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Vertebrate Impact on a Newly Deployed Shoreline Stabilization Project by Wildlife Camera Analysis

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ABSTRACT: Living shoreline stabilization is a technique that utilizes plants and other natural elements to protect estuarine coasts. Research has provided minimal information about which vertebrate species utilize living shorelines post-deployment. For this project, ten wildlife cameras were placed along a living shoreline site in Canaveral National Seashore (CANA) to document which vertebrate species utilize the living shoreline and surrounding vegetation. This shoreline was stabilized with red mangroves (*Rhizophora mangle*) and eastern oyster (*Crassostrea virginica*) shell bags in June 2019. The cameras, activated by motion sensors, remained at the site for five days a month for seven months (September 2019 - March 2020) to identify vertebrates and their behaviors. Wildlife camera footage provided data on which vertebrate species visited the site, what behaviors were exhibited, and what impact (if any) the vertebrate species had on the stabilization materials. Birds (i.e., wading birds and songbirds) and mammals (i.e., raccoons, feral hogs, deer, opossums, rats, and bobcats) were observed (total n=1,608). The North American raccoon (*Procyon lotor*; n=799) and the feral hog (*Sus scrofa*; n=523) were the most abundant vertebrates. Solitary foraging was the most observed behavior (n=552) among all vertebrate species, followed by group foraging (n=518). Both individuals and groups of *P. lotor* (n=9 for mangroves; n=38 for shell bags) and *S. scrofa* (n=6 for mangroves; n=0 for shell bags) contacted the stabilization materials. No consumption or dislodgement of stabilization materials by any species was observed. Results indicate that living shorelines provide habitat for many vertebrates (25 unique species) and these species do not negatively impact stabilization materials less than one-year post-deployment.

KEYWORDS: shoreline stabilization; living shoreline; wildlife cameras; vertebrate impact; mangroves and oyster shell bags

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INTRODUCTION

Coastlines are particularly vulnerable to rising mean sea level and to potentially increasing strength of tropical storms; these threats impact intertidal ecosystems through erosion and habitat alteration (Ellison et al., 1991; Scavia et al., 2002; Zhang et al., 2004; Nicholls et al., 2007; Overpeck & Weiss, 2009). Coastal erosion due to sea level rise is a significant problem for numerous coastal plant and animal species and the ecosystems they inhabit (Garner et al., 2015; Von Holle et al., 2019). Additionally, losses of sediment from wind and boat wakes have caught the attention of many policy makers and scientists, resulting in the deployment of hard-armoring methods, such as seawalls, rock revetments, and jetties (Manis et al., 2015). Unfortunately, hard-armoring structures have damaging effects on the ecological and economic aspect of coastal ecosystems (Scyphers et al., 2011). These structures have reduced species heterogeneity when compared to natural systems, resulting in the absence of microhabitats and decreased epibiotic diversity (Firth et al., 2014). Living shorelines have been identified as a viable alternative to hard-armoring and can combat erosion while also providing native habitat. Living shorelines are defined as a type of restoration that utilizes natural materials such as oyster reefs and native vegetation to stabilize the area of interest (Chaya et al., 2019). This type of restoration has multiple additional benefits including nutrient cycling, habitat provisioning, food production, and increased recreational opportunities (Scyphers et al., 2011).

Canaveral National Seashore (CANA) in New Smyrna Beach, Florida contains a diverse range of animal and plant species (National Park Service, 2014). Canaveral National Seashore allows visitors to view the preserved national seashore and lagoon with minimal disruptions (National Park Service, 2014). However, recreational boating traffic within the park has induced boat wakes which threaten the survival of seagrass, fish spawning areas, and oyster beds, and cause erosion of the native vegetation (National Park Service, 2014). The utilization of shoreline stabilization techniques deployed within CANA reduces these threats by planting mangrove and marsh grass species in the shoreline sediment. Oyster shell bags are placed seaward of the plants to break waves. Multiple shoreline stabilizations within Mosquito Lagoon have been previously deployed by UCF scientists, other researchers, and numerous volunteers. These shoreline stabilization techniques protect historic shell middens using natural materials, such as eastern oyster shells (*Crassostrea virginica*) and red mangroves (*Rhizophora mangle*) as a soft armoring technique (Manis, 2013; Donnelly et al., 2017). These areas are consistently monitored for resilience of the deployed materials (Manis, 2013), but minimal data are available regarding any impacts that vertebrates have on the deployed plants and shell bags. Wildlife cameras provide a viable option to fill this knowledge gap.

