Evaluating Predation and Associated Outreach Development for Sea Turtle Nesting on Virginia Key, Florida

An Internship Report

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In cooperation with
MORAES of South Florida

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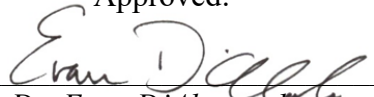

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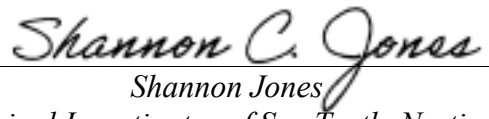

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Abstract of a master's degree internship report at the University of Miami, Rosenstiel School of Marine, Atmospheric, and Earth Science. Supervised by: *Dr. Evan D'Alessandro & Shannon Jones*. Number of pages in text: 34

The MORAES sea turtle nesting program began in 2021 to monitor sea turtle activity on Virginia Key, Miami, Florida. Since the organization itself is fairly new and has taken over the sea turtle nesting program for only the past two years, there is a strong need for organizational visibility and for building loggerhead (*C. caretta*) conservation awareness that reaches residents of Miami-Dade County. There is also a need for population and predation analysis of loggerhead data collected on Virginia Key, as 2022 was MORAES' first year testing wire mesh screens as an anti-predation measure. The objective of this project was to create an informative ArcGIS StoryMap as an environmental outreach project, using a combination of photos, storytelling, and maps from data of the 2016-2022 nesting seasons, and to begin to identify trends in population and predation. Under FWC permitting, daily nesting surveys were conducted from May through September by MORAES staff and volunteers who collected nesting data and photos, which in turn were analyzed and transformed into easy-to-read maps and content through the StoryMap. These were then uploaded to the MORAES website in October. The 2022 nesting season produced a record number of *C. caretta* nests for a 6-year period, and while the number of predations also increased, the mammalian predation rate decreased from 2021 to 2022 presumably due to the vast number of nests laid. The StoryMap included information and conservation issues unique to other loggerhead nesting beaches in the Miami-Dade area– primarily the political and conservation issues arising from the city's proposal for a homeless camp on the underdeveloped island. Future work involving *C. caretta* on Virginia Key may look vastly different from the 2022 nesting season, as the proposed homeless camp may break ground on Virginia Key before the 2023 nesting season, disrupting natural ecosystem processes and potentially increasing raccoon populations and light pollution. However, it is recommended that the wire screening protocol continues and expands to other areas of Virginia Key throughout future nesting seasons due to its apparent success in 2022.

Acknowledgements

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1.1 Loggerhead Turtles

The loggerhead turtle, *Caretta caretta,* is the predominant marine turtle species found in the region of South Florida (Witherington et al., 2011). Loggerhead turtles are temperate sea turtles; in the United States, their range extends up the east coast as far as New Jersey, and west into the Gulf of Mexico (Hawkes et al., 2007). Temperature is a key factor in loggerhead biology, as they are ectothermic reptiles that rely on their external environment for multiple purposes (Fuentes et al., 2011). During the winter, turtles lose their ability to swim and dive in waters colder than 8-10°C, so they aggregate offshore in the southeastern United States (Hawkes et al., 2007; USFWS, 2008). Arguably, the most important temperature-reliant life stage for loggerhead turtles is the terrestrial reproductive phase (Fuentes et al., 2011). Loggerhead turtles employ what is known as temperature-dependent sex determination in which the temperature of the sand during the development of eggs determines the sex of the resulting hatchling. The pivotal temperature that results in an equal ratio of males and females within a clutch is an even 29°C; cooler temperatures will result in males, and warmer temperatures will result in females, although the peak temperature for incubation is around 32-35°C (USFWS, 2008). The effects of climate change on loggerhead reproduction and recruitment have yet to be fully understood; however, environmental changes such as expected increases in temperatures and intense storms, along with rises in sea level are predicted to be major obstacles for loggerhead populations (Fuentes et al., 2011).

The loggerhead turtle is protected under multiple treaties, agreements, and laws including the Endangered Species Act of 1973, the Convention on International Trade of Wild Flora and Fauna (CITES), and the Canada Species at Risk Act (Ceriani et al., 2019). In particular, the Northwest Atlantic population located on the Southeast coast of the United States is designated

as a Distinct Population Segment, or DPS, which requires three elements for listing by the U.S. Fish and Wildlife Service: The discreteness of the population segment in relation to the remainder of the species; The significance of the population segment to the species; Conservation status (Ceriani et al., 2019; USFWS, 2008). Under the Northwest Atlantic DPS, loggerhead turtles are then split into five Recovery Units along the DPS's range in order to create more detailed recovery plans for these populations (USFWS, 2008). The Peninsular Florida Recovery Unit encompasses loggerhead turtles in South Florida, which have suffered a 26% decline from 1987-2008 and an even steeper decline of 41% from 1998 to 2006; however, an annual rate of increase of 1% is possible with 106,100 nests or more laid every year by this Recovery Unit (Ceriani et al., 2019; USFWS, 2008). The majority of nest monitoring for loggerhead turtles in the state of Florida is conducted through the Statewide Nesting Beach Survey (SNBS) program, under the Florida Fish and Wildlife Conservation Commission (FWC) (Ceriani et al., 2019). The SNBS program is designed to maximize the temporal and geographic surveillance of nesting activity with differing set times and survey frequency depending on the beaches (Ceriani et al. 2019; FWC, 2016).

