THE NESTING ECOLOGY OF SEA TURTLES: MANAGING PEOPLE, INFRASTRUCTURE, AND HABITAT

by

KATHRYN A. MASCOVICH

(Under the Direction of Kimberly M. Andrews)

ABSTRACT

An effective beach management plan (BMP) must focus on the beach habitat, infrastructure, and users (people). Here we studied how a BMP for loggerhead sea turtles (*Caretta caretta*) can be shaped. We looked at the factors influencing sea turtle nest success, finding that erosional habitats and maximum nest temperatures influence hatch success. We additionally investigated how to work with the beachfront infrastructure to minimize the threat that lights pose to nesting and hatching sea turtles. We found that an educational rack card designed to promote sea turtle-friendly lighting choices for hotel guests was not effective. Finally, we looked at two different types of education programs to determine their effectiveness at changing participants' behaviors to be more environmentally friendly. With no difference in the short-term outcomes, we recommend that organizations consider the cost and feasibility of these two program delivery methods when choosing between program types.

INDEX WORDS: Beach management plan, Conservation, Environmental education, Hotels, Lighting, Nest success, Sea turtles

THE NESTING ECOLOGY OF SEA TURTLES: MANAGING PEOPLE, INFRASTRUCTURE, AND HABITAT

By

KATHRYN A. MASCOVICH

B.S., The University of California, Berkeley, 2011

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2018

THE NESTING ECOLOGY OF SEA TURTLES: MANAGING PEOPLE,

INFRASTRUCTURE, AND HABITAT

by

KATHRYN ANN MASCOVICH

Major Professor: Kimberly Andrews

Committee: Lincoln Larson
Clark Alexander

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
May 2018

DEDICATION

I dedicate my thesis to those people who have kept me going throughout my entire life, and especially through the ups and downs of working on this degree. My parents, Joe and Sara Mascovich, have been a foundation of support since day one, providing me with unconditional love for which I am eternally grateful. My brother Jay is a similar pillar of encouragement and friendship, having always been a source of inspiration. I cannot thank my best friend Cat Jorgenson enough for being my twin sister – even if biology says we are not actually related. And although he came in during the final writing stage of my degree, I have to acknowledge the companionship during the late nights of writing, the laughter, and the unconditional love provided by my dog Bo.

There are also many people who I consider to be my second family who absolutely deserve thanks for helping me finish my master's degree and keeping me sane in the process. In addition to my family and friends listed above, these people have been my lab mates, my shoulders-to-cry-on, the first to know the good and bad, laugh-until-I-cry friends: Breanna Ondich, David Zailo, Rick Bauer, Katie Parson, Greg Skupien, Talia Levine, Darren Fraser, Lance Paden, Ashley LaVere, Zach Butler, Kristen Zemaitis, Ray Emerson, Katherine Adams, Joseph Colbert, and Rachel Walman. Without these people, my life would have included fewer laughs and harder days. For that, I cannot thank them enough.

ACKNOWLEDGEMENTS

I must acknowledge many organizations for their financial, in-kind, and field support to make this project a reality: the Jekyll Island Authority (JIA) as a whole, as well as the JIA's Georgia Sea Turtle Center, Georgia Sea Grant and Marine Extension, National Oceanic and Atmospheric Administration, the Westin Jekyll Island, the University of Georgia's Odum School of Ecology, and the University of Georgia's Center for Applied Isotope Studies.

Certain individuals from the above organizations merit acknowledgement for going above-and-beyond to help with this project: Kimberly Andrews, Lincoln Larson, Clark Alexander, Breanna Ondich, Terry Norton, Katie Higgins, Lori Hunt, Nicki Thomas, Alison Ballard, Brian O'Neal, Katy Smith, Bryan Fleuch, Mona Behl, Mark Risse, Sandi Altman, Megan Lovell, Mikayla Warren, Ashley LaVere, Zach Butler, Kristen Zemaitis, Stephanie Sowa, Alyssa Thornton, Lauren Schaale, Ray Emerson, Ben Carswell, Joseph Colbert, Yank Moore, and all of the 2016 Georgia Sea Turtle Center Turtle and Sunrise Walk guides.

This publication is supported in part by an Institutional Grant (NA10OAR4170084) to the Georgia Sea Grant College Program from the National Sea Grant Office, National Oceanic and Atmospheric Administration, United States Department of Commerce. Research was carried out with permission from the University of Georgia Institutional Review Board under Study #00003362.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

Growing human populations and the expansion of development inevitably leads to human-wildlife conflicts. When conflicts result in negative impacts on a population level for wildlife, then the species may become threatened with the risk of extinction. One species that faces persistent anthropogenic threats is the loggerhead sea turtle (*Caretta caretta*). Loggerheads are listed on the United States (US) Endangered Species Act as "threatened" and on the International Union for the Conservation of Nature's Red List as "vulnerable." In recent years, loggerhead sea turtle nesting totals have been increasing in portions of the southeastern US (Dickson, 2013). While this trend is encouraging, wildlife and natural resource managers must still focus efforts on mitigating the threats that apply pressure on the viability of this species' populations.

Although sea turtles are dominantly aquatic, many of the reasons why they are threatened relate to human activities on the beaches they utilize for nesting (e.g., Hailman & Elowson, 1992; Oliver de la Esperanza, Martínez, Tuz, & Pérez-Collazos, 2017; Witherington & Bjorndal, 1991a, 1991b). Human population sizes and densities in coastal areas are far greater than the national average, meaning that human-sea turtle conflicts are not likely to diminish in the future in these areas of concentration (Crossett, Ache, Pacheco, & Haber, 2014). Anthropogenic alterations to beach habitats, coastal development, and direct human-turtle interactions can all impact the reproductive success of loggerhead sea turtles in the southeastern US (e.g., Hailman

& Elowson, 1992; Oliver de la Esperanza et al., 2017; Witherington & Bjorndal, 1991a, 1991b). Natural resource managers wishing to successfully protect the species may focus efforts on certain issues, but ultimately a comprehensive effort to conserve these reptiles will have to incorporate: 1) ecological features of the nesting habitat; 2) beachfront infrastructure; and, 3) the people utilizing beaches during sea turtle nesting season. This thesis is a collection of three manuscripts researching questions related to those three topics. We analyzed various habitat features that were suspected to influence sea turtle nest success. Additionally, we analyzed the efficacy of mitigating infrastructure conflicts using education materials aimed at encouraging sea turtle-friendly lighting choices in a beachfront hotel. Finally, we assessed the impacts of education programs on influencing people's sea turtle knowledge, attitudes, and participation in environmentally friendly behaviors.

Sea Turtle Nesting Habitat

The reproductive success of sea turtle nests is heavily dependent on the incubation environment (e.g., Brost et al., 2015; Turkozan, Yamamoto, & Yilmaz, 2011). Therefore, it is imperative that natural resource managers understand which habitat types currently provide suitable nesting habitat, as well as which habitats may become unsuitable under future climate change and shifting shoreline scenarios. First and foremost, a major determining factor in a nest's success is the nesting sea turtle's decision regarding where to lay her eggs. Unless biologists have immediate reason to intervene due to a concern that the nest is at risk of failing in its *in situ* location, that place will be where the eggs remain until they hatch or perish. A sea turtle has a limited extent of available beach habitat from which to choose where to lay her eggs – if positioned too close to the tide line the nest is at risk of being washed over or washed away (Brost et al., 2015). Tidal washovers can significantly decrease the hatching and emergence success of a nest (Brost et al., 2015) due to an increase in the nest's moisture content and salinity, as well as temperature fluctuations (Foley, Peck, & Harman, 2006; Kobayashi et al., 2017; Maulany, Booth, & Baxter, 2012). While tidal washover is more likely to occur the closer a nest is to the spring high tide line, nesting farther back in the dunes can also put a nest at risk. If a nest is laid too near vegetation, roots may penetrate and destroy the incubating eggs (Brost et al., 2015). Additionally, a more inland location results in a longer crawl to the ocean for successful hatchlings, which is dangerous due to the threats of dehydration, exhaustion, and predation (Florida Marine Research Institute, 2003).

Although a few studies exist in the literature regarding the influence of vegetation on sea turtle nest development (Hays & Speakman, 1993; Hays, Mackay, Adams, & Mortimer, 1995; Turkozan, Yamamoto, & Yilmaz, 2011), there is relatively little information published about which vegetation species are most commonly present near loggerhead sea turtle nests in the southeastern US and whether they may have an impact (either negative or positive) on a nest's success.

The effect of temperature on the outcome of the nest in terms of both its success and the sex ratios of hatchlings is relatively well established in the literature (Hanson, Wibbels, & Martin, 1998; Horne et al., 2014; Mrosovsky, 1988). For loggerheads, a pivotal nest temperature of 29°C within the middle third of incubation (i.e., the thermosensitive period) is considered the temperature at which a roughly equal number of male and female hatchlings will be produced. Anything cooler than this and the nest will be primarily male; warmer than 29°C and a more female-dominated nest will be produced (Mrosovsky, 1988, 1994). Additionally, critical maximum temperatures have been suggested that result in the complete failure of a nest when exceeded (Horne et al., 2014; Maulany et al., 2012). Thus, climate change models predicting warmer air temperatures in the future could result in negative consequences for incubating turtles. Therefore, if critical thresholds are exceeded more frequently, then hatching success could diminish. A warmer climate could also result in a population overly skewed toward females which could be an issue if there are not enough males to fertilize eggs and if genetic diversity declines.

The stability of the beach is yet another habitat variable to consider in regard to its impacts on nest success, through temperature and tidal washovers. Depending on local dynamics, beaches may be stable, experience sand accretion, or experience sand erosion. In the southeastern US, barrier island beaches are dominantly erosional. Coastal development may exacerbate erosional processes, as shorelines are prevented from responding in a natural way. With no room for the beach to retreat inland, sea level rise as predicted under various climate change scenarios may cause erosion to advance landward until no beach remains (Grilli, Spaulding, Oakley, & Damon, 2017). Establishing where nesting habitats with erosional characteristics are currently located and analyzing the impact on nesting success can aid resource managers in making important management decisions to bolster sea turtle conservation efforts.

Development and human-made structures further alter sea turtle nesting habitat by presenting obstacles around which turtles must navigate, assuming they do not completely prevent the animal from nesting. Shoreline armoring, fencing, and dune crossovers and boardwalks are among dozens of anthropogenic structures that negatively impact sea turtle nesting habitat (Witherington, Hirama, & Mosier, 2011). Along Florida nesting beaches, potential barriers to nesting can comprise close to one-fifth of the beach area available to sea turtles (Witherington et al., 2011). Where objects do not present a physical obstacle for nesting and hatchling sea turtles, artificial lighting from coastal development can negatively influence sea turtle movements on beaches by attracting the animals inland rather than toward the ocean (Witherington & Bjorndal, 1991a, 1991b).