Over the last 30 years, camera trap studies have become more common due to improved technology and decreased prices (e.g., Potter et al., 2019). Wildlife cameras have been previously used to study numerous species, including the black grouse lek (*Lyrurus tetrix*) (Gregerson et al., 2014), Asian elephant (*Elephas maximus*) (Naing et al., 2015), crab-eating mongoose (*Herpestes urva*) (Naing et al., 2015), and jaguar (*Panthera onca*) (Silver et al., 2004). Wildlife cameras allow for a large collection of data without disturbing the observed animals. Pilot testing of wildlife cameras in the Mosquito Lagoon have recorded footage of multiple species in their natural habitats, including numerous threatened/endangered birds, feral hogs (*Sus scrofa*), white-tailed deer (*Odocoileus virginianus*), North American raccoons (*Procyon lotor*), and Florida wild bobcats (*Felidae rufus floridanus*).

Understanding the impact of vertebrate species is essential because they could negatively impact the stabilization materials. For example, *S. scrofa* has damaged 19% of exposed basin marsh in Florida wetlands (Engeman et al., 2003), and they are known to uproot large patches of vegetation, disturb areas for exotic plant species to grow, eat native amphibians and reptiles, and erode water quality (National Park Service, 2020). Additionally, *P. lotor* is another species that could negatively impact the stabilization materials, as they are known to heavily prey on marine turtle eggs and ghost crabs on beaches throughout the United States. The foraging activity of *P. lotor* has been documented to increase on nests previously preyed on by ghost crabs during peak marine turtle nest hatchling season, which could indicate *P. lotor* impacts the stabilization materials while foraging (Stancyk, 1982; Engeman et al., 2005; Barton & Roth, 2008; Brown, 2009). Another species of concern is *O. virginianus*, as they have exceeded their carrying capacity, causing degradation to native plant communities and loss of habitat diversity in their residing areas. This could indicate *O. virginianus* will eat the mangrove leaves, as mangroves are native to Canaveral National Seashore (U.S. Fish and Wildlife Service, 2008). The diet of *F. r. floridanus* has yet to be recorded, however, the diet of the

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bobcat (*Lynx rufus*) primarily consists of hares and rabbits but can incorporate other animals (e.g., rats, reptiles, and deer) depending on geographical variation (Maehr, 1986; Delibes et al., 1997). *F. r. floridanus* may impact the stabilization materials through foraging activity.

Research on how vertebrate species interact with and impact living shorelines is a topic that has not yet been documented in Florida, let alone globally. This is highly valuable information because any of these species could inhibit the success of shoreline stabilization materials, which are expensive and timely to deploy. For example, according to Marine Resources Council, *R. mangle* propagules are $1 each, with one-year and three-year old plants costing $15 and $35 each, respectively (C. Savoia, personal communication on December 1, 2020). To better understand how vertebrate species interact with shoreline stabilization materials, ten wildlife cameras were deployed on a new (June 2019) living shoreline. In order to protect shoreline stabilization efforts, we need to know how resident vertebrate species utilize their environment and if they are disrupting the shoreline stabilization materials. To answer these questions, we used wildlife cameras on the study site's living shoreline to observe a variety of vertebrate species that utilized the shoreline (either submerged or dry), assess each vertebrate's behavior in the video footage, and indicate if the vertebrates consumed or dislodged the stabilization materials.