Major threats to the loggerhead turtle are less attributed to illegal takings of meat and eggs, and more from industrial and development pressures throughout its range (Lutz et al., 1997). The state of Florida boasts 90% of nesting habitat for sea turtles in the United States, so accessibility to nesting space is critical for reproductive output (Fuentes et al., 2016). However, this accessibility, for all species of sea turtles in South Florida, is under threat from multiple anthropogenic sources such as habitat degradation and climate change (Doney et al., 2012). Coastal ecosystems in particular are at risk of ecosystem deterioration, and beaches worldwide, not just in South Florida, are in danger of experiencing heightened erosion due to sea level rise

and storm surge brought by climate change (Doney et al., 2012; Fish et al., 2008). Another threat to loggerhead turtles that has the potential to be amplified by climate change is severity and frequency of named storms, such as cyclones, tropical storms, and hurricanes. Large storms can lead to increased nest washouts, washovers, and overall egg mortality (Lindborg et al., 2016). Man-made barriers to nesting, such as jetties, coupled with intense wave action from these large storms, can lead to habitat degradation and have the potential to negatively impact loggerhead recruitment (Fuentes et al., 2019). Although jetties are constructed to conserve beach space and can be found on Virginia Key beaches, they have the potential to disrupt natural ecosystem processes by altering sediment transport and the natural profiles of the beach, which in turn can deter nesting loggerhead turtles from returning to the same beach over time (Fish et al., 2008; Witherington et al., 2011).

In addition to the threats named above, loggerhead turtles and their eggs have a significant threat of predation by multiple animals in South Florida. Common predators include ghost crabs (*Ocypode quadrata*), raccoons (*Procyon lotor*), fire ants (*Solenopsis invicta*), and even shorebirds such as yellow-crowned night herons (*Nyctanassa violacea*). Ghost crabs, while common, can be limited to the amount of eggs and hatchlings they can predate upon during incubation and emergence, and can even have failed predation attempts (Erb & Wyneken, 2019). However, ghost crabs have the ability to create tunnels that can reach the egg chamber despite the presence of a mesh screen, and the odors resulting from predation can attract raccoons (Leighton et al., 2011). Raccoons, which are a native species in coastal Florida, tend to flourish in heavily urbanized areas due to both direct and indirect feeding from non-natural human activity (Engeman et al., 2003).

The balance between managing overpopulated beaches to assist sea turtle conservation and

respecting native predator species can be challenging. Raccoons are a predominant source of egg mortality for loggerhead turtles in the Southeastern United States; despite this, their presence on beaches is crucial to keeping coastal beach ecosystems functioning, as they are omnivores that feed on other organisms such as ghost crabs (Barton & Roth, 2008). The direct removal of raccoons has been contested throughout literature with mixed results and success rates. Removing and even trapping raccoons in order to curb loggerhead egg mortality could have a disproportionate effect on ghost crab populations and indirectly increase loggerhead egg mortality through exposure to the elements and other predators, in a phenomenon known as intraguild predation (Barton & Roth, 2008; Engeman et al., 2003).

An alternative method that has been used to decrease raccoon predation is treated wire mesh laid parallel to the sand to keep out medium-sized mammals such as raccoons, while still allowing hatchlings to pass through (Bjorndal & Jackson, 2002). These screened nests, if secured properly, can reduce predation rates on sea turtle nests without disrupting natural ecosystem integrity (Ratnaswamy et al., 1997). Virginia Key did not have clearance from the FWC to implement mesh screens to deter predation from raccoons until the 2022 nesting season; therefore, there is a need for the formation of identifying trends in sea turtle nesting populations, particularly associated with predation on Virginia Key.

1.2 Virginia Key

One of the sea turtle nesting beaches in Miami-Dade County is Virginia Key, located in Biscayne Bay between mainland Miami and Key Biscayne. As of 2016, Virginia Key remains uninhabited and the most prominent establishments include Mast Academy Charter School, Miami Seaquarium, NOAA Southeast Fisheries Science Center, and the University of Miami's

Rosenstiel School of Marine, Atmospheric, and Earth Science (Bush, 2016). The beaches themselves have a significant amount of history pertaining to the civil rights movements of the 1900's. Virginia Key was a part of the fight for African Americans to secure access to public parks and beaches in Miami (Bush, 2016). An event called "The Wade In" in 1945 began as a protest in Baker's Haulover in Northeast Miami, and led to Virginia Key Beach becoming a designated beach for not only African Americans, but for Cuban and Haitian immigrants. This event rarely receives recognition despite occurring 9 years before Rosa Parks and 14 years before the sit-ins in Greensboro, NC, which are accredited as some of the first civil rights protests in the United States (Bush, 2016).

1.3 MORAES

MORAES of South Florida is a 501(c)(3) environmental non-profit whose mission is to help others understand and protect their local marine environment through conservation, research, and environmental stewardship. Through this, MORAES aims to align scientists and conservationists in the Miami-Dade area with their "passion projects" to create personal and meaningful local science. These projects extend from aerial cetacean surveys in Grassy Key to habitat restoration at Darwin Beach on Virginia Key. MORAES is also responsible for sea turtle nesting surveys on the island of Virginia Key. Although sea turtle nesting populations have been tracked for over 30 years, MORAES took over the marine turtle permit to conduct nesting surveys in 2021 and developed their sea turtle nesting program with the mission of monitoring sea turtle activity on Virginia Key Beach. This program offers volunteer opportunities for individuals to assist in collecting local nesting data for FWC and their SNBS program for the state of Florida. Data is collected in order to track regional sea turtle population trends and determine necessary

conservation efforts needed on Virginia Key Beach. These conservation efforts can result in new and adjusted beach policies and regulations, and increased education and outreach on the importance of sea turtles for locals.

As MORAES is a relatively new non-profit, there is a need for increased organizational visibility to residents in Miami-Dade County and South Florida, since local communities are extremely important for conservation outreach programs, donors, sponsors, and the scientific community (Boulon Jr., 1999). Getting local communities involved in MORAES' sea turtle nesting program can also assist in bridging the gap between public support of sea turtle conservation and the lack of knowledge on sea turtle threats and life history. Public attitudes towards sea turtle conservation are mostly positive, partly due to sea turtles becoming the figurehead of the anti-plastic movement, but those who support sea turtle conservation and engage in ocean news consumption do not necessarily know as much about sea turtles as they think they do, according to a study by Santos & Wong-Parodi in 2022.