Other habitat factors that can impact hatching success include precipitation, the water table level, groundwater salinity, sand particle composition, duration of nest inundation, and the number of people present on the beach at night (e.g., Foley et al., 2006; Johnson, Bjorndal, & Bolten, 1996). Naturally, it is far beyond the scope of a single study to identify which of the many variables discussed here is most influential to the reproductive success of sea turtles. However, we sought to identify which of a subset of these variables were significantly impacting sea turtle nesting success on a southeastern US barrier island. Our aim was to assess nest temperatures, vegetation composition and cover, habitat type, and tidal inundation. While other factors are indeed important in sea turtle nest management, these are variables that are more easily accessible for coastal managers to quantify, making assessment and implementation goals more realistic

The Impact of Infrastructure on Reproductive Success

Sea turtles have a well-documented sensitivity to the light pollution emanating from coastal infrastructure. The primary method of sea-finding in nesting and hatchling sea turtles is through visual cues offered by the brightest location along the horizon (Mrosovsky & Shettleworth, 1968; Witherington, 1992; Witherington & Bjorndal, 1991a). Light pollution poses a threat to turtles' reproductive success along developed beachfronts when hatchlings crawl toward the artificial light rather than the ocean (McFarlane, 1963; Philibosian, 1976). However, not all lights are viewed equally for sea turtles: certain wavelengths of light do not attract sea turtles, and therefore do not negatively affect a turtle's crawl to the ocean. In general, loggerhead sea turtles are not attracted to red-colored lights above 600 nanometers on the wavelength spectrum (Levenson, Eckert, Crognale, Deegan & Jacobs, 2004; Witherington & Bjorndal, 1991b).

Since sea turtles are protected under the US Endangered Species Act, multiple counties along the Gulf and East Coasts of the United States have enacted legislation requiring beach-visible lighting to be sea turtle friendly (e.g., Glynn County, Ga., Code Ordinances ch. 2-23, art. I, 1997; Georgetown County, Sc., Code Ordinances ch. 5.5, art. III, 2016; Brevard County, Fl., Code Ordinances ch. 46, art. III, 2017; Broward County, Fl., Code Ordinances ch. 39, art. IX, 2017). Regulations often specify minimum wavelengths of light, height requirements for fixtures, and shielding of bulbs for exterior fixtures such that they are not directly visible from the beach. Interior room lighting is generally not covered by beach lighting regulations and can be controlled through closing curtains or blinds or turning off interior lights when not in use. Owners of beachfront structures (e.g., homeowners, business owners) typically become familiar over time with their community's lighting regulations (M. Dodd, personal communication May 21, 2016). On the other hand, out-of-town visitors are often unfamiliar with local lighting ordinances (personal observation). It is therefore important for natural resource managers to team up with governmental and industry partners to find solutions that ensure sea turtle-friendly lighting regulations are followed.

Human Behavior toward Sea Turtles on Nesting Beaches

People visiting sea turtle nesting beaches during the nesting and hatching seasons often behave in ways that can negatively impact sea turtles. These impacts can include walking in the sand dunes where turtles nest, littering and marine debris, leaving large objects on the beach that can later present an obstacle to sea turtles, and approaching or intruding upon nesting sea turtles.

These behaviors may be practiced intentionally, but based on personal observations, the public is often unaware that their actions can result in harm to sea turtles.

Education programs are considered to be one of the methods through which people can learn how to engage in environmentally friendly behaviors. Indeed, existing research has demonstrated that positive wildlife tourism experiences have the capacity to influence visitors' knowledge and attitudes, as well as increase appreciation and awareness (Ballantyne & Packer, 2005; Lee & Moscardo, 2005). In some cases, these experiences can even promote ecologically sustainable actions and environmental stewardship behavior (Ballantyne, Packer, & Falk, 2011; Kim, Airey, & Szivas, 2011; Powell & Ham, 2008; Powell, Vezeau, Stern, Moore & Wright, 2017). But what types of education programs create actual changes in people's behaviors, and what types of short- and long-term impacts might they generate? Answers to such questions about program structure remain elusive in the environmental education literature, which historically has focused more heavily on program impacts than on delivery methods (Stern et al., 2014).

The environmental education community emphasizes the importance of active and experiential learning that typically involves direct engagement with authentic conservation problems (Hungerford & Volk, 1990; Volk & Cheak, 2003; Stern et al., 2014). Educational experiences associated with wildlife tourism provide opportunities where such authentic connections can occur (Ballantyne et al., 2011). The experiences become even more valuable when educators or tour guides model effective stewardship behaviors linked to specific places and issues (Stern, Powell, & Ardoin, 2010), especially when those behaviors can be integrated into tourists' daily lives or routines (Newsome, Dowling, & Moore, 2004). When carefully managed and instructed, guided eco-tours might impact individual behavior beyond the specific site in which the experience occurs (García-Cegarra & Pacheco, 2016). In addition to offering ways for visitors to acquire knowledge and skills in real-world settings, wildlife tourism experiences create unique opportunities for fostering emotional connections with wildlife species through direct observations and live animal encounters (Skibins, Powell, & Stern, 2012). For example, research suggests that direct contact with animals elicits powerful affective responses and subsequent attitudinal or behavioral change (Ballantyne, Packer, Hughes, & Dierking, 2007; Ballantyne et al., 2011), particularly in cases involving reptiles (Ballouard, Provost, Barré, & Bonnet, 2012; Hassan et al., 2017; Morgan & Gramann, 1989; Skupien, Andrews, & Larson, 2016). Such positive encounters also enhance visitors' satisfaction with their overall trip experience (Ballantyne et al., 2007; Ballantyne & Packer, 2011).

Considering the trends noted above, it is not surprising that personal forms of education and interpretation such as face-to-face programs and guided tours typically have a strong influence on visitors' knowledge (Ren & Folta, 2016; Sharp, Larson, Green, & Tomek, 2012) and may have pronounced effects on their attitudes and behaviors (Hughes & Morrison-Saunders, 2005; Weiler & Ham, 2010). Guided eco-tours are a popular programming approach in the wildlife tourism context due to this educational potential and their ability to adaptively influence visitor interactions with important wildlife species and habitat. But guided programs vary substantially in their duration, location, focus, audience, and intensity of experience, all of which could produce different types of learning outcomes (Ballantyne & Packer, 2009; Powell & Stern, 2013). For example, visitors might respond very differently to a short, guided program with a large group than they would to a small-group program of longer duration with more experiential elements. Studies that suggest group size, program duration, and program type might not be important predictors of interpretive outcomes also highlight the unique benefits of intimate programs in outdoor settings (Powell & Stern, 2013). To date, few studies have specifically compared the effect of different types of programs – particularly wildlife education programs – on learning outcomes (Stern, Powell, & Hill, 2014). The third chapter of this thesis focuses on this final question and how education programs influence participants.

Creating Effective Beach Management Plans

The multi-layered impacts that habitat quality, beachfront infrastructure, and tourists have on the nesting success of loggerhead sea turtles can make forming effective conservation plans a challenging process. The purpose of this thesis is to investigate each of those areas and pull together a guiding document for natural resource managers on developed beaches in the southeastern US.

Literature Cited

Ballantyne, R., & Packer, J. (2005). Promoting environmentally sustainable attitudes and behaviour through free-choice learning experiences: what is the state of the game? *Environmental Education Research, 11*, 21-35.

Ballantyne, R., & Packer. (2009). Introducing a fifth pedagogy: experience-based strategies for facilitating learning in natural environments. *Environmental Education Research, 15,* 243-262.

Ballantyne, R., & Packer, J. (2011). Using tourism free-choice learning experiences to promote environmentally sustainable behaviour: the role of post-visit ‘action resources’. *Environmental Education Research*, *17,* 201-215.

Ballantyne, R., Packer, J., & Falk, J. (2011). Visitors’ learning for environmental sustainability: Testing short-and long-term impacts of wildlife tourism experiences using structural equation modelling. *Tourism Management, 32,* 1243-1252.

Ballantyne, R., Packer, J., Hughes, K., & Dierking, L. (2007). Conservation learning in wildlife tourism settings: lessons from research in zoos and aquariums. *Environmental Education Research, 13*, 367-383.

Ballouard, J.M., Provost, G., Barré, D., & Bonnet, X. (2012). Influence of a field trip on the attitude of schoolchildren toward unpopular organisms: an experience with snakes. *Journal of Herpetology, 46*, 423–428.

Brost, B., Witherington, B., Meylan, A., Leone, E., Ehrhart, L., & Bagley, D. (2015). Sea turtle hatchling production from Florida (USA) beaches, 2002-2012, with recommendations for analyzing hatching success. *Endangered Species Research 27*, 53-68.

Crossett, K., Ache, B., Pacheco, P., & Haber, K. (2014). National coastal population report, Population trends from 1970 to 2020. National Oceanic and Atmospheric Administration, Department of Commerce, developed in partnership with the US Census Bureau. Retrieved from: https://coast.noaa.gov/digitalcoast/training/population-report.html.

Dickson, T. (2013, August 14). Loggerhead population rising, biologists optimistic after four years of record-setting nest numbers. *Florida Times Union*, pp. A1.

Florida Marine Research Institute. (2003). *Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches* (3rd ed.). St. Petersburg, FL: Witherington, B.E., & Martin, R.E.

Foley, A. M., Peck, S.A., & Harman, G.R. (2006). Effects of sand characteristics and inundation on the hatching success of loggerhead sea turtle (*Caretta caretta*) clutches on low-relief mangrove islands in Southwest Florida. *Chelonian Conservation and Biology 5*, 32-41.

García-Cegarra, A.M., & Pacheco, A. S. (2016). Whale-watching trips in Peru lead to increases in tourist knowledge, pro-conservation intentions and tourist concern for the impacts of whale-watching on humpback whales. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *27*, 1011-1020.

Grilli, A., Spaulding, M.L., Oakley, B.A., & Damon, C. (2017). Mapping the coastal risk for the next century, including sea level rise and changes in the coastline: application to Charlestown RI, USA. *Natural Hazards*, 88, 389-414.

Hailman, J.P., & Elowson, A. M. (1992). Ethogram of the nesting female loggerhead (*Caretta caretta*). *Herpetologica*, *48*, 1-30.

Hanson, J., Wibbels, T., & Martin, R.E. (1998). Predicted female bias in sex ratios of hatchling loggerhead sea turtles from a Florida nesting beach. *Canadian Journal of Zoology 76*, 1850-1861.

Hassan, R., Yahya, N.K., Ong, L.M., Keng, L.K., Abidin, Z.Z., Ayob, A., & Jainal, A.M. (2017). Public awareness program and development of education toolkit for green sea turtle conservation in Sarawak, Malaysia. *International Journal of Environmental & Science Education*, *12*, 463-474.

Hays, G. C., & Speakman, J.R. (1993). Nest placement by loggerhead turtles, *Caretta caretta*. *Animal Behavior 45*, 47-53.