METHODS

Study Site

This research was conducted on a living shoreline in Florida's Indian River Lagoon system (IRL), within CANA boundaries (Figure 1). Located on the east coast of Central Florida, CANA consists of wetlands, open lagoons, barrier islands, coastal hammocks, and pine flatwoods, and is managed by the National Park Service (Walters et al., 2001). Within the IRL, over 3,500 plant and animal species have been identified, making it one of the most diverse estuaries in North America (Smithsonian, 2009). High levels of biodiversity documented within the IRL are mostly due to its temperate and subtropical climates (Walters et al., 2001). The study site contained 680 m of coastline (Lat, Long: -80.789387 W, 28.867135 N to -80.793203 W, 28.872368 N) and is part of the barrier island. The shoreline was stabilized by 640 planted *R. mangle* and 1,050 oyster shell bags made from marine grade plastic mesh bags connected by zip ties and filled with *C. virginica* shells. These materials were placed in June 2019 by the University of Central Florida's Coastal and Estuarine Ecology Laboratory.

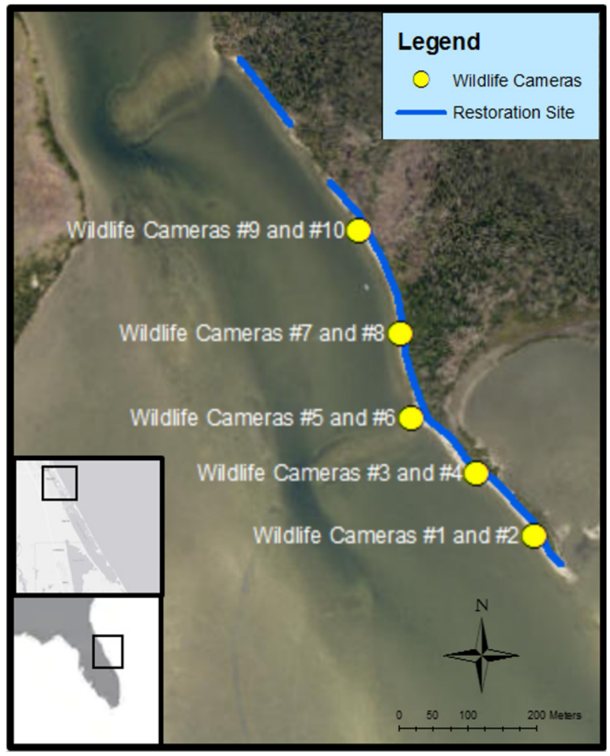

Figure 1. Living shoreline study site at Canaveral National Seashore with the ten wildlife camera locations.

Procedure

The living shoreline site was visited by boat twice a month beginning in September 2019 and ending in March 2020 with permission from the National Park Service. The first visit each month (day 1) involved deploying ten Bushnell "Trophy Cam HD" cameras to five locations along the stabilized shoreline (2 per site). The cameras were placed at haphazard locations across the shoreline stabilization site, and then remained in the same place for the entirety of the project. The cameras were set to motion detection and were activated by any movement during the day and night. Each video activation captured ten seconds of video footage and continued to take new, 10-second video clips until movement ceased. At each location, one camera was designated to record the shoreline, while a second camera, approximately five meters from the shoreline, recorded the vegetation. The shoreline cameras were secured by PVC pipes and the landward cameras were secured by native, structured vegetation (Figure 2).

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Figure 2. Bushnell "Trophy Cam HD" attached to a tree within the surrounding vegetation on the living shoreline site.

The second visit of each month (day 5) involved removing the cameras from the shoreline.

Camera footage analysis

The wildlife camera footage was analyzed to 1) determine which vertebrate species utilize the study site's living shoreline, 2) document subsequent vertebrate behaviors, and 3) determine if these species negatively impact the shoreline stabilization materials (i.e., by consuming or dislodging). Additionally, data were recorded from the videos to find out the total number of each vertebrate species and if water contact was made by any individual. Vertebrate behaviors were categorized as solitary foraging, group foraging, walking, standing, investigating camera, feeding (i.e., consuming food source), mating behaviors (i.e., mounting or intercourse), and flying. In some cases, animals appeared to repeatedly walk back and forth past a camera. In these cases, a 10-minute rule was devised for observational analyses; if an animal that physically appeared to be the same individual passed the camera more than once within 10 minutes, it was counted as the same individual. Using this rule, different behaviors exhibited within a 10-minute span would be recorded as from the same individual.