1.4 Visual Storytelling & Storymaps

There is a cultural aspect to science, as science is created by humans with various identities and heritages and not by mindless machines; scientific culture contains stories embedded within it and these stories are used to convey scientific content (Richter et al., 2019). The use of stories in science communication, either verbal or visual, is a communications method in which the communicator creates a narrative in order to tell a story with the potential to result in some sort of social change through the influence of beliefs and actions (Altinay & Williams, 2019; McGrath, 2021). Narratives are thought to be more representative of human thought in comparison to "expository" text that simply gives facts and information about a topic

(Dahlstrom, 2014). For the reader, narratives offer benefits in the steps of processing information and assisting in long-term memory and reading comprehension, regardless of topic interest and familiarity (Dahlstrom, 2014). Through the use of storytelling, communicators can foster dialogue between scientists and society by triggering connections between aspects of everyday life and scientific discovery that can create further interest in participation amongst those outside of the scientific community (Dahlstrom, 2014; Richter et al., 2019).

Visual storytelling in particular is growing in popularity among scientists, conservationists, and communicators, and is a subdivision of visual communication, which can incorporate mediums such as digital imagery, video, infographics, and even maps (Altinay & Williams, 2019). Its appeal lies in making conservation issues more accessible to an audience by "tailoring" available knowledge, such as from scientific publications, into formats that conservationists and others can decipher and convert into better management practices and conservation-oriented behaviors (Cortes et al., 2020). These visual narratives often incorporate tactics like emotionalization to highlight the charisma, beauty, or allure of a species in order to trigger desired responses from target audiences, especially when dealing with familiar charismatic megafauna such as whale sharks and sea turtles (McGrath, 2021). However, it is important that communicators take consideration of ethics and the danger of misrepresenting science, as narratives accepted by an audience are more difficult to counter with evidence than logic-based science communication (Dahlstrom, 2014).

The Environmental Systems Research Institute, or ESRI, has created a web application to publish Geographic Information Systems (GIS) findings from their cloud-based program, ArcGIS Online, to audiences outside of their organization (Cope et al., 2018). Through the ArcGIS StoryMap application, users can create visual narratives to communicate scientific

findings by incorporating text, visuals, and ArcGIS maps, the latter of which can be interacted with by readers to view different data points and locations (Cope et al., 2018). StoryMaps can be accessible through any smart device (laptop, tablet, or cell phone) without needing to download any additional software to view; however, the largest limitation to accessibility is the need for internet access (Cope et al., 2018). Despite this limitation, the use of an ArcGIS StoryMap as a visual communication method can help make conservation issues more tangible and accessible to target audiences (Cortes et al., 2020).

Given the needs of the organization and the problems at hand, the primary objective of the internship project is to create an environmental outreach product using a combination of research, communication, and environmental outreach strategies and methods. By using nesting survey data from the 2022 nesting season and past data from the FWC from 2016 to 2021, an informative ArcGIS StoryMap will be created as an environmental outreach product for MORAES' use, with informational content and GIS analyses focusing on nest locations, predation, and loggerhead conservation issues pertaining to Virginia Key. The project's intent is to increase involvement and sponsorship of future sea turtle nesting programs and other MORAES programs.

2.0 Methodology

2.1 Overview & LOGIC Model

This project was created through a seasonal internship hosted by MORAES of South Florida. The use of FWC data collected from 2016 through the 2022 season was allowed through FWC Research Permit 937 and Marine Turtle Permit #153, and incorporates major conservation efforts and Recovery Actions highlighted in the U.S. Fish and Wildlife's Recovery Plan for the Northwest Atlantic population of *C. caretta*, which include efforts to increase public education

and awareness, efforts to improve communication and access to information, and to minimize the effects of climate change on loggerhead habitats. The computer programs ArcGIS Pro and Microsoft Excel were utilized to create charts, maps, and graphs in order to understand trends on Virginia Key, and the programs ArcGIS Online and ArcGIS StoryMap were used to combine maps, data layers, and charts into a comprehensive visual story for viewers to MORAES of South Florida's website. The methodology for this project was subdivided into three categories, aided by the LOGIC model: the collection of data through daily surveys, the organization and visualization of data through Microsoft Excel and ArcGIS Pro, and the creation of the ArcGIS StoryMap.

The LOGIC model created for this project was revised from the initial proposal created by the intern in March of 2022. Individual stages and deadlines measuring personal progress on the project were created by the intern and discussed with the committee chair and internship supervisor in February and March prior to the project start in April. Organizational needs were identified along with the project type allowing for growth of the intern's skills. Ultimately, MORAES was interested in an outreach product of an ArcGIS StoryMap, enabling growth of the intern's ArcGIS Pro skills and scientific content formatting for outreach and education purposes. The nesting season had a predetermined completion date of September 30th, and deadlines for creating the ArcGIS maps and StoryMap were oriented around the completion and review of data from the season by October. Key stakeholders include those in the Miami-Dade and South Florida areas who are interested in sea turtle conservation or MORAES as an organization, or those who want to learn how to get involved with marine conservation topics. Test audiences for the ArcGIS StoryMap included the intern's committee, family, and colleagues to determine its ease of navigation. The evaluation of impacts from the ArcGIS StoryMap will be measured from

growth in interest in next season's sea turtle program and an increase in social media followings for MORAES.

