biscayne and north of Key Largo. It is the largest marine park under the National Park System (NPS) with 95% of its acreage covered by water. The park is mostly accessed by private boat and serves as a grounds for swimming, fishing, cruising, camping, snorkeling, and diving.

Biscayne National Park has a long and rich history. The bay was discovered by Spanish explorers in the 1500s and named “Biscayne”, although debate about the origins of the word exists with some believing it to be a Native American word from the Tequestra tribe and others claiming the word comes from Biscanya, Ponce de Leon's home in Spain. The park is very difficult to navigate by boat without detailed knowledge of the park's water depth, which can go from very deep to less than one foot with little warning. This is evidenced by Biscayne National Park's 50 shipwrecks, many of which are accessible to snorkelers and divers.

Biscayne National Park, as it is today, almost ceased to exist; in 1961, thirteen area landowners unanimously voted to create the City of Islandia on what is now park land. They aimed to construct a highly developed urban landmass surrounded by water in order to attract tourists and wealthy landowners. A plan to dredge 8,000 acres of the bay in order to build a jetport went underway, and in 1962, plans to create Seadade, an industrial seaport, was introduced. The building of Seadade required the dredging of a 40-foot deep channel on the bay's flats.

Local outcry towards the proposed development of such a pristine, biologically diverse area gained momentum and evolved into a strong environmental grassroots movement. Those against the Islandia project wanted the land to be turned into a national park that would both provide refuge for wildlife and natural areas for people; they called their vision the Biscayne National Monument. Support for this movement escalated and reached an all-time high in 1968. However, a nasty battle ensued between South Florida and the thirteen landowners—who, angered by growing support for the national monument—brought in bulldozers and plowed down an area six miles wide and seven lanes long on Elliott Key, one of the bay's unspoiled islands (this tract is now referred to as “Spite Highway”)[3]. This seemed to help fuel efforts against Islandia, and later that year Congress created the Biscayne National Monument, describing the area as "a rare combination of terrestrial, marine and amphibious life in a

[3] “Spite Highway” is now an integral park of Biscayne National Park, serving as the park's only nature trail.

tropical setting of great natural beauty." On October 18, 1968, the bill was signed by President Lyndon Johnson. In 1980, the Biscayne National Monument was renamed Biscayne National Park, a name it holds to this day.

The park protects four primary ecosystems: mangrove shoreline, Biscayne Bay, the northernmost Florida Keys, and a barrier reef. Wildlife in the park is abundant and includes various species of whales, turtles, sharks, and fish (350 species), in addition to manatees, dolphins, sea birds, rays, butterflies, small mammals, crustaceans, and native plants. Various endangered or threatened species reside within park waters for at least part of the year, including the threatened loggerhead sea turtle (*Caretta caretta*).

Because loggerheads are protected under the Endangered Species Act and Biscayne National Park is federal property, the park is required to carry out a loggerhead sea turtle conservation plan. Besides monitoring/maintaining park grounds and their loggerhead turtle conservation work, BNP staff also house a coral nursery, conduct fish and creel surveys, host a lobster mini-season, respond to stranded and stray animals, and host reef/channel/beach clean ups.

Given that the number of loggerhead nests have significantly declined in the past decade, that barrier island conservation is understudied, and that the relocation of hatchlings in Southern Florida is oftentimes debated due to highly female sex ratios, an analysis of the conservation approaches of Elliott Key in South Florida is warranted and important.

Methods

This research project analyzes whether the loggerhead turtle conservation efforts of the National Park Service (NPS) at Biscayne National Park (BNP) are successful in protecting females and their nests during the nesting period. While there are various indicators of successful conservation, the author cannot address them all and instead will focus on two major indicators, hatchling success and false crawl rates over time: have hatchling success and false crawls increased or decreased since the program's inception, and how do hatchling success rates compared to the US Fish and Wildlife Service minimum of 60% success? Hatchling success is defined as the percentage of hatchlings assumed to enter the Atlantic (out of total eggs laid). Assessing the program's efficacy through hatchling success is reliable because it is directly associated with predation, which the Biscayne National Park program is responsible for reducing. Using other types of indicators, such as total *number* of nests laid over time, would not be an effective approach because it would require the factoring of measures beyond BNP's control; nest numbers are impacted by population numbers, which in turn are a consequence of neritic and oceanic zone threats and not a failure of terrestrial conservation approaches.