Hays, G. C., Mackay, A., Adams, C.R., & Mortimer, J.R. (1995). Nest site selection by sea turtles. *Journal of the Marine Biological Association of the United Kingdom 75*, 667-674.

Horne, C. R., Fuller, W.J., Godley, B.J., Rhodes, K.A., Snape, R., Stokes, K.L., & Broderick, A.C. (2014). The effect of thermal variance on the phenotype of marine turtle offspring. *Physiological and Biochemical Zoology 87*, 796-804.

Hughes, M., & Morrison-Saunders, A. (2005). Interpretation, activity participation, and environmental attitudes of visitors to Penguin Island, Western Australia. *Society & Natural Resources*, *18*, 611–624.

Hungerford, H.R., & Volk, T.L. (1990). Changing learner behavior through environmental education. *Journal of Environmental Education*, *21*, 8–21.

Johnson, S.A., Bjorndal, K.A, & Bolten, A.B. (1996). Effects of organized turtle watches on loggerhead (*Caretta caretta*) nesting behavior and hatchling production in Florida. *Conservation Biology*, *10*, 570-577.

Kim, A.K., Airey, D., & Szivas, E. (2011). The multiple assessment of interpretation effectiveness: Promoting visitors' environmental attitudes and behavior. *Journal of Travel Research*, 50, 321-334.

Kobayashi, S., Wada, M., Fujimoto, R., Kumazawa, Y., Arai, K., Watanabe, G., & Saito, T. (2017). The effects of nest incubation temperature on embryos and hatchlings of the loggerhead sea turtle: Implications of sex difference for survival rates during early life stages. *Journal of Experimental Marine Biology and Ecology 486*, 274-281.

Lee, W.H., & Moscardo, G. (2005). Understanding the impact of ecotourism resort experiences on tourists' environmental attitudes and behavioural intentions. *Journal of Sustainable Tourism*, *13*, 546-565

Levenson, D.H., Eckert, S.A., Crognale, M.A., Deegan, J.F., II, & Jacobs, G.H. (2004). Photopic spectral sensitivity of green and loggerhead sea turtles. *Copeia*, *2004*, 908–914

Maulany, R.I., Booth, D.T., & Baxter, G.S. (2012). Emergence success and sex ratio of natural and relocated nests of olive ridley turtles from Alas Purwo National Park, Easter Java, Indonesia. *Copeia 2012*, 738-747.

McFarlane, R.W. (1963). Disorientation of loggerhead hatchlings by artificial road lighting. *Copeia*, *1963*, 153.

Morgan, J.M., & Gramann, J.H. (1989). Predicting effectiveness of wildlife education programs: a study of students' attitudes and knowledge toward snakes. *Wildlife Society Bulletin, 17*, 501–509.

Mrosovsky, N. (1988). Pivotal temperatures for loggerhead turtles (*Caretta caretta*) from northern and southern nesting beaches. *Canadian Journal of Zoology 66*, 661-669.

Mrosovsky, N. (1994). Sex ratios of sea turtles. *Journal of Experimental Zoology* 270, 16-27.

Mrosovsky, N. & Shettleworth, S.J. (1968). Wavelength preferences and brightness cues in the water finding behaviour of sea turtles. *Behaviour, 32*, 211–257.

Newsome, D., Dowling, R.K., & Moore, S.A. (2004). Wildlife Tourism. Clevedon/Buffalo: Channel View Publications.

Oliver de la Esperanza, A., Martínez, A.A., Tuz, M., & Pérez-Collazos, E. (2017). Are anthropogenic factors affecting nesting habitat of sea turtles? The case of Kanzul beach, Riviera Maya-Tulum (Mexico). *Journal of Coastal Conservation*, *21*, 85-93.

Philibosian, R. (1976). Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights. *Copeia*, *1976*: 824.

Powell, R.B., & Ham, S.H. (2008). Can ecotourism interpretation really lead to pro-conservation knowledge, attitudes and behaviour? Evidence from the Galapagos Islands. *Journal of Sustainable Tourism*, *16*, 467-489.

Powell, R.B., & Stern, M.J. (2013). Speculating on the role of context in the outcomes of interpretive programs. *Journal of Interpretation Research*, *18*, 61-78.

Powell, R.B., Vezeau,, S.L., Stern, M.J., Moore, D.D., & Wright, B.A. (2017). Does interpretation influence elaboration and environmental behaviors? *Environmental Education Research, 2017*, 1-14.

Ren, Q., & Folta, E. (2016). Evaluating environmental interpretation with mixed method. *Journal of Interpretation Research, 21*, 5-19.

Sharp, R.L., Larson, L.R., Green, G.T., & Tomek, S. (2012). Comparing interpretive methods targeting invasive species management at Cumberland Island National Seashore. *Journal of Interpretation Research, 17*, 23-43.

Skibins, J.C., Powell, R.B., & Stern, M.J. (2012). Exploring empirical support for interpretation's best practices. *Journal of Interpretation Research, 17*, 25–44.

Skupien, G.M., Andrews, K.M., & Larson, L.R. (2016). Teaching tolerance? Effects of conservation education programs on acceptance capacity for the American alligator. *Human Dimensions of Wildlife, 21*, 264-279.

Stern, M.J., Powell, R.B., & Ardoin, N.M. (2010). Evaluating a constructivist and culturally responsive approach to environmental education for diverse audiences. *Journal of Environmental Education, 42*, 109–122.

Stern, M.J., Powell, R.B., & Hill, D. (2014). Environmental education program evaluation in the new millennium: what do we measure and what have we learned? *Environmental Education Research, 20*, 581-611.

Turkozan, O., Yamamoto, K., & Yilmaz, C. (2011). Nest site preference and hatching success of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) sea turtles at Akyatan Beach, Turkey. *Chelonian Conservation and Biology 10*, 270-275.

Volk, T.L., & Cheak, M.J. (2003). The effects of an environmental education program on students, parents, and community. *Journal of Environmental Education*, *34*, 12–25.

Weiler, B., & Ham, S.H. (2010). Development of a research instrument for evaluating the visitor outcomes of face-to-face interpretation. *Visitor Studies*, *13*, 187–205.

Witherington, B.E. (1992). Behavioral responses of nesting sea turtles to artificial lighting. *Herpetologica*,, *48*, 31–39.

Witherington, B.E., & Bjorndal, K.A. (1991a). Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta*. *Biological Conservation*, *55*, 139–149.

Witherington, B.E., & Bjorndal, K.A. (1991b). Influences of wavelength and intensity on hatchling sea turtle phototaxis: Implications for sea-finding behavior. *Copeia*, *1991*, 1060–1069.

Witherington, B., Hirama, S., & A. Mosier. (2011). Barriers to sea turtle nesting on Florida (United States) beaches: linear extent and changes following storms. *Journal of Coastal Research*, 27, 450-458.

CHAPTER 2

NEST SITE CHARACTERISTICS AND THEIR INFLUENCE ON LOGGERHEAD SEA TURTLE (*CARETTA CARETTA*) HATCHING SUCCESS[1]

[1] Mascovich, K.A. and K.M. Andrews. To be submitted to *Journal of Herpetology*.

Abstract

The reproductive success of sea turtle nests is heavily dependent on the incubation environment. Many variables can impact the success of nests, including biotic, abiotic, and anthropogenic factors. Of interest in our study were those that can be relatively easy to study by natural resource managers: nest temperatures, vegetation composition and cover, habitat type, and tidal washovers. We built a generalized linear model to determine which of our many covariates significantly impacted loggerhead sea turtle hatch success. Significant covariates in the final main effects model included the maximum nest temperature for the entire duration of incubation (positive effect), the maximum nest temperature for the final third of incubation (negative effect), and the number of tidal washovers (positive effect). Our study adds to the complex literature on this topic, as well as fills in an information gap about southeastern US plant species that occur near loggerhead sea turtle nests and if these species impact nest success.

Introduction

The reproductive success of sea turtle nests is heavily dependent on the incubation environment (e.g., Brost et al., 2015; Turkozan, Yamamoto, & Yilmaz, 2011). With most species of sea turtles being listed as federally endangered or threatened within the United States, nest protection efforts are an important part of species conservation plans. Therefore, it is imperative that natural resource managers understand which habitat types currently provide suitable nesting habitat, as well as which habitats may become unsuitable under future climate change and shifting shoreline scenarios. First and foremost, a major determinant in a nest's success is the nesting sea turtle's decision regarding where to lay her eggs. Unless biologists have immediate reason to intervene due to a concern that the nest is at risk of failing in its *in situ* location, that place will be where the eggs remain until they hatch or perish. A sea turtle has a limited extent of available beach habitat from which to choose where to lay her eggs – if positioned too close to the tide line the nest is at risk of being washed over or washed away (Brost et al., 2015). Tidal washovers can significantly decrease the hatching and emergence success of a nest (Brost et al., 2015) due to an increase in the nest's moisture content and salinity, as well as temperature fluctuations (Foley, Peck, & Harman, 2006; Kobayashi et al., 2017; Maulany, Booth, & Baxter, 2012). While tidal washover is more likely to occur the closer a nest is to the spring high tide line, nesting farther back in the dunes can also put a nest at risk. If a nest is laid too near vegetation, then roots may penetrate and destroy the incubating eggs (Brost et al., 2015). Additionally, a more inland location results in a longer crawl to the ocean for successful hatchlings, which is dangerous due to the threats of dehydration, exhaustion, and predation (Florida Marine Research Institute, 2003).

Although few studies exist in the literature regarding the influence of vegetation on sea turtle nest development (Hays & Speakman, 1993; Hays, Mackay, Adams, & Mortimer, 1995; Turkozan et al., 2011), there is relatively little information published about which vegetation species are most commonly present near loggerhead sea turtle (*Caretta caretta*) nests in the southeastern United States (US) and whether the vegetation composition or the extent of coverage may have an impact (either negative or positive) on a nest's success.

The effect of temperature on the outcome of the nest in terms of both its success and the sex ratios of hatchlings is relatively well established in the literature (Hanson, Wibbels, & Martin, 1998; Horne et al., 2014; Mrosovsky, 1988). For loggerheads, a pivotal nest temperature of 29°C within the middle third of incubation (i.e., the thermosensitive period) is considered the temperature at which a roughly equal number of male and female hatchlings will be produced. Anything cooler than this and the nest will be primarily male; warmer than 29°C and a more female-dominated nest will be produced (Mrosovsky, 1988, 1994). Additionally, the temperature of 35.1°C has been suggested as the maximum critical temperature at which a nest can survive; a nest is at high risk of failure should it exceed this temperature (Horne et al., 2014). Similarly, Maulany et al. (2012) reported that olive ridley turtle (*Lepidochelys olivacea*) nests which exceeded 34°C three days in a row had decreased hatching success. Thus, climate change models predicting warmer air temperatures in the future could result in negative consequences for incubating turtles. Therefore, if critical thresholds are exceeded more frequently, then hatching success could diminish. A warmer climate could also result in a population overly skewed toward females, which could be an issue if there are not enough males to fertilize eggs and if genetic diversity declines.