The decision to use an ArcGIS StoryMap to convey both scientific findings and conservation issues from the 2022 nesting season and to increase organizational visibility was discussed between the intern, intern supervisor, and marine turtle permit holder. For many non-scientists, charismatic megafauna such as sea turtles are the animals that often come to mind when prompted about conservation issues in the marine environment. Positive attitudes and support for the conservation of sea turtles can be attributed to their "safe" and non-threatening nature compared to other threatened or endangered species, and has even risen in popularity as the figurehead of the anti-plastic movement (Liordos et al., 2017; Santos & Wong-Parodi, 2022). However, there is a disconnect between public support of sea turtle conservation and the knowledge about their conservation status, threats, and even their life history (Santos & Wong-Parodi, 2022). Conservationists may be able to bridge the knowledge gap and engage audiences in conservation behaviors by employing the use of educational outreach products that use digital media and visual communication.

Visual storytelling in particular, such as through an ArcGIS StoryMap, can help make conservation issues more accessible and tangible to an audience, and can influence their beliefs and actions to encourage conservation behaviors (Cortes et al., 2020; Altinay & Williams, 2019). However, increasing the accessibility of information on endangered species such as loggerhead turtles can be tricky to navigate. While improving public knowledge can help spread awareness of conservation issues the species faces, there is also a risk of the public knowing too much about the locations of these animals, and disrupting natural processes that are critical for boosting populations. The StoryMap can show past data and maps without the danger of public

interference, since the season will have concluded with all nests hatched and gone from the study area before the public will have had access to the information.

The overarching goal for the project is to create an organized, visually effective outreach product accessible with any smart device, that will be able to stay on the MORAES webpage for at least the offseason, between the 2022 and 2023 sea turtle nesting season on Virginia Key Beach, and promote increased involvement within the organization, particularly in future seasons of the sea turtle nesting survey program. Within the LOGIC model, the StoryMap is categorized as an output, and the hope for increased organizational visibility is a medium-term outcome, as it promotes behavioral action amongst the target audience. This goal is accompanied by other goals for the project, such as increased followings and engagement on social media, increased volunteer interest and donations to MORAES programs, and ultimately, the growth of MORAES as an organization. These goals were established by the intern's personal desires as well as collaboratively with the intern supervisor and marine turtle permit holder.

As the proposal and LOGIC model were created at the very beginning of the loggerhead turtle nesting season on Virginia Key, edits and modifications to the original LOGIC model and StoryMap contents were expected in order to create a more efficient end outreach product as the data collected began to reveal the unique narrative of the 2022 nesting season. This included predation as a main conservation concern, human interference, and the recent uncertainty surrounding the development of Virginia Key. It was also decided that the final StoryMap narrative would exclude intense named storms as a major component, as Virginia Key had an unusually hot and dry rainy season and did not experience nearly as many washovers as predations. However, the end datasheets and maps were expected to remain consistent from the beginning of the planning phases.

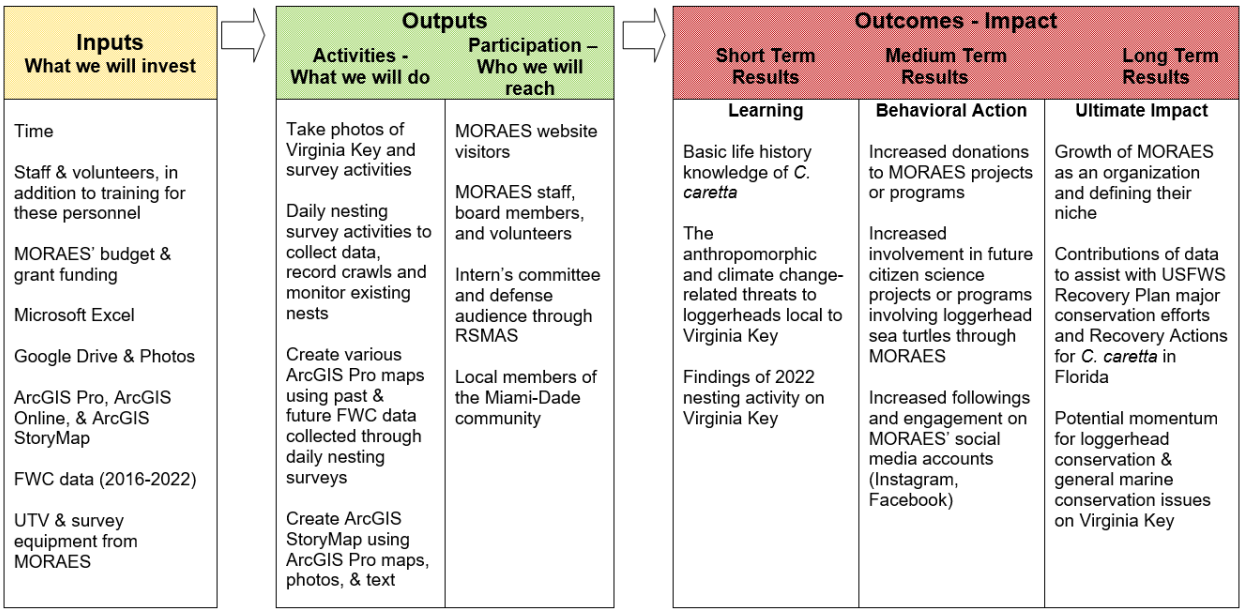

Figure 1. LOGIC Model

2.2 Surveys and Data Collection

In order to conduct sea turtle surveys on Virginia Key, MORAES of South Florida was granted authorization by the FWC under Marine Turtle Permit #153. Under this permit, MORAES takes part in the SNBS program, which monitors sea turtle nesting in the state of Florida (FWC, 2016). Daily surveys were conducted on Virginia Key beginning on April 26th until September 30th, with additional monitoring of two remaining nests completed until N126 washed out on October 3rd, and N127 hatched on October 27th. The survey site was separated into five components for data recording purposes: Norris Cut (VKC), Virginia Key North Point (VKN), Virginia Key Main (VKM), Virginia Key Historic (VKH), and Virginia Key South (VKS). Segments VKC and VKS were not surveyed daily; VKS was surveyed every other day, and VKC was surveyed once every two weeks due to height of tides limiting accessibility by surveyors.