RESULTS

Vertebrate Species Identified

Between the months of September 2019 and March 2020, 1,608 observations of 25 unique vertebrate species were recorded through camera footage on the living shoreline site in CANA (Table 1). The most abundant vertebrate species was *P. lotor* (799 individuals observed), followed by *S. scrofa* (523 individuals observed). Only one individual was observed of the tricolor heron (*Egretta thula*), eastern gray squirrel (*Sciurus carolinensis*), North American river otter (*Lontra canadensis*), and American white ibis (*Eudocimus albus*).

Vertebrate Species Identified		
Wading Birds		
Scientific Name	Common Name	Number of Observations
Pelecanus erythrorhynchos	American white pelican	3
Columbina passerina	Common ground dove	18
Phalacrocorax auritus	Double-crested cormorant	9
Ardea herodias	Great blue heron	36
Ardea alba	Great white egret	4
Egretta caerulea	Little blue heron	25
Nycticorax spp.	Night heron	7
Arenaria interpres	Ruddy turnstone	17
Egretta thula	Snowy egret	1
Actitis macularius	Spotted sandpiper	24
Egretta tricolor	Tricolored heron	19
Cathartes aura	Turkey vulture	10
Calidris mauri	Western sandpiper	6

Table 1. Vertebrate species observed via camera footage at the living shoreline stabilization site between September 2019 and March 2020.

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Tringa semipalmata	Willet	5
Eudocimus albus	American white ibis	1
Songbirds		
Setophaga palmarum	Palm warbler	2
Passeri spp.	Unidentified songbird	2
Mammals		
Felidae rufus floridanus	Florida wild bobcat	23
Odocoileus virginianus	White-tailed deer	63
Sus scrofa	Feral hog	523
Didelphis virginiana	Virginia opossum	4
Procyon lotor	North American raccoon	799
Rattus spp.	Rat	5
Sciurus carolinensis	Eastern gray squirrel	1
Lontra canadensis	North American river otter	1
	Total Observations	1,608

Table 1 continued. Vertebrate species observed via camera footage at the living shoreline stabilization site between September 2019 and March 2020.

Vertebrate Behaviors

Foraging was the most observed behavior, including solitary foraging and group foraging (Figures 3 and 4). The only vertebrate species that did not forage during observations were *E. thula* and *L. canadensis*. *Procyon lotor* exhibited all categories of behaviors that could be expected to be observed in a terrestrial organism. Only *P. lotor*, *C. aura*, *O. virginianus*, and *F. r. floridanus* investigated the camera. Mating behaviors were only exhibited by *P. lotor* and *C. aura*.

Vertebrate Contact with Stabilization Materials

Eight vertebrate species were observed touching the stabilization materials, either intentionally or unintentionally (Figure 5). These species contacted the materials either while the materials were submerged during high-water season or while the materials were dry during low-water season (Figure 5). *Procyon lotor* made the most contact with the stabilization materials, including both *C. virginica* shell bags and *R. mangle*. Although eight species contacted the materials, no species were observed damaging shell bags or removing leaves or branches from deployed mangroves. Therefore, these species neither consumed nor dislodged the materials; they only came into contact with the materials while foraging.