The stability of the beach is yet another habitat variable to consider in regard to its impacts on nest success, through temperature and tidal washovers. Depending on local dynamics, certain beaches may be stable, experience sand accretion, or experience sand erosion. In the southeastern US, barrier island beaches are dominantly erosional. Coastal development may exacerbate erosional processes, as shorelines are prevented from responding in a natural way. With no room for the beach to retreat inland, sea level rise as predicted under various climate change scenarios may cause erosion to advance landward until no beach remains (Grilli, Spaulding, Oakley, & Damon, 2017). Establishing where nesting habitats with erosional characteristics are currently located and analyzing the impact on nesting success can aid resource managers in making important management decisions in prioritizing where and when to bolster sea turtle conservation efforts.

Development and human-made structures further alter sea turtle nesting habitat by presenting obstacles around which turtles must navigate, assuming they do not completely prevent the animal from nesting. Shoreline armoring, fencing, and dune crossovers and boardwalks are among dozens of anthropogenic structures that negatively impact sea turtle nesting habitat (Witherington, Hirama, & Mosier, 2011). Along Florida nesting beaches, potential barriers to nesting can comprise close to one-fifth of the beach area available to sea turtles (Witherington et al., 2011). Where objects do not present a physical obstacle for nesting and hatchling sea turtles, artificial lighting from coastal development can negatively influence sea turtle movements on beaches by attracting the animals inland rather than toward the ocean (Witherington & Bjorndal, 1991a, 1991b).

Other habitat factors that can impact hatching success include precipitation, the water table level, groundwater salinity, sand particle composition, duration of nest inundation, and the number of people present on the beach at night, among others (e.g., Foley et al., 2006; Johnson, Bjorndal, & Bolten, 1996). Naturally, it is far beyond the scope of a single study to identify which of the many variables discussed here is most influential to the reproductive success of sea turtles. However, we sought to identify which of a subset of these variables were significantly impacting sea turtle nesting success on a southeastern US barrier island. Our aim was to assess nest temperatures, vegetation composition and cover, habitat type, and tidal inundation. While other factors are indeed important in sea turtle nest management, these are variables that are more easily accessible for coastal managers to quantify, making assessment and implementation goals more realistic. We hypothesized that extremely high temperatures, large temperature fluctuations (i.e., high variance), more vegetative cover, a high frequency of washovers, and erosional habitats would correspond with the lowest hatching success rates based on the literature cited above.

Methods

Study Site

Jekyll Island is one of 14 barrier islands in the state of Georgia, USA. It is a state park in southern Georgia, managed by the Jekyll Island State Park Authority (JIA); however, it receives no state funding and must therefore be financially self-reliant. To maintain park operations and be financially stable, the island is approximately one-third developed with restaurants, hotels, golf courses, a water park, and other amenities. Additionally, a portion of the land is available to be leased by individuals for private homes. Despite this development, a majority of the island is currently – and will remain – undeveloped.

The primary sea turtle species that nests on Jekyll Island – and the focus of this study – is the loggerhead sea turtle; however, sporadic nesting by green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) sea turtles has been documented (Ondich & Andrews, 2013). There are approximately 15.3 kilometers (km) of beachfront on Jekyll Island where sea turtles have historically nested. While sea turtles can theoretically nest along the entire beachfront, large portions of the beach are erosional, are armored with a rock revetment, or are immediately adjacent to beachfront development (Figure 2.1; Ondich & Andrews, 2013).

Sea Turtle Nest Data Collection

Nesting season for loggerheads on Jekyll Island begins in May and typically ends in August with hatching season extending from July through October (Ondich & Andrews, 2013; Georgia Sea Turtle Center, unpublished data). The JIA's Georgia Sea Turtle Center (GSTC) begins monitoring the beachfront for nesting activity annually on 1 May. Beach patrols continue daily to monitor nesting activity and incubating nests until the final nest has been inventoried. Nests laid below the previous night's high tide line or in an area otherwise deemed unsuitable for incubation (e.g., in front of popular beach access locations) were relocated to the nearest habitat identified by patrol to be suitable. Research patrol teams documented the number of tidal washovers (a single washover was counted if the nest was washed over at least once within the 24-hour period since the previous nest check), depredation events, and exact (when possible) hatching dates of every nest. Five days after a nest hatched, or 70 days after the nest's deposition with no signs of a hatch observed, the nest was inventoried to determine hatching and emergence success. Clutch size was determined by adding together the number of hatched and unhatched eggs in the chamber. An unhatched egg was one which was still intact, while a shell was considered hatched if it was broken, but one-half or more of the shell still remained. Hatch success was the percentage of hatched eggs divided by the clutch count. Emergence success was the number of hatched eggs minus the number of alive and dead hatchlings in the nest, with that difference divided by the total clutch count. For more detailed methods and additional history on the Jekyll Island Sea Turtle Project, refer to Ondich and Andrews (2013).

Sea Turtle Nest Temperatures

Sea turtle nest temperatures were recorded in the 2015–2017 nesting seasons. We used Onset® HOBO® Pendant™ data loggers (±0.53°C accuracy), programmed to record temperature once per hour, on the hour. These data loggers were approximately the size of a loggerhead sea turtle egg and waterproof. Loggers were often placed the same night or morning following nest deposition. Because not all turtles were encountered during the nesting process, it was not possible to place all temperature loggers in the nest at the time of deposition. Due to the extra time it would have taken to place loggers in the middle of the clutch after deposition, as well as the disturbance this poses to the incubating eggs, we chose to place temperature loggers underneath the topmost layer of eggs. Temperature loggers were retrieved by the sea turtle patrol team during the nest's inventory. Data were offloaded from the loggers using the Onset® HOBOware software and then converted into comma separated values files for analysis.

Many studies that characterize sea turtle nest temperatures often focus on how the nest's mean temperature affects hatching success. While temperature has been found to be a significant predictor variable (van Lohuizen, Rossendell, Mitchell, & Thums, 2016), we felt that other temperature metrics may also have an impact on hatch success. Therefore, in addition to the mean temperature, we chose to incorporate the following temperature variables into our analyses: maximum and minimum temperatures, mean daily maximum, mean daily minimum, mean daily variance, and mean daily maximum. For each of these variables, we further assessed whether there was any significant impact from any of these four time periods (designed around the occurrence of the thermosensitive period for sex determination; Mrosovsky, 1988, 1994): the total incubation period, first third of incubation, middle third of incubation, and final third of incubation. We defined the incubation period as the number of days from when the nest was deposited to the day at which the nest was observed to have hatched. For nests that did not hatch or the signs of a hatch were missed (as occasionally happens), we calculated the mean incubation period for all the successfully hatched nests one week prior to and after the nest was laid. Because incubation period can range depending on temperature (Matsuzawa, Sato, Sakamoto, & Bjorndal, 2002), we felt this approach provided a good proxy from which to establish an average incubation length where those data were missing.

Vegetation Plots

For each nest in 2016 and 2017, we established 5-meter-by-5-meter quadrats centered on the nest egg chambers to assess vegetative and sand cover. We conducted vegetation plots at every nest, with the exception of nests in which we knew at the time of deposition that the clutch count was abnormally low (i.e., below 30 eggs). The plot extended outward 2.5 m in each direction: perpendicular to and away from the ocean and parallel to the ocean. This scale was chosen in order to ensure that we captured impacts from any potential vegetative species whose roots could theoretically reach the egg chamber (Makowski, Finkl, & Rusenko, 2013). Our sampling methodologies were adapted from Peet, Wentworth, and White (1998) by using a ten-point cover-class scale by which an estimated percentage of vegetative and sand cover could be determined. This surveying method has been found to be reliable across multiple surveyors and sites, which we found favorable for consistent data collection. The cover classes were as follows: trace, 0-1%, 1-2%, 2-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, and 95-100% (Peet et al., 1998). To ensure the entire plot was classified – even in the absence of any vegetation – we created a cover class representing sand absent of vegetation, such that the sand cover class was the inverse of the total vegetated cover. Any plants that were rooted within the plot were identified to species (or genus if species could not be determined) and given an estimated percentage of cover within the plot.

We surveyed the nest twice to capture both the vegetative characteristics at the time of the nest's deposition as well as any growth or loss that may have occurred during incubation. The first survey was conducted within seven days of the nest's deposition. Due to the unpredictable incubation duration of nests and the logistics of surveying, our second sampling date had to be standardized relative to the nest's deposition. Because the fastest incubation period on Jekyll is around 46 days (GSTC, unpublished data), we conducted our second vegetation surveys between day 45 and day 50 of the nest's incubation.

At each nest, we determined the species diversity (i.e., the maximum number of plant species present between the two surveys), the initial percentage of bare sand cover, the maximum estimated cover of a single plant species (in the event that certain species had a greater impact on nest success), and the estimated change in growth (estimated by taking the midpoint value for each sand cover class and subtracting the two values).

Shoreline Change Classification

In conjunction with the Geographic Information Systems Department for Glynn County, Georgia, habitat profiling was conducted approximately every 0.5 km along Jekyll Island's beach within one hour of the daily low tide. Transects were perpendicular to the ocean, began at the primary dune line, and extended to the water line. These were done once each spring (May) and fall (October or November). Using ESRI's ArcMap 10.5.1, transects were overlaid to classify each one as being erosional, stable, or accretional. These determinations were made on the trends of beach elevation, as well as the beach width (erosion was visible if the dune line retreated farther inland; accretion was noticeable if the beach width increased). Where trends were not strong, the beach was classified as stable. Each nest was then assigned one of these three habitat types based on which transect was closest.

Additionally, the sea turtle patrol team on Jekyll Island used kilometer markers to delineate the beach. Kilometer (KM) 1 begins on the north end of the island and KM 15 is the final kilometer on the southern end of the island. Because the broad habitat classifications outlined above might not capture very much variability, we additionally tested for differences in hatch success, frequency of washovers, vegetative cover, and species diversity between beach kilometers.

Data Analysis

Differences across the beach were tested using a one-way analysis of variance (ANOVA). Where the assumption of equal variance was not met, we used a Kruskal-Wallis H

Test. Independent samples t-tests were conducted to look at the relationship between hatching success and nests that exceeded critical temperatures. Although these tests violated the assumption of a normal data distribution, our sample sizes were large enough for the robust test to provide reliable statistics.