While surveying, the intern and volunteers kept the following materials with them in the Utility Terrain Vehicle (UTV): a survey backpack, at least one or two sets of stakes, and at least one

mesh screen. Within the survey backpack, the intern and other trained volunteers had the use of the following items: various datasheets, a GPS, marking tape, a first aid kit, hand sanitizer, bug spray, clipboards, and writing utensils. Two binders were kept in the main survey backpack: a nest binder specifically for nesting data sheets, and one main binder for datasheets to record false crawls (non-nesting emergences), observations, missed nests, Obstructed Nesting Attempts (ONA), and disorientations.

FWC required photographs to be taken of the first thirty emergences of the season, whether they resulted in a false crawl or nest. Photos taken of crawls after the first thirty were optional, but taken occasionally by the intern or other volunteers if the crawl appeared unusual. A daily crawl sheet was kept to record the number of crawls per day, whether nests, false crawls, or no crawls were found that day, along with an observation log to mark any unusual activity or incidents such as washovers, predation, ONA, and so on.

For every false crawl cataloged, information was written on the false crawl data sheets kept in the main binder, which recorded the species using track shape in the sand, GPS location, zone code, track width, and distance to dune and high tide line in meters and inches. The final digging activity made by the nesting loggerhead would also be recorded, as No-Dig (ND), Body Pit (BP), or Abandoned Egg Chamber (AEC).

When nests were found, the area would be marked off with a set of three wooden stakes and orange tape set in a triangle, with the egg chamber or an approximation of the egg chamber's location in the middle of the enclosed area. One stake would be purposely hammered in the eastern direction, containing a yellow FWC warning sign stapled to the front to make sure beachgoers did not interfere with the nest. A MORAES nesting identification code was written on the front and back of this particular stake. The same information recorded for false crawls was

recorded in the nest binder, with the addition of a physical, man-made identifier with direction to and distance from the egg chamber, and the date recorded. Nests located in a specific range within VKM and VKH were screened for protection against predation only if the surveyors were able to locate the egg chamber.

At the beginning of the season, it was determined by the MORAES team, based on past predation data, that nests within a specific section of VKM and VKH should be outfitted with self-releasing screens to protect against raccoons, using 4' x 4' pieces of 2" x 4" mesh welded wire laid parallel to the sand. This section extended north from Jetty 04 all the way south to NOAA's Southeast Fisheries Science Center (identified as stars on Figure 5). However, due to a large number of predations on unscreened nests early in the season, and previously excavated nests with biological material re-buried at the original nest site, the screening procedure was re-evaluated by the MORAES team. Screening was expanded to all nests on Virginia Key, starting on July 28th.

Approximately two months after nests were laid, surveyors began to look for hatch-outs: the emergence of fully developed hatchlings from the egg chamber and up onto the open beach. To be considered a hatch-out, the nest must have had at least 5 hatchling crawls emerging from the nest: tracks left from the hatchlings that are usually emerging at night. Hatch-outs were marked on the original nest data sheet, and marked on one of the stakes with a piece of flagging tape in a specified color. The date three days after the hatch date was recorded on the calendar data sheet, along with the location code and jetty number in the case of hatch-outs located on VKM. Nest excavations also began around this time, as the first excavation was completed on July 4th. Excavations were completed 3 days after the initial recorded hatch-out of the nest, at the 70-day mark of an unhatched nest, 80-day mark for an inundated or washed over nest, or when the nest

was depredated all the way to the bottom of the EC, which was rare. An excavation team of two to three permitted individuals would assign someone to dig, someone to record data, and someone to count the eggs and hatchlings into different categories. Dry, empty egg shells without any trace of biological material were counted as a hatched egg, and separated into piles of ten for easier counting. Eggs that were completely whole, had biological material, or an underdeveloped hatchling inside were counted as a whole egg.

Dead pipped eggs contained a fully developed hatchling, who had begun to break out of the shell but did not make it all the way out. Live pipped hatchlings were hatchlings who had begun to break out of the shell and were still inside at the time of excavation. Live hatchlings had completely broken out of their shells, as had dead hatchlings. The notes and observations section included any damage to the eggs, the presence of roots impeding hatchling emergence or crowding the eggs, and any standing water from washovers.

2.3 Visualization of Current & Past Data

Microsoft Excel tables from FWC containing nest locations for 2016, 2017, 2019, 2021, and 2022 were uploaded to the program ArcGIS Pro to create individual maps for each year to show the locations of nests on Virginia Key. The coordinates of the nests were uploaded onto the map by displaying the X and Y data from the Excel tables on ArcGIS Pro, and an additional shapefile of the Virginia Key survey area was created and added to each year's map. Excel tables from the FWC were not available for 2018 & 2020. Charts using the 2016-2022 SNBS report data were created using Microsoft Excel and Word to look at the rate of nests laid and the emergence rate from 2016-2022. Emergences include whenever a nesting mother attempted to nest (false crawl) or successfully nested (nest). Nests located outside of the survey area shapefile due to GPS error were not excluded from predation and nest rate analyses, but were excluded from the visual

StoryMap component.

The 2022 FWC data was also analyzed specifically for the locations of predations. Marked predations on Excel included nests with any mark of raccoon activity, such as eggshells scattered outside the egg chamber or dug up, or nests with fire ants consuming or disfiguring hatchlings & biological material within the nest. Charts were created using this data showcasing predation rates from 2016-2022 and nest treatment methods compared to the number of depredated nests for the 2022 season. Unknowns for nest predation status were excluded from these analyses.

2.4 Creation of an ArcGIS StoryMap

A StoryMap template was custom created in order to choose visually appealing fonts, colors, and layouts that would be engaging for viewers and would translate well on both a desktop and mobile layout. Care was taken for ADA compliant color contrast with the layout's background and text, but due to the limitations of the StoryMap application, the webpage was not completely ADA compliant in terms of user accessibility using text-to-speech. Using the maps created on ArcGIS Pro, the shapefiles and point layers were exported and uploaded through ArcGIS Online, then uploaded onto blank maps for the StoryMap. Select charts created from the data analyses were also included in several sections to show visual trends of nesting rates, emergence rates, and predation rates from 2016 to 2022.