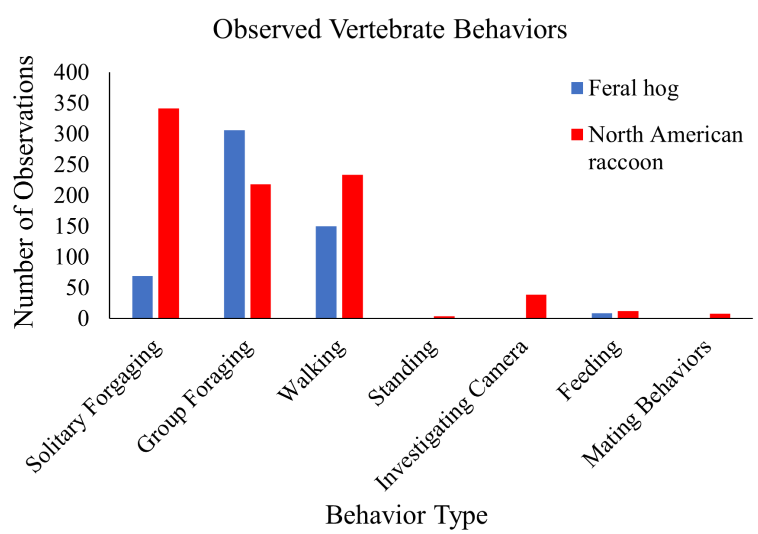

Figure 3. Behaviors of the two most observed vertebrate species, P. lotor and S. scrofa, via camera footage between September 2019 and March 2020.

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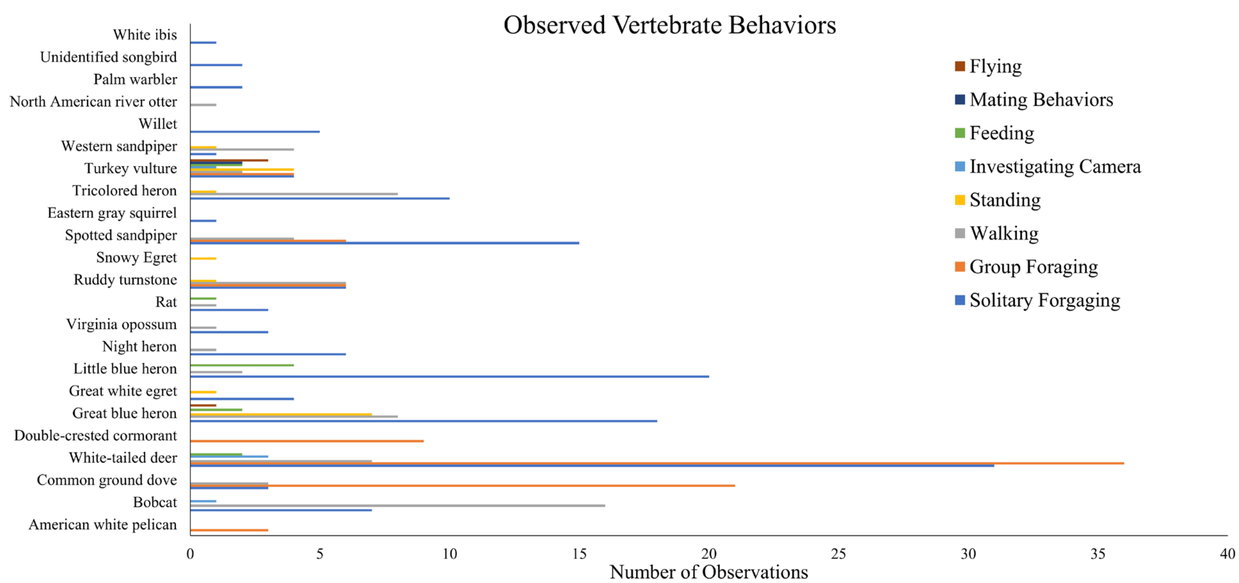

Figure 4. Documented behaviors for all other vertebrate species via camera footage between September 2019 and March 2020.