In the model described below we utilized the hatching success and the location where relocated nests incubated (as opposed to the *in situ* location). However, we additionally wanted to test whether a nest's shoreline change classification category had a significant impact on the hatching success based on its *in situ* location. To accomplish this, relocated nests were treated as if they were left *in situ* and assigned theoretical hatch success rates under three scenarios: a worst-case scenario in which the nests would have failed had they remained *in situ* (i.e., 0% hatch success); a relatively poor hatch success rate had the nests been left *in situ* (20% hatch success); and a scenario in which the nests saw moderate hatch success (40%) had they been left to incubate *in situ*. Nests that were not relocated were assigned the hatch success values that they experienced in their *in situ* location. These theoretical *in situ* hatch success values were tested against the shoreline change classification category for the nest's *in situ* location using a one-way ANOVA.

Generalized Linear Model to Predict Hatch Success

To determine which factors most greatly influence a nest's hatching success, we built a generalized linear model (GLM) in RStudio, version 1.0.136 (2016). Hatch success (proportion of hatched eggs in the clutch) was our response variable. Covariates were chosen from all variables we thought might be significant:

- mean, maximum and minimum temperatures; mean daily maximum temperature; mean daily minimum temperature; mean daily temperature variance; and mean daily maximum temperature (each of these was assessed for the entire incubation period, and for each third of incubation);

- the initial percentage of bare sand cover, the maximum estimated cover of a single plant species, and the estimated change in growth;
- the number of times a nest was washed over by the tide during incubation;
- a categorical variable for shoreline change classification category: accretional, stable, or erosional.

Each of these variables' suitability in predicting hatch success was first assessed via a univariate model. Covariates with a p-value < 0.25 were included in the saturated GLM. Covariates were then removed based on low significance and AIC values until all remaining variables added significantly to the model. Initial variables that were not entered into the saturated model were added in at this stage to ensure that they did not significantly alter any of the covariate coefficients. Once all significant covariates were deemed to be included, this represented the preliminary main effects model. At this stage, the model's assumptions were checked to ensure they were not violated, including that of collinearity and a linear relationship with the response variable.

Results

Summary Statistics

In the three years of the study, a total of 458 loggerhead sea turtle nests were laid on Jekyll Island. We deployed 425 temperature loggers; due to tidal washouts and erosion from extreme tidal surge events (e.g., king tides, tropical storms), we recovered 355 loggers with a complete set of data for each nest's incubation period (Table 2.1). We conducted 161 vegetation plots in 2016 and 128 plots in 2017 (Table 2.1). In total, 352 nests were included in analyses that did not include vegetation parameters and 226 were included when vegetation variables were factored in (Table 2.1).

Nest Success & Temperatures

Mean hatch success for the three seasons was 70% (2015), 68% (2016), and 73% (2017). Mean nest temperatures ranged from 27.31 to 34.18°C (for the entire duration of incubation). The minimum temperature recorded in any nest was 20.90°C and the maximum was 39.96°C. Mean daily variance ranged from 0.42 to 5.71°C. One hundred forty-two nests exceeded a temperature of 34°C for three or more consecutive days. An independent samples t-test showed that these nests did not exhibit a significantly different mean hatch success (71%) from those that did not exceed temperatures of 34°C for three or more consecutive days (69%; $t = -0.349$, $df = 350$, $p = 0.727$). Eighty-three nests exceeded 35.1°C at some point during incubation. While the mean hatch success of nests exceeding 35.1°C (66%) was slightly lower than that of nests that did not exceed this critical temperature (71%), the difference was not statistically significant ($t = 1.252$, $df = 350$, $p = 0.211$). Only 7 of the 83 nests (8%) exceeding this critical temperature exhibited complete failure to hatch (i.e., had 0% hatch success). Finally, 318 nests had a mean incubation temperature greater than 29°C during the critical period (middle third of incubation) for sex determination.

Vegetation

Forty-nine species of plants were identified within the vegetation plots. In terms of vegetative cover, most nests had 50-95% bare sand (i.e., less than half of the area was covered by vegetation; Figure 2.2). A few nests (15%) had almost no vegetative species present, while 7% of nests were dominated by vegetation (Figure 2.2). Species diversity ranged from no vegetative species present to as many as 16 species (Figure 2.3), with a mean of 5 species and a standard deviation of 3 species at each nest. Species that were present at more than 10% of nests are listed in Table 2.2, with sea oats (*Uniola paniculata*) and seashore dropseed (*Sporobolus virginicus*) being the top two most dominant species in terms of presence. When focusing on individual species coverage at each nest, most species occupied between 10-25% of the plot area (Figure 2.4). Again, *U. paniculata* was the most dominant species in terms of land cover. Most vegetation plots did not experience a noticeable change in vegetative cover over the incubation period, with 88% of nests showing the same coverage of bare sand between the two sampling periods. Five percent of nests exhibited a loss of vegetative cover during incubation, while 7% saw an increase in vegetation cover.

Washovers, Shoreline Change Classification & Differences Across the Beach

The number of washovers for the three seasons ranged from 0 to 17, with a mean of 1.92 and a standard deviation of 0.65; 285 nests (81%) were never washed over. Thirty-three nests were laid in accretional habitat, 159 in stable habitat, and 160 in an erosional section of beach. After taking into consideration where the nests incubated (in other words, the relocated nest locations), 29 nests incubated in accretional habitat, 159 in stable habitat, and 164 in erosional habitat.

When the *in situ* nest locations of relocated nests were analyzed against theoretical hatch success rates, we found that there were significant differences between shoreline change classifications. Under a worst-case scenario of all relocated nests experiencing 0% hatch success if left *in situ*, nests laid in erosional habitats had a significantly lower mean hatch success (46%) than nests laid in stable (73%) and accretional (62%) habitats (Welch's $F_{2, 87.210} = 21.282$, $p < 0.0005$). Under a scenario assuming 20% hatching success if relocated nests had been left *in situ*, nests laid in erosional habitats had significantly lower mean hatch success (52%) than those laid in stable parts of the beach (73%), but not when compared to those laid in accretional zones (62%; Welch's $F_{2, 85.885} = 17.574$, $p < 0.0005$). Finally, under a relatively generous scenario of 40% hatch success for relocated nests had they been left *in situ*, we see similar results as above, with nests laid in erosional habitats having significantly lower mean hatch success (58%) than those laid in stable habitats (74%); however, the mean hatch success of nests in erosional habitats did not differ significantly from those laid in accretional habitats (62%; Welch's $F_{2, 84.795} = 12.443$, $p < 0.0005$).

When analyzing differences across the beach using the finer-scale measurement of kilometer delineations, a few differences emerge. Analysis of hatch success revealed that there were significant differences between beach kilometers ($\chi^2 = 22.929$, df = 9, p = 0.006). Post-hoc pairwise comparisons using Dunn's procedure with a Bonferroni correction revealed that hatch success in the erosional KM 2 (43%) was significantly lower than that in stable KM 11 (80%; p = 0.044).Significant differences were also seen across the beach when looking at the number of washovers nests experience ($\chi^2 = 35.584$, df = 9, $p < 0.0005$). Again, the erosional area of KM 2 stood out, with a significantly higher mean number of washovers (4) than all other sections of the beach (mean number of washovers for other kilometers ≤ 1; $p \leq 0.001$). There were no significant differences across the beach in terms of initial vegetative cover ($\chi^2 = 8.117$, df = 9, p = 0.522), but mean species diversity did vary significantly across the beach ($\chi^2 = 31.369$, df = 9, $p < 0.0005$). Nests located on the north end of the island in KM 1 had a significantly higher mean number of species (7) than were in KM 8 (4; p = 0.001) and KM 11 (3 species; $p < 0.0005$). While some vegetation variables differed across the beach, we did not see any correlation between vegetation cover and hatch success.

Generalized Linear Model to Predict Hatch Success

Univariate testing returned 14 covariates to be entered into the saturated GLM. Of those, just three remained significant to the main effects model: maximum temperature for the entire incubation period, maximum temperature for the final third of the incubation period, and the number of washovers (Table 2.3). While each of these covariates was a significant predictor for hatch success, the coefficient estimates were relatively low (Table 2.3). The maximum temperature for the entire incubation period, as well as the frequency of washovers yielded a positive effect on hatch success, while the maximum temperature for the final third of incubation yielded a negative effect on hatch success. The top five candidate models are shown in Table 2.4.

Discussion

Our results indicated that many nests exceeded temperature thresholds previously reported in the literature to result in nest failure; however, we did not see significantly lower hatch success in these nests. Furthermore, we documented nearly 50 plant species growing near nests, but none of our vegetation variables significantly affected hatch success. A nest's hatch success was significantly different based on the shoreline change classification within which it incubated, with those in erosional areas being the least successful. This result was additionally supported when the beach was examined on the finer kilometer-level scale. Finally, our GLM determined that the most significant variables in predicting hatch success were maximum nest temperatures during the entire incubation period, as well as the final third of incubation, and the frequency of tidal washovers.

Nest Temperatures

The mean incubation temperature found in our study was similar to that reported in other studies; however, the minimum and maximum temperatures were more extreme (Horne et al., 2014).

These more extreme values are likely attributable to a difference in methodologies. Horne et al. (2014) placed temperature loggers in the middle of the clutch; however, in our study we placed temperature loggers near the top of the clutch to maximize our sample size with minimal disturbance to the eggs. It is therefore unsurprising that we would find more extreme maximum and minimum values, as the top portion of the clutch is more vulnerable to temperature fluctuations (Hanson et al., 1998). While we cannot be certain given the differences in our methods, the fact that we saw a high percentage of nests exceed critical temperatures for nest failure (>34°C for three consecutive days; Maulany et al., 2012) is noteworthy, although the hatching success rates of those nests were not significantly lower than nests that did not exceed this critical temperature. That said, these observations suggest that an increase in temperatures, such as is expected under global climate change, could tip the critical maxima temperatures to a point of failure for many loggerhead nests on Jekyll Island and across the Georgia coast.

Similarly, we saw that many of Jekyll Island's nests exceeded a mean temperature of 29°C during the middle third of their incubation at the top of the egg chamber. This temperature is critical for prediction of sex ratios; above this critical value, and the nest is expected to produce mostly female turtles (Mrosovsky, 1988). Of particular concern is that other studies conducted in Florida (where the climate is slightly warmer) report significantly lower mean temperatures at the top of an egg chamber during this critical time period when compared to the middle of the egg chamber where metabolic heating produces higher temperatures (Hanson et al., 1998). This pattern suggests that Jekyll Island might be producing nests that are female-biased. While sea turtles have multiple paternity and may be able to persist under a somewhat female-skewed population this is still cause for concern for the long-term perpetuation of the species.

Vegetation

Our results give moderate support to past findings that loggerhead turtles prefer to avoid nesting in vegetation (Hays & Speakman, 1993; Turkozan et al., 2011). Most nests had a moderate level of vegetation nearby, but bare sand dominated in the nest area. Somewhat surprisingly, no vegetation measures were included in the final GLM as significant covariates in predicting hatching success. Although we characterized only selected nesting habitat and did not characterize the full beach habitat available with respect to vegetation, this result may be a function of the immediate area surrounding nests being fairly sparse of vegetation, as nesting loggerheads tend to prefer (in other words, loggerheads are likely selecting against heavily vegetated areas).