3.0 Results & Outputs

One hundred and twenty-seven nests were marked by MORAES surveyors on Virginia Key from May 4th to October 27th, 2022. Of the 127 nests marked, 35 were pulled with no egg chamber found at the 70-day mark, potentially false crawls incorrectly marked as nests, and 3 experienced complete predation or a complete wash-out. Ten nests were missed through surveys, and were

discovered through predation, hatchling tracks, or the observation of a depression, resulting in 137 total nests for the season. 187 false crawls, or non-nesting emergences, were recorded, with a total of 324 emergences made by adult loggerhead turtles on Virginia Key. The peak of the season's emergences was the week of June 12th, with 51 emergences. The average clutch size for nests laid on Virginia Key was 96 eggs (standard deviation 31.523, standard error 3.168). 27 nests were depredated during the 2022 nesting season; the total depredation rate was 19.71%, with 18.98% by raccoons. 31 total nests were screened upon initial discovery, 95 were unscreened and remained unscreened, and 11 were originally unscreened but then changed to screened at some point before inventory due to exposure from predation or other causes.

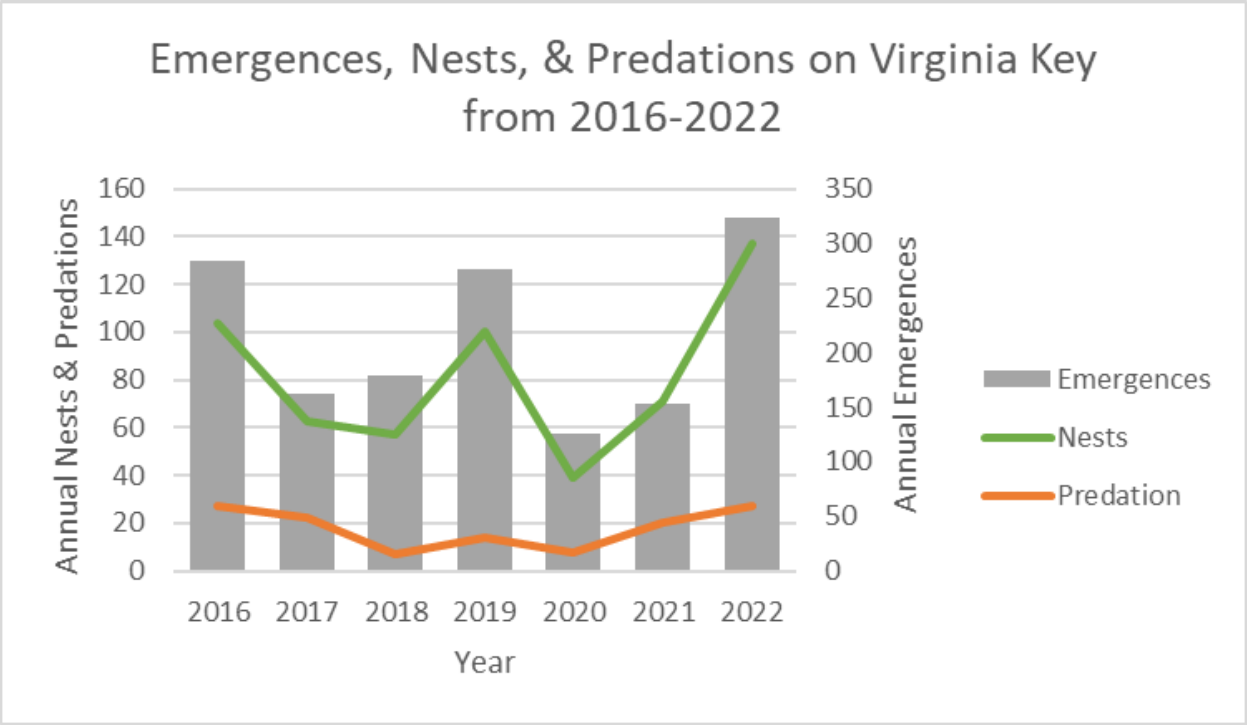

Figure 2. Emergences, Nests, & Predations on Virginia Key from 2016-2022

The completed StoryMap was posted to MORAES' website in December of 2022, titled "Creatures of the Key: Loggerhead Turtles in a Changing World". The overall narrative

conveyed the 2022 nesting season in review, noting predation as the largest short-term threat to loggerhead turtles on Virginia Key and describing MORAES' efforts to reduce rates. The first section gave a brief overview of the initial results from the 2022 nesting season on Virginia Key, before moving onto a visual look at nesting and emergence rates over the past six years using the ArcGIS Pro maps of nest locations, graphs of annual emergences, nests, & predations, and pictures along with text.

Next, an explanation of MORAES' new anti-predation measures and its apparent success, with the addition of a side-by-side comparison map, was put in, along with specific conservation issues that loggerheads face on Virginia Key. Then, a section outlining conservation issues specific to Virginia Key and their implications for future nesting seasons followed, and how others can help through conservation-oriented behaviors. Pictures of hatchlings and marked nests included on the StoryMap as visual aids were taken by the intern and volunteers with explicit permission and credit given to the creator to use on the StoryMap. Instagram and Facebook social media handles for MORAES were included at the bottom of the StoryMap to increase visibility, which could be measured to see the impact of the product on target audiences. Interactive buttons were also included that led to FWC's wildlife report form and MORAES' donation page to fund future sea turtle nesting survey seasons.