In 2001, NPS staff incorporated the placement of mesh wiring over nests into their monitoring program. Before 2001, nests were recorded and then left alone, and there was significant loss of nests due to raccoon predation. However, between 2004 and 2008, BNP staff, alongside University of Miami ecology faculty, trapped and euthanized seventy raccoons living in BNP's transitional islands. Raccoons were trapped in BNP campgrounds, visitor center, and one nesting area, Tannehill Beach.

The goal of mesh wiring is to prevent raccoons from digging up eggs, as the wire mesh poses a barrier between them and the eggs. The mesh wiring is not removed until hatchlings leave the nest; spaces between mesh are wide enough for hatchlings to climb through when they emerge. A z-test was used to compare hatchling success rates between two independent groups: nests before 2001 (pre-intervention) and after 2001 (post-intervention). Statistical analyses were done using MegaStat and Excel. Statistical tests used were t-tests, z-tests, chi-squared tests, regressions, one factor ANOVAs, and Pearson correlation coefficients. Alpha was set at .05 unless otherwise noted.

In addition to the “hatchling success over time” measure, the FWS 60% minimum hatchling success rate will be compared with BNP hatchling success rates, as the FWS number offers a reliable national standard that will provide a good comparison between BNP beaches and others beaches across the country.

False crawl rates also serve as an important indicator. A false crawl occurs when a nesting female goes on land to lay her eggs but returns to the ocean without doing so. False crawls indicate a problem with the nesting environment—such as beach debris, excessive vegetation or disturbance—and therefore *are* the sole result of a terrestrial zone complication (and therefore the responsibility of BNP).

NPS at Biscayne National Park has maintained a loggerhead nest database since 1991. The database is carried on-site and entered manually by BNP staff, interns, and volunteers when a nest or false crawl is found. Later, the information is transmitted into an Excel file. The BNP database serves as the primary tool for assessing BNP's success (as outlined above). The database is extensive and, among other things, includes:

- the date of an observed nest
- BNP beach where nest is located
- whether there was a false crawl or an actual nest
- the apparent reason for a false crawl
- whether there has been nest predation and if so then: what predator and the number of unhatched predated eggs
- the number of eggs
- the distance between the nest and the high tide line
- date of excavation by NPS personnel
- the total number of live and dead hatchlings
- the number of eggshells seen outside and seen inside the nest.

I analyzed BNP's database with the following questions in mind:

1. How do BNP's hatchling rates compare with the National Marine Fisheries standard of at least a 60% hatchling success rate?
2. Is there a relationship between predation and nest placement? Nest placement factors include beach chosen and the nest's distance to the tide line.
3. Is there a relationship between predation risk and the number of eggs laid in a nest?
4. Does predation in partially predated nests affect the hatchling success of remaining eggs in the nest?
5. Have BNP's hatchling success rates and/or false crawl rates changed over time?

6. Do certain beaches have higher false crawl rates than others?
7. Do certain beaches have higher predation than others?
8. Is there a relationship between predation and false crawl rates?
9. How has the implementation of mesh wiring on nests affected predation rates?
10. Has the raccoon eradication program affected predation rates?

To fully familiarize myself with the methods employed at BNP and also assist in their conservation efforts, I accompanied NPS staff twice a week and assisted with nest monitoring. During my time with NPS staff, I observed various facets of the program, including the consistency of monitoring; the consistency of data input; whether the data accurately represented field conditions; how soon after observation the data was entered; and whether the same staff goes every day, and if not, whether the data is entered the same way by everybody.

Additionally, I have assessed how well BNP's conservation efforts match up to the latest scientific literature on false crawl prevention and hatchling success promotion. The relevant issues in the literature for these areas include predator control, nest inundation, relocation, beach cleanups, beach armoring, and beach nourishment. However, it is important to keep in mind that the BNP beaches are on transitional islands, which often call for site specific considerations not covered in the literature.

Quantitative Results

The average number of nests laid per nesting season varied greatly between pre-intervention (before 2001) and post-intervention (after 2001) groups. Due to dwindling numbers of loggerhead nests across the country, post-intervention nest numbers were substantially lower, with an average of 8.1 nests (sd=7.5) laid between 2002-2008 versus an average of 13.7 (sd= 3.8) nests between 1991-2000.