Washovers, Shoreline Change Classification & Differences Across the Beach

We found that erosional habitats regularly had the poorest performance in regards to hatch success than the other two shoreline change classifications (stable and accretional). These differences became particularly apparent under the scenarios involving theoretical *in situ* hatch success values for nests that were relocated. That shoreline change classifications were not a significant predictor in the GLM, but did show significant differences in these theoretical situations is important; this finding lends suggests that the current relocation protocols in place on Jekyll Island are effective at improving hatch success. Furthermore, when the beach is assessed on the finer kilometer-level scale, we saw that KM 2 on the northern end of the island experiences significantly more washovers and lower hatch success rates than other kilometers. Given the poor performance of nests in this kilometer, it would perhaps be wise for the Jekyll Island sea turtle patrol team to relocate nests more often in this area to sections of the beach that generally see higher success rates.

Generalized Linear Model to Predict Hatch Success

The final GLM included just three covariates – two relating to maximum temperature and the third being tidal washovers. Moreover, the results from the model were counterintuitive and did not support our overall hypothesis. While the full incubation period maximum temperature returned a positive effect (i.e., increases in maximum temperature will have a positive result on hatching success), the opposite held true for the maximum temperature in the final third of the incubation period. This contrast may be attributable in part to the metabolic heating processes that occur throughout the entire incubation period, especially within the thermosensitve period (Hanson et al., 1998). The positive effect of the higher overall mean nest temperatures may reflect that successful nests saw more metabolic heating. In contrast, warmer temperatures seen after the thermosensitive period could suggest that older embryos are more sensitive to hot temperatures as they are further along in development.

Finally, the positive coefficient value associated with tidal washovers was an unexpected result. This relationship is counter to the findings in the published literature and against personal observations that tidal washovers are a negative occurrence. It is possible that many washovers were short in duration and the water drained through the nest quickly without significant impacts on the embryos. If that was the case, then it is also possible that these brief washovers acted to cool the nest down and provided some benefit. That said, there are other effects that a tidal washover can have on a nest that may impact the nest's success and bear further investigation (e.g., increasing salinity; Ackerman, 1997). Ultimately, while the effect size of the washover coefficient value in our model was small (a 0.20% increase in hatching success with each additional washover), we feel that this result is perhaps flawed in some way and is likely not reflective of the true biology of the species.

Limitations & Implications for Future Research

While we did our best to assess the variables of interest, we still encountered limitations to our study that should be acknowledged. As is stated above, we believe that tidal washovers are negatively correlated with nest success, as this has been documented in the literature previously. However, a major limitation to many nest monitoring projects is that accurately assessing the degree and timing of tidal washovers is difficult. It is typically done on a coarse scale as a binary response variable (yes the nest was washed over, or no it was not). Being able to quantitatively assess the amount of water to inundate a nest and the length of time for which the eggs are submerged would provide a more accurate assessment of the relationship between hatching success and tidal washover.

Additionally, while shoreline change classification was not a significant predictor in our full model, the results including various hatching success scenarios if all nests had remained *in situ* suggest that habitat stability does indeed play an important role in a nest's success. That said, coarse measurements such as what we used to establish the overall habitat type may not capture the within-season dynamics of the microhabitat. A study that can focus on the dynamics experienced by a nest on a microhabitat scale would be extremely beneficial in teasing apart this research question.

Even where our model yielded three significant predictor variables, the effect sizes were relatively small. This suggests what many sea turtle biologists already suspect – that many variables are at play in influencing a nest's success. Alternative methods of data collection to assess the variables of interest from this study could provide better insight to those variables' effects on hatch success. On the other hand, experimental studies closely simulating field conditions could also shed light on how different variables impact nests.

Finally, we were limited in comparing our temperature findings with other published studies as very few report any other metrics than the mean, minimum, and maximum nest temperatures. If these other values were more widely reported, it would be easier for researchers to understand patterns in the temperature-nest success relationship between and across various regions and populations of nesting sea turtles.

Conclusions

Ultimately, our inconclusive results indicate that researchers must continue to lean on past findings in the literature and support future research projects as outlined above to help guide management decisions. However, we do feel confident that our results regarding critical nest temperatures for sex ratios and nest failure are informative regarding the threat of rising temperatures in a changing global climate. Additionally, our study filled in the literature gap of the vegetation species which occur near sea turtle nests in the southeastern US (Mascovich, unpublished data) and that these plant species do not appear to have a significant effect on the overall hatching success rates. These species, many of which are pioneering species on the dune forefront, may be critically important in maintaining viable sand dunes and sea turtle nesting habitat (e.g., sea oats; Miller, Yager, Thetford, & Schneider, 2003). Healthy beach dunes and stable habitats are important to the conservation of sea turtles. Therefore, the whole range of factors – from vegetation to shoreline change – needs to be taken into consideration when seeking out avenues to promote sea turtle nesting success.

Acknowledgements

This study was made possible in large part to the support of the Jekyll Island Authority and Georgia Sea Turtle Center staff. Specifically, we would like to thank Dr. Terry Norton, Breanna Ondich, and the many GSTC AmeriCorps members, interns, staff, and volunteers who helped with data collection in the 2015-2017 nesting seasons. This publication is supported in part by an Institutional Grant (NA10OAR4170084) to the Georgia Sea Grant College Program from the National Sea Grant Office, National Oceanic and Atmospheric Administration, United States Department of Commerce.

Literature Cited

Ackerman, R.A. (1997). The nest environment and the embryonic development of sea turtles. In: P.L. Lutz & J.A. Musick, (Eds.), *The Biology of Sea Turtles* (pp. 83-106). Boca Raton, FL: CRC Press.

Brost, B., Witherington, B., Meylan, A., Leone, E., Ehrhart, L., & Bagley, D. (2015). Sea turtle hatchling production from Florida (USA) beaches, 2002-2012, with recommendations for analyzing hatching success. *Endangered Species Research 27,* 53-68.

Florida Marine Research Institute. (2003). *Understanding, assessing, and resolving light pollution problems on sea turtle nesting beaches* (3rd ed.). St. Petersburg, FL: Witherington, B.E., & Martin, R.E.

Foley, A. M., Peck, S.A., & Harman, G.R. (2006). Effects of sand characteristics and inundation on the hatching success of loggerhead sea turtle (*Caretta caretta*) clutches on low-relief mangrove islands in Southwest Florida. *Chelonian Conservation and Biology 5*, 32-41.

Grilli, A., Spaulding, M.L., Oakley, B.A., & Damon, C. (2017). Mapping the coastal risk for the next century, including sea level rise and changes in the coastline: application to Charlestown RI, USA. *Natural Hazards*, 88, 389-414.

Hanson, J., Wibbels, T., & R.E. Martin. (1998). Predicted female bias in sex ratios of hatchling loggerhead sea turtles from a Florida nesting beach. *Canadian Journal of Zoology 76*, 1850-1861.

Hays, G. C., & Speakman, J.R. (1993). Nest placement by loggerhead turtles, *Caretta caretta*. *Animal Behavior 45*, 47-53.

Hays, G. C., Mackay, A., Adams, C.R., & Mortimer, J.R. (1995). Nest site selection by sea turtles. *Journal of the Marine Biological Association of the United Kingdom 75*, 667-674.

Horne, C. R., Fuller, W.J., Godley, B.J., Rhodes, K.A., Snape, R., Stokes, K.L., & Broderick, A.C. (2014). The effect of thermal variance on the phenotype of marine turtle offspring. *Physiological and Biochemical Zoology 87*, 796-804.

Johnson, S.A., Bjorndal, K.A, & Bolten, A.B. (1996). Effects of organized turtle watches on loggerhead (*Caretta caretta*) nesting behavior and hatchling production in Florida. *Conservation Biology, 10*, 570-577.

Kobayashi, S., Wada, M., Fujimoto, R., Kumazawa, Y., Arai, K., Watanabe, G., & Saito, T. (2017). The effects of nest incubation temperature on embryos and hatchlings of the loggerhead sea turtle: Implications of sex difference for survival rates during early life stages. *Journal of Experimental Marine Biology and Ecology 486*, 274-281.

Makowski, C., Finkl, C.W., & Rusenko, K. (2013). Suitability of recycled glass cullet as artificial dune fill along coastal environments. *Journal of Coastal Research 29*, 772-782.

Matsuzawa, Y., Sato, K., Sakamoto, W., & Bjorndal, K.A. (2002). Seasonal fluctuations in sand temperature: effects on the incubation period and mortality of loggerhead sea turtle (*Caretta caretta*) pre-emergent hatchlings in Minabe, Japan. *Marine Biology 140*, 639-646.

Maulany, R.I., Booth, D.T., & Baxter, G.S. (2012). Emergence success and sex ratio of natural and relocated nests of olive ridley turtles from Alas Purwo National Park, Easter Java, Indonesia. *Copeia 2012*, 738-747.

Miller, D. L., Yager, L., Thetford, M., & Schneider, M. (2003). Potential use of *Uniola paniculata* rhizome fragments for dune restoration. *Restoration Ecology 11*, 359-369.

Mrosovsky, N. (1988). Pivotal temperatures for loggerhead turtles (*Caretta caretta*) from northern and southern nesting beaches. *Canadian Journal of Zoology 66*, 661-669.

Mrosovsky, N. (1994). Sex ratios of sea turtles. *Journal of Experimental Zoology* 270, 16-27.

Ondich, B.L., & Andrews, K.M. (2013). A history of sea turtle tagging and monitoring on Jekyll Island, Georgia, USA. *Marine Turtle Newsletter 138*, 11-15.

Peet, R.K., Wentworth, T.R., & White, P.S. (1998). A flexible, multipurpose method for recording vegetation composition and structure. *Castanea*, 63, 262-274.

Turkozan, O., Yamamoto, K., & Yilmaz, C. (2011). Nest site preference and hatching success of green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) sea turtles at Akyatan Beach, Turkey. *Chelonian Conservation and Biology 10*, 270-275.

van Lohuizen, S., Rossendell, J., Mitchell, N.J., & Thums, M. (2016). The effect of incubation temperatures on nest success of flatback sea turtles (*Natador depressus*). *Marine Biology 163*, 150-162.

Witherington, B.E., & Bjorndal, K.A. (1991a). Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta*. *Biological Conservation, 55*, 139–149.

Witherington, B.E., & Bjorndal, K.A. (1991b). Influences of wavelength and intensity on hatchling sea turtle phototaxis: Implications for sea-finding behavior. *Copeia, 1991*, 1060–1069.

Witherington, B., Hirama, S., & A. Mosier. (2011). Barriers to sea turtle nesting on Florida (United States) beaches: linear extent and changes following storms. *Journal of Coastal Research*, 27, 450-458.