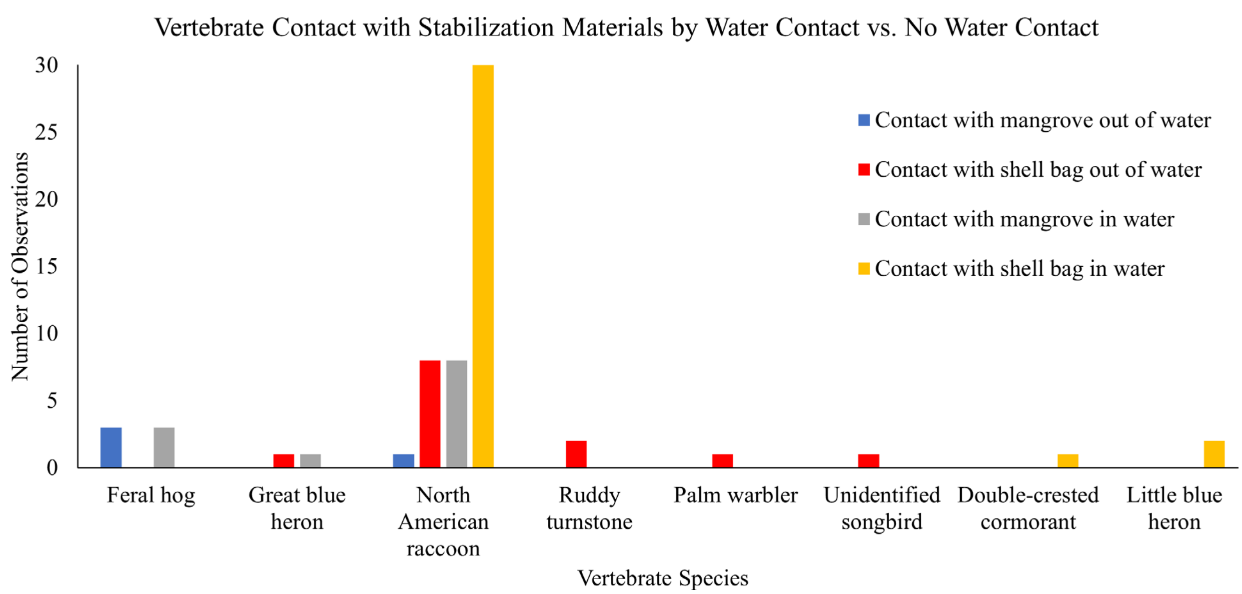

Figure 5. Vertebrate contact with stabilization materials based on water contact vs. no water contact.

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DISCUSSION

Vertebrate Species Identified

Twenty-five vertebrate species were documented on a living shoreline in CANA (1,608 individuals). Of the 25 vertebrate species, 15 species were wading birds (60%), two species were songbirds (8%), and eight species were mammals (32%) (Table 1). All birds were observed on the sandy/shelly shoreline (Figure 4), and never in the surrounding vegetation located within our research site. All eight behaviors were exhibited by one or more of the 25 species observed (Figures 3 and 4). The most important finding was that no vertebrate species negatively impacted the mangroves or oyster shell bags through consumption or dislodgement.

Procyon lotor was the most documented species with 799 individual observations. The raccoon population is flourishing because its known predators (the red wolf and the Florida panther) are no longer present in CANA (National Park Service, 2020). Moreover, raccoons are distributed throughout North, Central, and South America and are highly adaptable to changes in their environment and climate (Sawyer et al., 2009; Singer, 2020). Their adaptability likely explains their high activity levels on the shoreline and in the water. The second most observed species was *S. scrofa*, with 523 individual observations. Although *S. scrofa* are not native to Florida, they have been previously documented in CANA in large numbers (National Park Service, 2020).

Odocoileus virginianus were often seen at the study site (63 individuals). *Odocoileus virginianus* are native to Florida, and the multiple subspecies located throughout Florida can travel by land and through water, which likely explains the large number of observations of *O. virginianus* in the IRL (Mohlenbrock, 2018). *Felidae rufus floridanus* is another vertebrate species that was observed in the video footage that has previously been seen in CANA (National Park Service, 2020). Additionally, over 310 bird species have been documented within CANA (National Park Service, 2014), including the 17 species we observed.