The installation of mesh wiring in 2001 was not associated with a reduction in nest predation; in fact, the proportion of nests predated was higher after 2001, although at marginal levels of significance (z = -1.83; p, two-tailed = .067). (See chart 1.)

The distance between the nest and mean high tide was not correlated with the number of eggs predated in the nest (r_p = -0.185, df = 40, P > 0.20). (See chart 2)

Nests with smaller clutch sizes had less chance of predation than nests with larger clutch sizes, though at marginal levels of significance (b = -.38, t(9) = -1.97, p = .077).

The four beaches varied significantly in level of predation (χ^2 = 8.50; df = 3, p= .037). Nests on the beaches on Adelle Cove and Palm Cove were more likely to be predated than nests on other beaches, with a 75% and 78% predation rate, respectively. By contrast, Petrel Point had an average predation rate of 48% and Tannehill Beach's predation rate was 55%. (See chart 3)

Partial nest predation—the predation of a nest that leaves some eggs intact—did not affect the hatching rates of remaining eggs in a partially predated nest. (t= 1.31; df= 66; P = 0.196); that is, no significant difference was noted between the average number of unhatched eggs in unpredated nests and the average number of unhatched eggs in partially predated nests.

The beach chosen by a nesting turtle showed a near-significant impact on the ratio of nests to false crawls (Chi^2 = 7.59; df = 3; p= .055). (See chart 4). Different nesting years varied widely, and significantly, in the proportion of nests relative to false crawls (χ^2 = 35.44; df = 13; p = .0007).

Hatching success—the percentage of eggs that hatch per nest—averaged 58.6% and did not differ significantly across beaches (F = 1.49, df = 5 ,51, p = .209). (See chart 5) Furthermore, hatching success averages did not differ across years (F = 1.62, df = 12,44, p = .121). (See chart 6).

Qualitative Results

BNP staff are diligent about nest monitoring, and beaches are almost always monitored daily, save special circumstances such as inclement weather, boat failure, park events, and staff illness. However, at the program's inception in the early 1990's, monitoring was less strict—beaches were sometimes only visited once or twice a week. Within a few years, however (and certainly before the mesh wiring tactic began), the program strengthened with the addition of a new loggerhead monitoring supervisor and the establishment of a strong volunteer base. Despite these vast improvements, BNP's data logging continues to lack in rigor. Though better than data entries in the nineties, which were often completely blank besides the nesting date and beach location, various columns for recent years continue to remain empty where nesting information should have been entered. As late as 2008—the last nesting year analyzed—a nest's location on the beach (north, south, mid-beach, etc), for example, sometimes is not logged.

There is no standard training for volunteers and interns who input data; whoever is most experienced in the field will log the information while others look on. If newer volunteers are the only ones out monitoring and they find a nest, they attempt to record log entries on their own without guidance. Oftentimes local volunteers will help monitor beaches for years and become incredibly knowledgeable about data input, but paid loggerhead interns—who do the bulk of nest monitoring—change every summer. Due to these restrictions, the analysis was limited; some nests had to be completely omitted from analysis due to lack of information.

Data input seemed to accurately reflect field conditions. Data was logged on-site and hatched eggs (eggshells) were counted twice for accuracy.

All interns watched a marine turtle nesting video with nesting footage in order to learn how to spot turtle nests and differentiate them between species.

Discussion

Before delving into a discussion of the results, it is necessary to clarify a point: whenever a nest was predated, this predation never occurred after the nest was protected with mesh wiring. It always occurred in the time frame that existed between a loggerhead laying a nest and the nest being found by NPS staff. In this regard, the intervention was a resounding success. However, after 2001 a significant amount of predation continued to occur, with nests being consumed during the short time lapse between nest and wire-placing. When referring to nest predation (post-intervention) throughout this discussion, it should be understood that this always occurred before wire placement, either in the evening hours between a nest being laid and BNP staff arriving in the morning, or on weekends, when nests are not monitored.

Proportional continuity

A comparison of the proportion of predated nests showed no statistical significance between pre-intervention (before 2001) and post-intervention (after 2001) groups. That is, the ratio of predated to unpredated nests did not change on any beach, despite the installation of mesh wiring. Although this seems to suggest that the mesh wiring intervention had no effect on predation, one must consider other relevant factors.