Table 2.1: Sample sizes for temperature loggers and vegetation plots for each season. Temperature data for 2015 were only included in the univariate testing and not in the full GLM as there were no corresponding vegetation data for that year.

	2015	2016	2017	Total
Total Nests	159	169	129	457
Loggers Deployed	134	164	127	425
Loggers Recovered	127	152	76	355
Vegetation Plots	0	161	128	289
Included in Analysis	126	150	76	352 (226 in GLM)

Table 2.2: The most abundant plant species identified at sea turtle nests. Only those species that were present at more than 10% of nests are shown here. In addition to those listed here, 37 other species were identified near sea turtle nests in 2016 and 2017.

Species	% Nests Present
Sea oats (*Uniola paniculata*)	49
Seashore dropseed (*Sporobolus virginicus*)	49
Silver-leaf croton (*Croton punctatus*)	46
Beach marsh-elder (*Iva imbricata*)	35
American sea-rocket (*Cakile edentula*)	27
Coastal sandbur (*Cenchrus spinifex*)	27
Russian thistle (*Salsola kali*)	23
Bitter panicgrass (*Panicum amarum*)	23
Beach morning-glory (*Ipomoea imperati*)	17
Yellow nutsedge (*Cyperus esculentus*)	16
Camphorweed (*Heterotheca subaxillaris*)	13
Beach pennywort (*Hydrocotyle bonariensis*)	11

Table 2.3: Results of the main effects generalized linear model. Maximum temperature throughout the entire incubation period (full incubation), maximum temperature in the final third of the incubation period, and the number of tidal washovers were all significant covariates in predicting hatch success.

	Estimate	Std. Error	t-value	p-value
Intercept	3.16	0.86	3.67	$p < 0.001$
Max Temperature (Full Incubation)	0.80	0.14	5.56	$p < 0.001$
Max Temperature (Final Third Incubation)	-0.86	0.14	-5.96	$p < 0.001$
Number of Washovers	0.20	0.04	5.24	$p < 0.001$

Table 2.4: The top five candidate GLM models showing the relationship between hatch success and each variable in the model. Shown for each model is the Akaike's Information Criterion (AIC) and the difference in AIC from the top-ranked model (ΔAIC). Variables are abbreviated as follows: all (the time period pertaining to the entire incubation duration), first (the first third of incubation), last (final third of incubation), max (maximum nest temperature), mean (mean nest temperature), mean daily max (the mean daily maximum nest temperature), and washovers (the number of washovers the nest experienced).

Model	df	AIC	ΔAIC	AIC weights
~ all max + last max + washovers	349	-209.35	0	0.64
~ last mean + all max + last max + washovers	349	-207.30	2.05	0.23
~ first mean + last mean + all max + last max + washovers	349	-205.42	3.93	0.09
~ first mean + last mean + all max + last max + first mean daily max + washovers	349	-203.50	5.85	0.03
~ first mean + last mean + all max + last max + first mean daily max + last mean daily max + washovers	349	-201.67	7.68	0.01

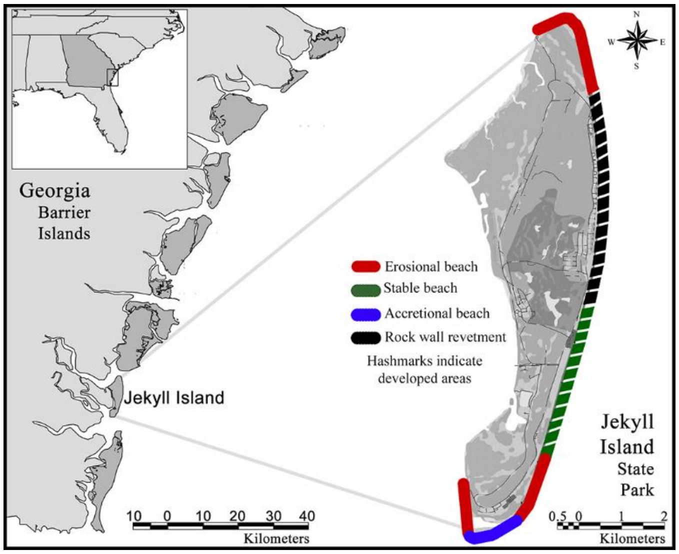

Figure 2.1: The study site, Jekyll Island, GA, USA.

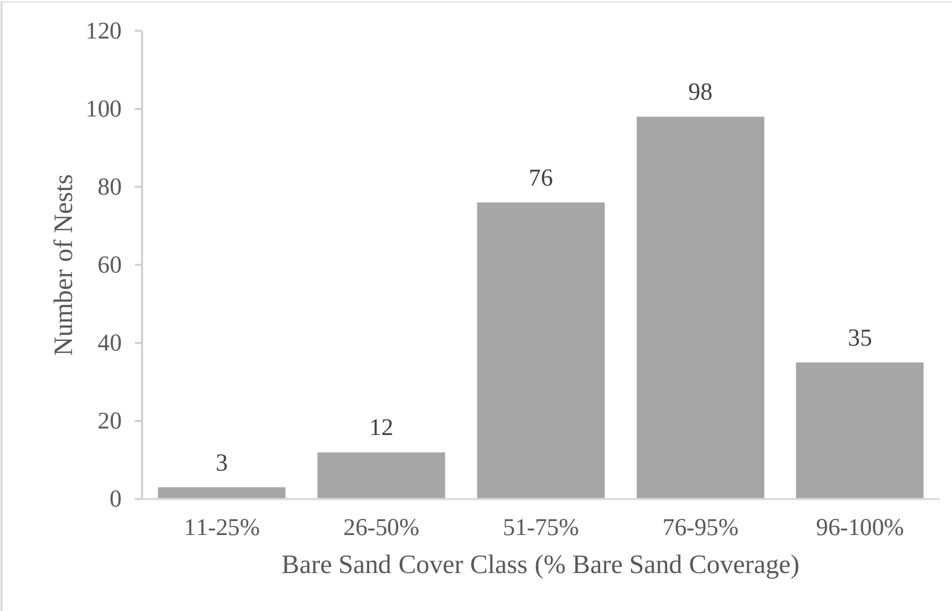

Figure 2.2: The number of nests within each bare sand cover class.

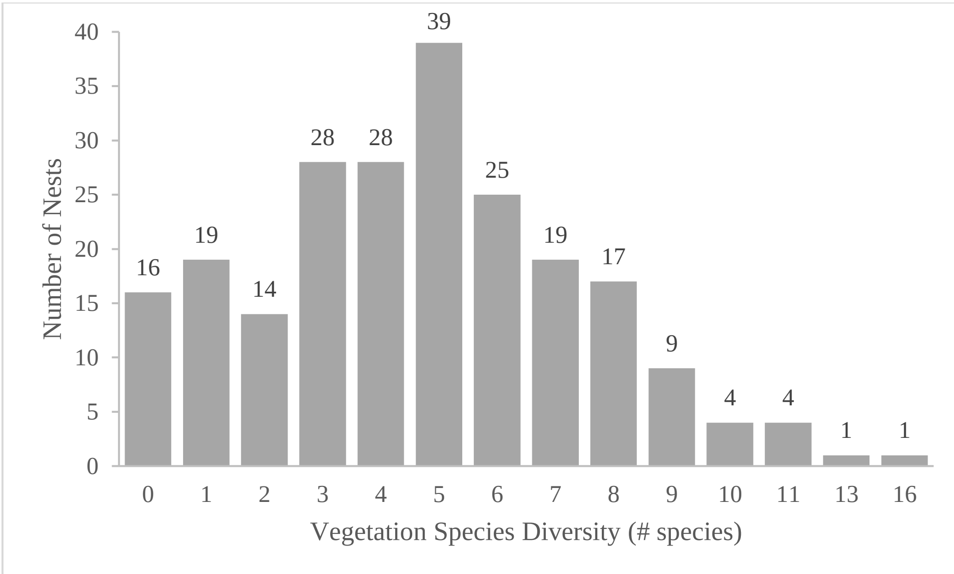

Figure 2.3: Species diversity present at nests.

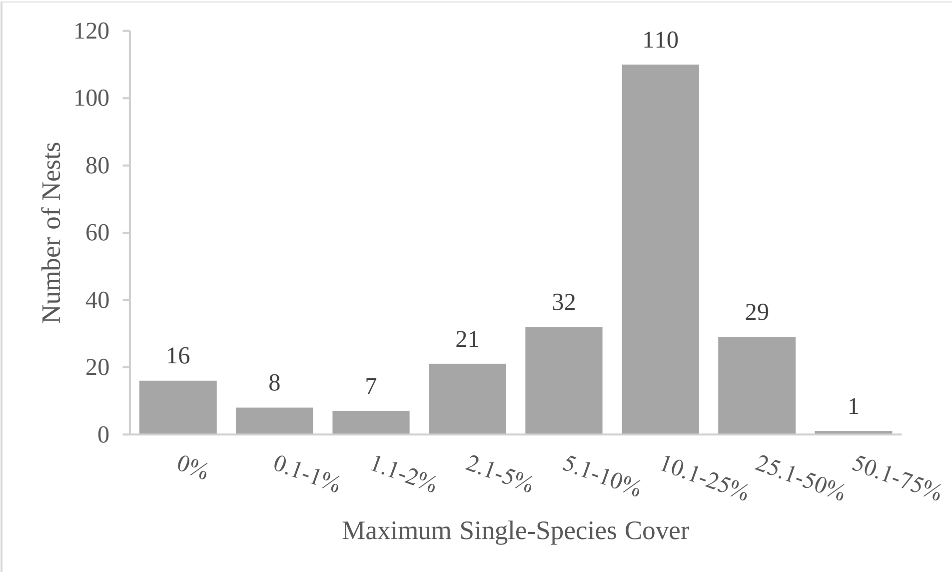

Figure 2.4: The maximum area coverage within a plot seen by a single plant species.

CHAPTER 3

LIGHTS ON, OR LIGHTS OFF? HOTEL GUESTS' RESPONSE TO NON-PERSONAL EDUCATIONAL OUTREACH DESIGNED TO PROTECT NESTING SEA TURTLES[2]

[2] Mascovich, K.A., L.R. Larson, and K.M. Andrews. Accepted by *Chelonian Conservation and Biology*. Reprinted here with permission of the publisher.

Abstract

Light pollution from beachfront hotels has the potential to impact nesting and hatching sea turtles. Education strategies could be used to alter visitor behavior and mitigate this threat. We tested the efficacy of a sea turtle-friendly education card that encouraged visitors to “protect the night, hide the light.” Cards were placed in beachfront hotel rooms at a prominent sea turtle nesting site: Jekyll Island, GA. We assessed visitor responses by conducting nightly observations to determine the proportion of occupied guest rooms with beach-visible lights under two different scenarios (cards present or cards absent). We found that less than half of all hotel guests closed room blinds to minimize artificial light on the nesting beach, and compliance rates seemed to be lower during peak visitation times. The non-personal educational treatment (card) had little effect on visitors’ sea turtle-friendly lighting choices and behaviors, highlighting the need for other approaches to encourage responsible tourist behavior at ecologically sensitive beach destinations.