Vertebrate Behaviors

The 25 observed species exhibited an array of behaviors throughout the seven-month deployment (Figures 3 and 4). The most common behavior exhibited was solitary foraging. Mangrove systems are the most diverse and productive ecosystems on Earth because they support marine and terrestrial life with a variety of ecosystem services (Warne, 2011). Mangroves also provide shelter for numerous specialized species to grow and reproduce (Blaber, 2007; Elliott et al., 2007). Mangroves and other shoreline stabilization materials provide an excellent foraging and feeding ground for species, both individually and in a group (such as *P. lotor*, as observed in our study). Also, the IRL is home to high levels of biodiversity (Walters et al., 2001), which support the extensive food webs of numerous species.

No humans were observed walking along the stabilized shoreline. Vertebrates were observed walking along the shoreline, within the vegetation, and within the water throughout this study. It is likely these vertebrate(s) were foraging or feeding, however, we were unable to view these behaviors once the vertebrate(s) walked out of view of the camera. Standing was another behavior displayed by vertebrate species. This behavior could be due to the vertebrate resting, or it could be associated with a foraging behavior. For example, the great blue heron slowly moved or stood-in-wait while stalking prey in shallow waters (Kushlan, 1976a; Willard, 1977; Hom, 1983).

There were only four vertebrate species observed that investigated the wildlife cameras. *Procyon lotor* was documented investigating wildlife cameras the most, either sniffing or physically moving the camera. This behavior could be due to their known curious behavior and playful tendencies (Sawyer et al., 2009). The other vertebrate species that investigated the wildlife cameras were *F. r. floridanus*, *C. aura*, and *O. virginianus* (Figure 4). This behavior likely occurred while foraging to determine if the camera was a food source.

The last two behaviors observed during this project were flying and mating behaviors. *Ardea herodias* and *C. aura* were the only two vertebrate species observed flying on camera (Figure 4). The low number of birds flying is either due to the placement of the cameras and time limit on each recording, or these species are specifically coming to our research site because there is an increase in ecosystem productivity associated with restoration. Mating behaviors were only seen in two vertebrate species, *P. lotor* and *C. aura*. *Procyon lotor* were observed displaying mating behaviors eight times, while *C. aura* performed mating behaviors twice within range of our cameras.

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Vertebrate Contact with Stabilization Materials

The stabilization materials for this project consisted of mangroves and oyster shell bags. The concern was that vertebrate species could impact these materials by consuming or dislodging the materials, therefore, disrupting the success of the living shoreline. Deploying a living shoreline is a time-consuming process that takes years to determine if the stabilization materials have remained intact and are effectively reducing shoreline erosion (Donnelly et al., 2017). For these reasons, it is essential to know if vertebrates negatively impact the stabilization materials. Fortunately, no consumption or dislodgement of the materials was observed. Only eight of the 25 observed vertebrate species contacted the stabilization materials: *S. palmarum*, *A. interpres*, *P. lotor*, *E. caerulea*, *A. herodias*, *S. scrofa*, *P. auritus*, and *Passeri spp*. (e.g., brushing up against a mangrove or shell bag while foraging, foraging next to a mangrove or shell bag, and walking on the oyster shell bags while foraging). *Procyon lotor* made the most contact with both materials and proved to be the most active vertebrate in and out of the water. *Procyon lotor* were often seen walking on top of the shell bags while foraging, however, they had no impact on the materials, nor showed interest in the materials. *Sus scrofa* was a species of concern because they have previously caused considerable damage to nesting beaches south of CANA (National Park Service, 2020). *Sus scrofa* are known to cause the most impact to native habitats among exotic mammals in Florida (Layne, 1997), so it is encouraging to find they did not impact the stabilization materials.

The living shoreline utilized for this study was fairly new, as it was deployed in June 2019 and this research began in September 2019. The mangrove trees at the research site were planted at various life stages: adults (3-4 years old) with an average height of 61.5 cm and diameter of 2.2 cm, juveniles (~2 years old) with an average height of 48.3 cm and diameter of 1.6 cm, and seedlings (~1 year old) with an average height of 38.4 cm and diameter of 1.2 cm. Because the mangroves at the site were 4 years old at most, the vertebrates observed may not have had interest in the mangroves. Had the mangroves been further developed, it is possible the vertebrates may have seen the mangrove as more of a food source and consumed them.