One possibility is that lower nest numbers required raccoons to hunt for eggs more aggressively. Had the mesh not been placed, predation would have been much higher. If this is the case, then the lack of *increase* in predation proportions indicates the effectiveness of the intervention. That is, had there been no mesh, predation may possibly have reached 100%.

A second possibility is two-fold: 1) raccoons predate on nests during the first twelve hours of a nest being laid (making the wiring program useless), and; 2) raccoon population levels decreased in proportion to nest numbers. Indeed, when BNP staff monitored beaches they sometimes found a predated nest that had not been there the day before. This suggests that the nest was both laid and predated the previous evening. If so, wiring would have little effect unless staff remained on beaches throughout the night and immediately placed mesh over freshly laid nests.

With fewer nests laid and wiring possibly not posing a problem for raccoons, it would be unlikely for predation proportions to remain the same. However, there is reason to believe that raccoon numbers on beaches also decreased: a raccoon eradication program went into effect three years after the mesh intervention program went into place. Between 2004 and 2008, seventy raccoons were trapped and euthanized by Biscayne National Park staff; however, only thirteen of these were found on a turtle nesting beach, Tannehill Beach, with the vast majority of raccoons trapped on BNP campgrounds and near the BNP visitor center. It is unknown whether the fifty-seven raccoons euthanized on non-nesting areas were part of the raccoon population that predated on nests, though it is possible: raccoons are strong swimmers and climbers. This theory is further supported by the fact that predation was nonexistent in 2007 and 2008—and by then, fifty-one raccoons had been euthanized. On the other hand, the thirteen raccoons on Tannehill beach were not euthanized until late summer of 2007, suggesting that if raccoon eradication did play a significant role on predation, raccoons on non-nesting areas frequented nesting beaches and consumed eggs.

False Crawls

The number of nests and false crawls varied significantly from year to year. It is difficult to pinpoint why certain seasons have very high and low numbers of nests and false crawls because the loggerhead population is influenced by such a wide variety of factors, many of them beyond the shoreline in deep ocean. Since false crawls were part of the analysis, nesting years with statistically significant low numbers of false crawls and nests were years in which nesting females simply did not reach BNP beaches[4].

Years with statistically significant high numbers of false crawls on BNP beaches could be attributed to high levels of trash that wash on to nesting beaches from the deep ocean via gulf currents. Indeed, interviews with BNP monitoring staff revealed that staff are able to identify the cause of many false crawls by simply looking at the surrounding area; oftentimes a large piece of trash, such as a barrel, blocks the nesting female's path to the dunes. Other times, females will attempt to dig a nest atop a pile of trash, but then abandon the process and return to the ocean. One staff member recalled

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4 Reasons for drastic declines in nest numbers can be found in the background section of this essay.

finding one completed nest buried entirely in trash instead of sand, but this was an odd occurrence[5]; trash on beaches usually deters nest laying.

Hatchling Success

There was no statistically significant difference in hatchling success before and after the mesh wiring intervention (although, as mentioned earlier, this does not necessarily render the program unsuccessful). Fifty-eight percent (58%) of hatchlings on Biscayne National Park beaches were assumed to enter the Atlantic. Fish and Wildlife Service (FWS) provides a 60% minimum hatchling success target, making BNP's mean success rate slightly below the FWS minimum.

Predation was the single largest influence of hatchling success. The vast majority of unsuccessful hatchlings were predated on by raccoons. However, inundation accounted for some loss. A nest logged on July 22, 2002 in Tannehill Beach was protected with mesh before predation, but then listed as inundated. On July 2003, a nest in Tannehill Beach was found to be partially predated and mesh was placed to protect remaining eggs; it, too, was inundated. Unfortunately, incomplete data logging did not indicate whether the eggs in these two nests survived inundation. On August 2005, a nest on Petrel Point was found partially predated, with 57 eggs predated and 85 remaining eggs (for a total of 142 eggs in the nest). Mesh was placed to protect the remaining eggs but this nest was later inundated and the hatchlings never emerged. On November 11, 2005 the nest was excavated, and all eighty-five eggs were found unhatched. Because these eggs were not predated and nest inundation was noted, it is likely that inundation was the culprit, possibly due to a tropical storm—a common occurrence during summers in Florida, which produces heavy rainfall. No other nests were laid on Petrel Point that year, making comparisons difficult. An intact nest in Adelle Cove was logged on July 31, 2007 with 135 eggs laid. It was covered with wire and later became inundated. Only fifty-six of these eggs hatched, giving this nest a 41.5% hatchling success rate. The last two documented inundated

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[5] Unfortunately, this nest was fully predated by raccoons, presumably due to its access.

nests were logged on Tannehill Beach in 2008; neither had been predated yet both were total losses.