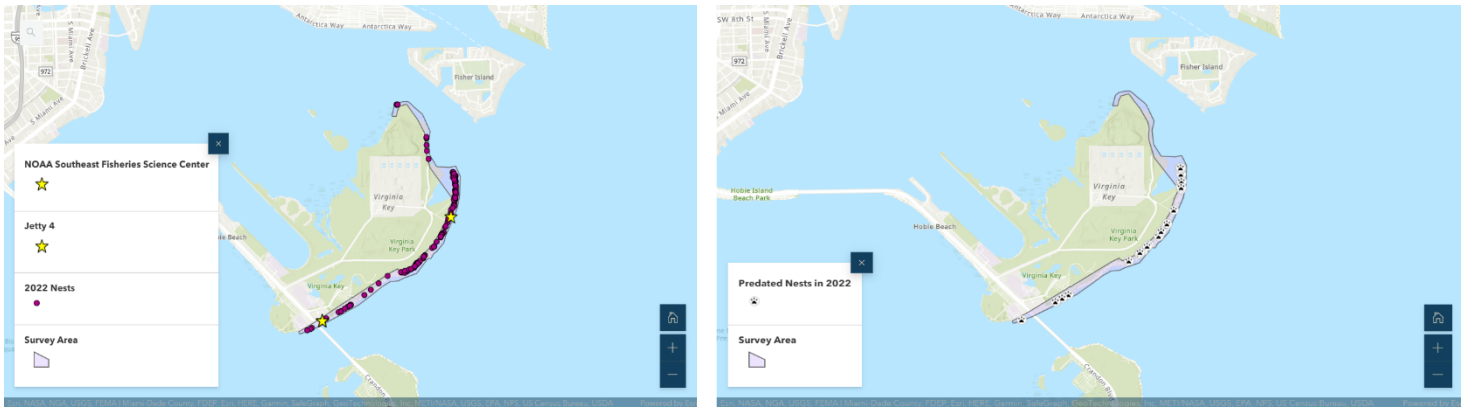

Figure 3: GIS map depicting 2022 nest locations (left) vs. 2022 depredated nest locations (right)

Background information on loggerhead turtles and the sea turtle nesting survey program are already located on MORAES' website and were not included to make sure the StoryMap content was not redundant. Not all figures created were included since it did not fit the main predation and conservation narrative of Virginia Key, and so readers were not overwhelmed with too much scientific jargon.

4.0 Discussion

Virginia Key experienced a record number of nests compared to the last six years, and an unusually hot and dry summer. According to the National Integrated Drought Information System, Miami-Dade County experienced its 12th driest August on record, measured over the past 128 years from 2022. There was also a lack of intense storms affecting South Florida in 2021, which could have resulted in a higher hatchling recruitment count compared to this year. The effects of temperature and rainfall on nest productivity were not measured for this project, but it is certainly worthy of note for the future.

Figure 2 demonstrated that the relationships between the number of nests, emergences, and predations correlate to one another. As the numbers of nests and emergences increase on Virginia Key, so do the predations. Leighton et al. 2011 states that predation risk can increase by

attracting predators to dense nesting beaches through scent; this was demonstrated with a higher number of depredated nests compared to 2021. However, the changes in depredated nests per year are not nearly as sharp as the annual changes in emergences & nests. While the number of depredated nests was higher, the ratio of depredated nests to the total number of nests laid for the season was lower compared to the previous season. This is a positive sign that predation rates could be relatively low in the future with the continuation of the screening protocols.

One of the main Recovery Actions stated in the U.S. Fish and Wildlife Service (USFWS)'s Recovery Plan for the Northwest Atlantic population of loggerhead turtles is to minimize annual predation rates from mammals within each recovery unit, taking care to use ecologically sound predator control programs. The target predation rate set by the National Marine Fisheries Service (NMFS) and USFWS was 10% or lower annually amongst loggerhead nests within the Peninsular Florida recovery unit. Under FWC permitting, MORAES used wire mesh self-releasing screens as their predator control method on Virginia Key in 2022, which resulted in a lower predation rate than the previous year but still larger than the 10% target goal set by the USFWS. This could be due to the implementation of the screens, the depth at which the nests were buried, or even the hot & dry weather; all in all, the implementation of the screens appears to have been a success. However, this is a short-term trend observation, since predation rates were only measured from the past 6 years. Past data extending at least several decades would be required to get a clearer idea of predation rates, while continuing nest screening for future seasons will give more insight to its effectiveness.

Another factor for the success of lowered predation rates from the 2021 season could be the removal of raccoons from Virginia Key prior to the start of nesting season. Virginia Key is a public park with lots of garbage present & artificially inflated raccoon populations. According to

the SNBS end of season reports for Virginia Key, the City of Miami has carried out direct removal of raccoons from the Key before the nesting season in the past: 2016 with 35-40 raccoons, 2018 with over 85 raccoons, 2019 with over 50 raccoons, and 2020 again with 50 or more raccoons removed. Raccoons were removed before the start of the 2022 season, but the exact number is unknown. There has been varied success & opinions made on this anti-predation measure; multiple studies conducted by Engeman et al. in 2003 and 2006 suggest that direct removal of mammalian predators is the most effective method to improve loggerhead nesting success. Another study by Barton & Roth in 2008 says otherwise, claiming that raccoon removal will have a disproportionate effect on the beach's ecology and other loggerhead predator populations such as ghost crabs. However, there has been no documented evidence suggesting that raccoon removal has increased ghost crab predation on loggerhead nests on Virginia Key. With less people and garbage on the beaches, ghost crabs should most likely have a larger presence on Virginia Key, but for now raccoons have remained the most predominant predators of loggerhead nests in this survey area every year the city has taken this measure.