From September 2019 to December 2019, the stabilization materials were in the water due to the high-water season. Because the materials were submerged in the water at this time, the vertebrate species had to enter the water to contact the stabilization materials. The vertebrates that contacted the materials while maintaining water contact were *P. lotor*, *E. caerulea*, *A. herodias*, *S. scrofa*, and *P. auritus*. These five species consisted of coastal birds and adaptable vertebrates that use the water to their advantage to acquire food sources. The water plays a pivotal role in how coastal birds (migratory and local) survive because their prey resides below the branches or shell bags in the adjacent water. Throughout this project, we observed *P. lotor* and *S. scrofa* juveniles accompanying adult conspecifics, suggesting that these vertebrate species, among others, have been in this area long enough to be able to exploit the advantages that shorelines like our study site provide.

CONCLUSION

Stabilization materials (i.e., mangroves and oyster shell bags) deployed on living shorelines provide numerous environmental and economic benefits when compared to hard armoring methods, which often lower the abundance and diversity of coastal species while negatively impacting habitats (Donnelly et al., 2017; Gracia et al., 2018). Through our camera analysis, we determined that the mangroves and shell bags on the living shoreline provide habitat for many juvenile species, and support foraging grounds for adolescent and adult species. Additionally, bird species represent over half of the species documented, demonstrating that mangroves and oyster shell bags provide ecosystem services to many bird species, whether local or migratory. The frequent observations of foraging behaviors in this study indicate that the stabilization materials form habitats for vertebrates, which support extensive food webs as the mangroves grow and oyster shell bags recruit oyster spat. Observing which species are active on these shorelines and around the stabilization materials gives us an idea of the impact each species may have on the stabilization materials. This is of concern for CANA and the state of Florida because stabilization materials deployed on shorelines are key in preventing erosion, while encouraging wildlife populations. However, living shorelines encounter habitat destroyers such as *S. scrofa* and *O. virginianus*. *Sus scrofa* and *O. virginianus*, two species likely to damage newly deployed living shorelines, did not consume or dislodge any mangroves or oyster shell bags, indicating that these stabilization materials were not in danger in this location during this post-restoration time frame. This is vital information because it gives scientists and policy makers confidence

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that this method will continue to have success without the disturbance of known habitat destroyers. The results from this study indicate stabilization materials are not impacted by vertebrate species which instills confidence in other state governments wanting to deploy soft-armoring techniques to stabilize their shorelines that face environmental pressures from vertebrate species.

Limitations

This project was completed over seven months and during this time we observed behaviors exhibited in both the high- and low-water season in the IRL. With that being said, our project did not collect data during the summer season when there is higher anthropogenic activity. To understand the full spectrum of species that migrate or inhabit our study site and other shorelines like it, additional months of data collection would be necessary.

Due to the inability to tag and track individual species, vertebrate individuals were counted as the same individual if they passed the camera more than once within ten minutes. Under- or over-estimates may have resulted from this methodology. It is also likely that individuals visited the site regularly and were seen on camera multiple times. However, this could not be ascertained from our methods. Thus, the abundance of vertebrate species is relative to observations and the abundance numbers indicate the activity of the species at the site.

Future Directions

Future studies should observe living shoreline sites and non-living shoreline sites to compare vertebrate abundance and behaviors. These studies should include multiple sites for each type of shoreline and should include more than ten cameras. Having more sites and more cameras will provide a larger database for analysis.

This study was conducted in central Florida but can be replicated at any shoreline. By studying vertebrate responses and impacts on living shoreline stabilization, we can establish a better understanding of how to ensure long-term project success. Thus far, the shoreline stabilization techniques found in this study have been deployed around the world and are still being researched to determine their effectiveness (Smith et al., 2020). However, impact analyses from vertebrate interactions are sparse and could provide valuable information for scientists, resource managers, and restoration practitioners.

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