Inundation may also become a larger problem in the future if weather patterns become more erratic. Indeed, there were no logged cases of inundation prior to 2002, which may indicate that nests are becoming more inundated than previously. However, data logging was less stringent in the earlier years of the program and it may just be that inundated nests were not properly documented. If inundation increases in frequency, relocation may be discussed. However, as mentioned earlier, relocating eggs is risky—it skews sex ratios and eggs must be handled gently during transport. Transport issues are particularly relevant on barrier islands because eggs would need to be relocated by boat and ocean water can be choppy and unpredictable, particularly during sudden inclement weather, which Florida is frequently subjected to. For this reason, relocation may not be a viable solution for barrier island nests. Yet these nests may, in the future, be the ones that most need relocating; barrier islands are known for being highly erosive, and shortened distances from dunes to the tide lines increases the chance of inundation.

It is important to note that measuring hatchling success in Biscayne National Park with averages—which are then subsequently used to conduct certain statistical tests—may be problematic. High variability exists between years, both with predation and hatchling success, making averages a bad indicator of actual nesting numbers. For example, predation rates from 2003-2006 were incredibly high: 85%, 90%, 75%, and 92%, respectively. In these years, nearly every nest got consumed by raccoons, as they found nests before BNP staff scoured beaches the next morning. In 2007 and 2008, however, predation plummeted to zero for both years (although hatchling success was not at 100% due to inundation for these years). When these high and low numbers are averaged, the rate which emerges is hardly indicative of general predation and success rates for those years; nest numbers drastically change between years and the mean just becomes the closest distance between these numbers, rather than an accurate reflection of the years' highly erratic nesting dynamics. Although important, an interpretation of BNP loggerhead behavior that only utilizes statistical methods may be misleading.

The erratic nature of BNP database logging, particularly during the earlier years, may have affected my results. A substantial amount of nests were not included in my analysis because of insufficient information. This is particularly problematic because various comparisons were borderline-significant; the omitted information may have provided stronger results in one direction (full significance or none at all). Furthermore, non-standardized data input training for interns and volunteers may have resulted in inaccurate logging, which could have influenced the actual statistical tests that were performed.

Conclusion

The Biscayne National Park loggerhead conservation program has made significant strides since its inception in the early 1990s: monitoring has increased, data has been logged more consistently, a volunteer program has been established, and new staff has revitalized the program. Staff dedication to loggerhead conservation is admirable; however, steps can be taken to further improve the program.

BNP staff members and volunteers should be more vigorous with data input. All fields relevant to the nesting situation at hand—whether a false crawl or a successful nest—should be completely filled in. BNP staff may want to consider having a separate notebook for jotting down noteworthy nest information that is not covered in the database. Furthermore, it may be helpful for all new interns to receive data input training in order to assure consistency. It would be preferable for the same person to train interns throughout the years.

When large debris—such as driftwood, barrels, plastic tarps—is found on a nesting beach, BNP staff should make their removal a priority. Staff should return either the same day or the next day with the proper waste removal equipment and boat; the longer large pieces of debris stay on a beach, the higher the likelihood of it causing a false crawl. Because nesting beaches are monitored daily, new debris can be located quickly. False crawls due to debris obstruction can therefore be significantly minimized if this debris is immediately removed.

Future researchers who analyze BNP's nesting data should pay particular attention to predation rates. Predation was down to zero for 2007 and 2008, but it seems premature to say at this point that BNP's mesh wiring program was a success. Zero predation on just a couple years of positive data may have been luck. If predation is shown to increase again despite the continuation of nest wiring, then meshing strategies may need to be more aggressive: beaches can be wired earlier, perhaps at dawn, and weekends should not be exempt from beach monitoring. As it is, BNP staff should consider monitoring on weekends, as a nest laid on a Friday evening is left vulnerable until Monday morning. A backup network of local volunteers, on-call for certain days, should be established in case staff or intern emergencies prohibit their monitoring on a certain morning.