The screening protocol did have one major limitation: only a certain section of VKM was outfitted with screens. This decision was made based on predation locations from the previous seasons, which was designated to be J3-J13 on VKM and all of VKH. While efficient in theory, raccoons are opportunistic omnivores with the ability to move between food sources easily. Taking away one source of food in one area of Virginia Key would only prompt them to move to a different area of the Key in search of another source. The combination of both screening nests and removing a certain number of raccoons before the nesting season begins could be the key to lowering predation rates within an urban setting. It must be noted that predator control methods, whether it be screening or removal, must be maintained continuously, as studies have shown that

a disruption in the protocol may not effectively lower predation rates (Engeman et al., 2006). According to Engeman et al. in 2005, urbanization in coastal Florida can raise raccoon predation on sea turtle nests laid on beaches near densely developed areas. Virginia Key, while currently unpopulated and isolated from human life, is located less than 5 miles outside of the City of Miami. Their population of raccoons are somewhat localized to the island, and so presents a unique circumstance amongst the other urban beaches of Miami-Dade County. If the direct removal of native raccoons combined with MORAES' screening protocol continues without any dramatic increase in raccoon populations, predation should theoretically continue to decrease. Unfortunately, there are other variables at play that leave the success of future loggerhead conservation efforts in Virginia Key uncertain: primarily, the City of Miami's proposed plan to develop an encampment of tiny houses for the homeless population. In July of 2022, a vote was passed by the City of Miami Commission to convert a portion of Virginia Key into a community for the homeless population in Miami. This vote included plans for an encampment of 50-100 tiny homes constructed on the northern portion of the island, and has raised concerns about environmental impacts to recovering ecosystems and ignorance to historic significance (Vazquez & Solomon, 2022). While the project has since been put on hold, there is potential for new data concerning sea turtle populations, including an increased raccoon population, and the ecological importance of Virginia Key that could effectively postpone any future development on the island. The urbanization of this natural area through increased human presence and waste would likely increase raccoon populations, light pollution, and disturbance to beaches (Engeman et al., 2005).

The major contribution of this work was the creation of StoryMap itself. ESRI's notes for effective storytelling includes simple maps, a driving narrative, and an alluring title (ESRI,

2017). The StoryMap included a unique title and narrative about the loggerhead nesting season on Virginia Key, which revolved around localized predation and conservation implications for the future on the currently underdeveloped island. This narrative was highlighted by pictures, text, and the maps and charts created by the 2022 data.

The largest potential error to outputs included the marking of nests by surveyors. While the data shows an increase in nesting rates over the past six years, it is important to note that MORAES obtained marine turtle permitting for nesting surveys in 2021, 2022 being their second season surveying on Virginia Key. From 2020 and the previous 31 years, surveying used to be conducted daily under this permit by Wendy Teas, a research fisheries biologist in the Marine Mammal and Sea Turtle Division of NOAA's Southeast Fisheries Science Center, and one other volunteer. Her experience and consistency in sea turtle surveying may have yielded more accurate nest counts compared to MORAES, whose surveyors are made up of a large group of volunteers who may not have as extensive field experience and volunteer once a week. While it is optimistic to say that nest rates are slowly rising, this may not be the case.

Other errors to outputs included unusual GPS coordinates for nests, particularly in 2021. Some were able to be fixed based on looking at other correct coordinate numbers, but others were not. The handheld GPS device used primarily by the surveyors on VKH also had issues calibrating and giving correct coordinates, and so any outliers were marked again correctly if possible, and excluded from the final spatial maps if not. Human errors were also common in recording data out in the field during morning surveys, particularly by those with less than two years' experience in the field. Recommendations to the host organization for best practices would include at least one training day out in the field for all volunteers and to continue pairing a "veteran" volunteer with a new volunteer during the first month of the survey season, in order to

make sure data collection efforts remain consistent and protocols are being followed correctly. There are multiple directions that this project could go in the future. In order to understand the true effects of MORAES' predation protocols, it is highly recommended that further research and evaluation of predation rates on Virginia Key be conducted, especially with the future of the island unknown. If possible, a larger number of nests should be screened in upcoming nesting seasons to monitor potential changes in predation rates. Comparisons with other urban beach sites that use wire screens as an anti-predation measure in South Florida would be beneficial, as well as analyzing predation impacts influenced by beach profiles and elevation, and vegetation coverage. Other variations of anti-predation measures against raccoons could also be studied, such as the implementation of 3D wire screens, which sit atop the nest as cages and prevent raccoons from reaching the sand near the egg chamber.

5.0 Conclusions

The barrier island of Virginia Key has a robust history, with more to be made with the possibility of further development looming on the horizon. While the balance between conservation and human activity is difficult to maintain in the natural world, loggerhead conservation efforts must be prioritized if more advancements are to be made within the USFWS' Recovery Plan for the species. For depredation efforts, a combination of measures may be required in more urban coastal areas; however, this will need to be researched and experimented on more in-depth in the future.

For the next phases of the project, the existing screening protocols should be monitored and continued for at least several more seasons. As 2022 was MORAES' first year utilizing treated wire mesh screens as an anti-predation measure, following and analyzing future trends with the success rate of these screens should be studied by future interns or loggerhead conservationists to

determine long-term success. In addition, the SNBS end of season reports should continue to gather and record data on raccoon removal efforts on Virginia Key. Finally, proper upkeep of the StoryMap with the addition of new FWC data, permitting allowing, should be done to inform audiences in the Miami-Dade area about the ongoing progress of loggerhead conservation in Virginia Key. Any changes to the current StoryMap narrative should reflect the ecological status of Virginia Key should any development occur.

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7.0 Appendices

7.1 List of 2022 Depredated Nests: N007, N008, N028, N029, N050, N055, N063, N070, N075, N084, N085, N088, N098, N100, N102, N104, N105, N110, N114, N117, N120, N121, N122, N125, N127, VKH0719NB1, VK0731AMD1

7.2 Table of Nests with their Screen Status:

	Number of nests	Number of nests depredated
Unscreened	95	11
Screened	30	6
Originally Unscreened then Screened	11	10
Originally Screened then Unscreened	1	0