Future researchers should also continue to monitor nest inundation rates. If predation is finally controlled, inundation is likely to become BNP staff's next big challenge, particularly if weather patterns continue to be erratic and more tropical storms hit South Florida. Should inundation rates skyrocket in the future, nest relocation—despite its large setbacks—may need to be considered.

Finally, it is important to stress that many recent failures in nesting, such as the sharp decrease in loggerhead nests in Florida, should not be blamed on beach conservationists. Threats posed to turtles in oceanic and neritic zones (such as the recent April 20th BP/Deepwater Horizon oil spill which has been catastrophic for turtles, or pelagic longline fishing vessels) will impact population numbers and therefore nest numbers; smaller nest numbers are not the fault of Biscayne National Park staff. However, once a nesting female reaches the shore, it is the responsibility of beach staff to minimize risks posed on their territory, such as environmental deterrents that result in false crawls and predation that result in nest losses.

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FIGURES

1. PREDATION BEFORE AND AFTER MESH INTERVENTION.

Hypothesis test for two independent proportions

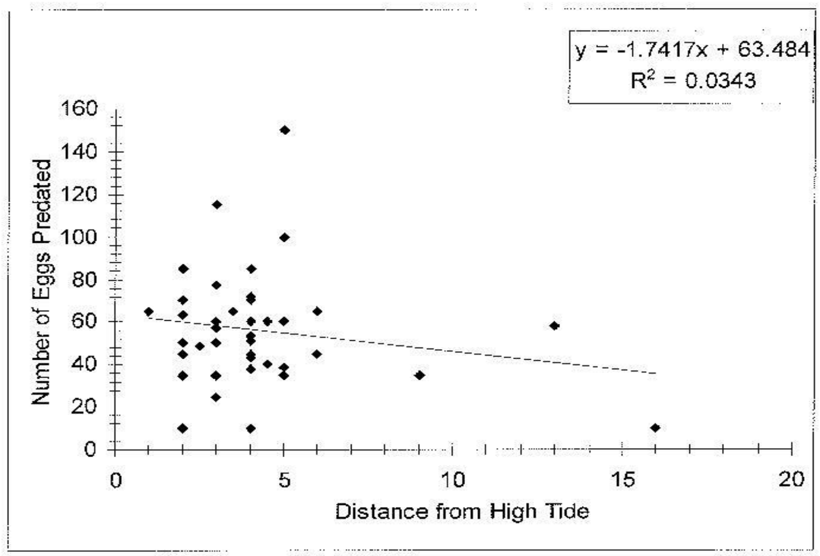
p1	p2	p_c	
0.5772	0.7193	0.6222	p (as decimal)
71/123	41/57	112/180	p (as fraction)
71.	41.	112.	X
123	57	180	n

-0.1421	difference
0.	hypothesized difference
0.0777	std. error
-1.83	z
.0337	p-value (one-tailed, lower)

The Z-test is -1.83 and the p value is .0337. Since it is less than x=0.05, we reject the null. Predation has increased since 2001.

2. RELATIONSHIP BETWEEN PREDATION AND NEST DISTANCE FROM HIGH TIDE LINE.

Excluding Zeros,



The correlation coefficient is -0.185. Since n=41, the critical value is 0308. The absolute value of the r is 0.185, which is less than the critical value. There is no statistically significant linear relationship between the nest's distance to the tide line and predation.

3. RELATIONSHIP BETWEEN PREDATION AND BEACH.

	Adelle Cove	Palm Cove	Petrel Point	Tannehill Beach
None	7	6	13	44
Partially/Totally	21	21	12	55

		Adelle Cove	Palm Cove	Petrel Point	nnehill Beach	Total
None	Observed	**7**	**6**	**13**	**44**	70
	Expected	10.95	10.56	9.78	38.72	70.00
	(O - E)² / E	1.42	1.97	1.06	0.72	5.18
	% of row	10.0%	8.6%	18.6%	62.9%	100.0%
	% of column	25.0%	22.2%	52.0%	44.4%	39.1%
	% of total	3.9%	3.4%	7.3%	24.6%	39.1%
Partially/Totally	Observed	**21**	**21**	**12**	**55**	109
	Expected	17.05	16.44	15.22	60.28	109.00
	(O - E)² / E	0.91	1.26	0.68	0.46	3.32
	% of row	19.3%	19.3%	11.0%	50.5%	100.0%
	% of column	75.0%	77.8%	48.0%	55.6%	60.9%
	% of total	11.7%	11.7%	6.7%	30.7%	60.9%
Total	Observed	28	27	25	99	179
	Expected	28.00	27.00	25.00	99.00	179.00
	(O - E)² / E	2.34	3.23	1.75	1.18	8.50
	% of row	15.6%	15.1%	14.0%	55.3%	100.0%
	% of column	100.0%	100.0%	100.0%	100.0%	100.0%
	% of total	15.6%	15.1%	14.0%	55.3%	100.0%

8.50 chi-square
3 df
.0367 p-value

Since p value is less than x=.05 at .05 significance, we reject the null. We are 95% confident that predation is related to the beach the nest is on.

4. RELATIONSHIP BETWEEN BEACH AND FALSE CRAWLS.

	Adelle Cov	Palm Cove	Petrel Poin	Tannehill Beach
Nest	28	27	25	98
False Craw	51	64	35	117

		Adelle Cove	alm Cove	etrel Point	hill Beach	Total
Nest	Observed	**28**	**27**	**25**	**98**	178
	Expected	31.60	36.40	24.00	86.00	178.00
	(O - E)² / E	0.41	2.43	0.04	1.67	4.55
	% of row	15.7%	15.2%	14.0%	55.1%	100.0%
	% of colum	35.4%	29.7%	41.7%	45.6%	40.0%
	% of total	6.3%	6.1%	5.6%	22.0%	40.0%
False Craw	Observed	**51**	**64**	**35**	**117**	267
	Expected	47.40	54.60	36.00	129.00	267.00
	(O - E)² / E	0.27	1.62	0.03	1.12	3.04
	% of row	19.1%	24.0%	13.1%	43.8%	100.0%
	% of colum	64.6%	70.3%	58.3%	54.4%	60.0%
	% of total	11.5%	14.4%	7.9%	26.3%	60.0%
Total	Observed	79	91	60	215	445
	Expected	79.00	91.00	60.00	215.00	445.00
	(O - E)² / E	0.68	4.05	0.07	2.79	7.59
	% of row	17.8%	20.4%	13.5%	48.3%	100.0%
	% of colum	100.0%	100.0%	100.0%	100.0%	100.0%
	% of total	17.8%	20.4%	13.5%	48.3%	100.0%

7.59	chi-square
3	df
.0553	p-value

Since p-value is less than 0.05, we fail to reject the null. We are 95% confident that the ratio of nests to false crawls does not change among beaches.

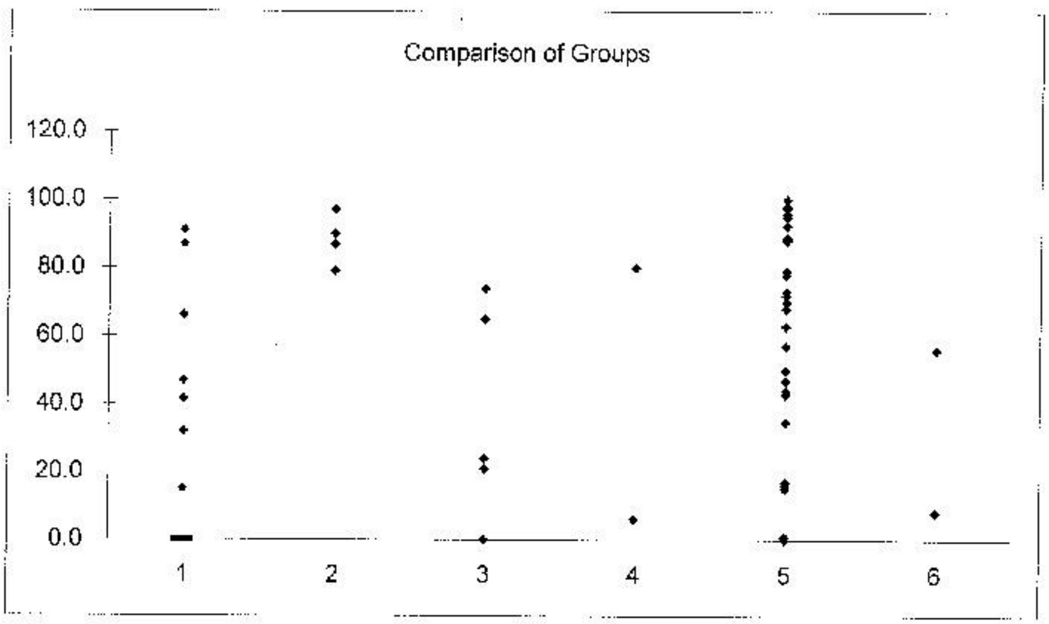
5. HATCHLING SUCCESS ACROSS BEACHES

One factor ANOVA

Mean	n	Std. Dev	
53.3	8	26.34	Adelle Cove
88.6	5	6.50	Palm Cove
43.0	6	31.94	Petrel Point
43.0	2	52.33	Sawyers Cove
60.7	34	35.81	Tannehill Beach
32.0	2	33.94	University North
58.6	57	33.96	Total

ANOVA table

Source	SS	df	MS	F	p-value
Treatment	8,238.21	5	1,647.641	1.49	.2089
Error	56,331.97	51	1,104.549		
Total	64,570.18	56			



Since p is less than x=.05, we fail to reject the null. We are 95% confident that hatchling success averages are equal to each other for all beaches.

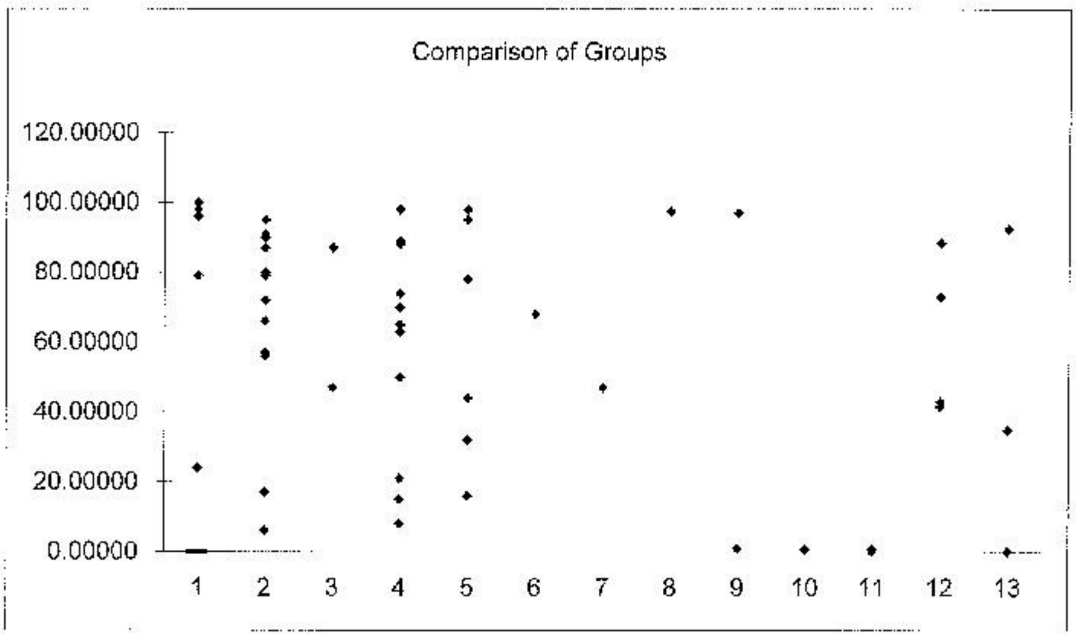
6. HATCHLING SUCCESS ACROSS YEARS

One factor ANOVA

Mean	n	Std. Dev	
82.83333	6	29.895931	AA1993
68.15385	13	28.257289	AA1996
60.33333	3	23.094011	AA1997
56.15385	13	31.328491	AA1998
60.50000	6	34.547069	AA1999
68.00000	1	0.000000	AA2000
47.00000	1	0.000000	AA2001
97.50000	1	0.000000	AA2002
48.94500	2	67.960033	AA2003
0.72000	1	0.000000	AA2004
0.36000	2	0.509117	AA2005
61.47500	4	23.123779	AA2007
31.80000	4	43.603670	AA2008
58.63035	57	33.956427	Total

ANOVA table

Source	SS	df	MS	F	p-value
Treatment	19,781.002989	12	1,648.4169157	1.62	.1211
Error	44,789.177537	44	1,017.9358531		
Total	64,570.180526	56			



Since p value is less than x=.05, we fail to reject the null. We are 95% confident that hatchling success averages are equal to each other for all years.