Introduction

The use of artificial lights at night in public locations is often seen as a benefit to public safety. However, for humans and many other species, light pollution can have damaging effects on individual health and reproductive success. Many studies have documented negative impacts of light pollution on multiple species (e.g., LeTallec, Théry, & Perret, 2015; Raap, Casasole, Pinxten, & Eens, 2016; Rodríguez et al., 2014). When artificial lights impact populations of declining, threatened, and endangered species, it becomes important to monitor and mitigate the effects.

One group of animals with a well-documented sensitivity to artificial lights is sea turtles. The primary method of sea-finding in nesting and hatchling sea turtles is through visual cues offered by the brightest location along the horizon (Mrosovsky & Shettleworth, 1968; Witherington, 1992; Witherington & Bjorndal, 1991a). Light pollution poses a threat to turtles' reproductive success along developed beachfronts when hatchlings crawl toward the artificial light rather than the ocean (McFarlane, 1963; Philibosian, 1976). However, not all lights are viewed equally for sea turtles: certain wavelengths do not appear to attract sea turtles, and therefore do not negatively affect a turtle's crawl to the ocean. In general, loggerhead sea turtles (*Caretta caretta*) are not attracted to red-colored lights above 600 nanometers on the wavelength spectrum (Levenson, Eckert, Crognale, Deegan, & Jacobs, 2004; Witherington & Bjorndal, 1991b).

Since sea turtles are protected under the United States Endangered Species Act, multiple counties along the Gulf and East Coasts of the United States have enacted legislation requiring beach-visible lighting to be sea turtle friendly (e.g., Glynn County, Ga., Code Ordinances ch. 2-23, art. I, 1997; Georgetown County, Sc., Code Ordinances ch. 5.5, art. III, 2016; Brevard County, Fl., Code Ordinances ch. 46, art. III, 2017; Broward County, Fl., Code Ordinances ch. 39, art. IX, 2017). Regulations often specify minimum wavelengths of light, height requirements for fixtures, and shielding of bulbs for exterior fixtures such that they are not directly visible from the beach. Interior room lighting is generally not covered by beach lighting regulations and can be controlled through closing curtains or blinds or turning off interior lights when not in use. Owners of beachfront structures (e.g., homeowners, business owners) typically become familiar over time with their community's lighting regulations (M. Dodd, personal communication May 21, 2016). On the other hand, out-of-town visitors are often unfamiliar with local lighting ordinances (personal observation).

In these communities, various forms of environmental education and interpretive materials may be required to: 1) inform visitors of sea turtle-friendly beach behaviors; and 2) encourage visitors to participate in these behaviors. A particular concern for nesting sea turtles is the light emanating at night from large beachfront hotel rooms (Kaska et al., 2010; Oliver de Esperanza, Arenas Martínez, Tzeek Tuz, & Pérez-Collazos, 2017). Despite requests to minimize artificial light to protect nesting turtles, many guests keep lights in their rooms on and visible well into the night (M. Dodd, personal communication May 21, 2016; personal observation). Our study sought to identify the magnitude of this problem and explore potential mitigation strategies.

Research in the fields of environmental education and interpretation highlights two primary methods of message delivery that may impact human behavior, both with unique advantages and disadvantages (Marion & Reed, 2007; Sharp, Larson, Green & Tomek, 2012). Interpersonal communication, or face-to-face interactions, allow for two-way communication between an interpreter and visitors (Knudson, Cable, & Beck, 2003). This approach typically is viewed as desirable by site managers, in part because it allows the interpreter to respond to audience reactions, needs, and questions (Munro, Morrison-Saunders, & Hughes, 2008; Wearing & Neil, 1999). However, interpersonal education is limited in its ability to reach large numbers of visitors and is often difficult to implement due to the high cost of training and staffing.

Alternatively, non-personal communication strategies (e.g., brochures, signage) enable educators to communicate with a broader audience without relying heavily on staff resources. This approach is relatively inflexible and requires visitors to access and interpret information on their own. For individuals with limited interest in or experience with a topic (e.g., nesting sea turtles), such drawbacks may limit message consumption and efficacy. The static nature of non-personal education makes it less desirable to many natural resource managers (Hughes, 2004); yet, due to its comparatively low costs, non-personal forms of communication typically dominate visitors' experiences (Knudson et al., 2003).

Important questions for natural resource managers therefore become: which type of educational materials should be used in different situations? Do the benefits of interpersonal communication justify the costs, or are cost-efficient and wide-reaching non-personal strategies equally effective at changing visitor behavior? As a result, outcome assessment is needed to identify best practices (Marion & Reed, 2007; Silverman & Barrie, 2000; Washburn, 2007).

Although many studies have examined the impact of different forms of interpretation on visitor knowledge and attitudes (Ham, 1992; Henker & Brown, 2011; Sharp et al., 2012; Widner & Roggenbuck, 2000), fewer have considered impacts on overt conservation behaviors (Ardoin, Heimlich, Braus, & Merrick, 2013; Munro et al., 2008). The few studies that have researched the effects of education on conservation actions have found that interpersonal efforts often produce positive conservation behavior outcomes, while non-personal education strategies have mixed results (e.g., Fielding et al., 2013; Kidd et al., 2015; Sharp et al., 2012; Taylor, Curnow, Fletcher, & Lewis, 2007; Warren, Becken, & Coghlan, 2017). In one case, research has shown that in-room messaging promoting water conservation at hotels (e.g., encouraging visitors to hang and re-use towels) can be effective (Morgan & Chompreeda, 2015). We sought to explore the efficacy of one education strategy (an in-room, non-personal informational rack card) on a particular conservation behavior: beachfront hotel guests' decision to engage in sea-turtle friendly actions such as turning off lights and/or closing their blinds at night.

We chose to explore this question on Jekyll Island, Georgia, USA, a popular tourist destination where sea turtles are a prominent attraction. Jekyll Island is also a place where coastal development could potentially disrupt sea turtle nesting patterns. In the past, lights from Jekyll's beachfront structures have attracted hatchlings landward rather than to the ocean (Bagwell 2001). Additionally, the presence of tourists on the beach at night can alter sea turtle nesting behavior (Hailman & Elowson, 1992). Therefore, sea turtle conservation is a high priority on Jekyll Island. Our study centered on two objectives. First, we wanted to understand when visible light ratios (the proportion of occupied hotel rooms with open blinds) were highest and identify factors associated with those peaks. Second, we wanted to evaluate the impact of a persuasive, non-personal communication tool (rack card) on hotel visitors' lighting choices. We hypothesized that we would see a significantly lower proportion of occupied guest rooms with visible lights when rack cards were present compared to nights when the cards were absent.

Methods

Study Site

Jekyll Island State Park is one of 14 barrier islands in the state of Georgia, USA. Between May and August, sea turtles use Jekyll's beaches to nest, with hatching season occurring from July to October. Loggerhead sea turtles are the predominant nesting species; however, green (*Chelonia mydas*) and leatherback (*Dermochelys coriacea*) sea turtle nests have been documented nesting on the island (Ondich & Andrews, 2013).

Jekyll Island has approximately 15.3 kilometers (km) of beach available on which sea turtles could nest. Approximately 8.3 km of beachfront is undeveloped, although about 5 km of that nesting habitat is located along eroding shorelines. Another 5 km of beach has a rock wall revetment which does not offer suitable nesting habitat (Georgia Sea Turtle Center (GSTC) unpublished data; Ondich & Andrews, 2013). A large portion of this rock wall beach coincides with beachfront residential homes and hotel development. An additional 2 km of suitable nesting habitat south of the rock wall is developed by hotels, restaurants, shops, a convention center, and popular public beach access locations (Figure 3.1). Since development introduces artificial lights, Glynn County, Georgia has legislation regulating lights visible from nesting beaches. Further, the Jekyll Island State Park Authority (JIA) passed its own ordinance in 1981 and updated it in 2008 to include stricter lighting regulations than those mandated by Glynn County (Jekyll Island Auth., Ga., Code Ordinances ch. 10, art. IV, 2015).

Educational treatment

During the time of the study (2015 – 2016), Jekyll Island had five beachfront hotels in operation, with all but one having guest rooms directly visible from the beach. The tallest of these hotels stands at five stories. Three of the building's sides can be seen from the adjacent beach (the north, east, and south faces). When guest room blinds are left open, the light from beach-facing rooms can be seen for at least 1 km in each direction (north/south) along the beach. The light seen from hotel guest rooms includes unshielded fixtures whose bulb or filament can be seen directly on the beach and shielded fixtures whose cumulative light may illuminate the beach.

In anticipation of the possible impact this might have on nesting and hatching sea turtles, the hotel's local management team approached the JIA's GSTC (a local sea turtle hospital, education facility, and research center) to assist them in developing an effective method to educate guests to close their blinds at night. A non-personal education method was chosen due to the benefits it prescribes regarding cost, time, and audience reach. An educational plaque affixed to the wall near guest room blinds was discussed initially, but corporate-level requirements dictating that rooms should look similar across all hotel locations made this idea infeasible. Because brochures do not have to be approved by corporate-level management, the decision was made to place a two-sided "Protect the Night, Hide the Light" rack card in each guest room (hereafter referred to as "rack card"). These rack cards are designed to catch the eye with colorful imagery and limited text on the front, with the back providing more detailed information on sea turtles' sensitivity to lights and how people can modify their behavior to remedy the problem (Figure 3.2).

To determine whether these cards were effective at educating guests, rack card distribution was carefully monitored in regard to study design. From May – October 2015, each guest room received a rack card (treatment group). Cards were placed in rooms regardless of whether the room could be seen from the beach to simplify the instruction to the housekeeping staff and to reduce confusion about which rooms received the cards. However, only beachfront rooms were surveyed and counted as part of the analysis. Rack cards were placed on the bed for maximum visibility and were restocked by housekeeping staff when new guests arrived or if one was removed or damaged. Through weekly spot checks of rooms and conversations with guests, we confirmed that rack cards were placed as we had requested. In 2016, guest rooms did not receive rack cards (control group).

Data Collection

Observational counts of lights in hotel rooms were conducted by the same observer three times weekly in 2015 and 2016 (unless inclement weather prevented a survey from occurring to ensure surveyor safety). Observations coincided with the months during which sea turtles were nesting or hatching and Jekyll Island's lighting ordinance was in effect (May – October). Observation sessions were randomly chosen through a number generator (Microsoft Excel, v. 2013) with at least one session per week occurring during peak visitation times on a Friday, Saturday, or Sunday. To reduce the effect that day-of-week-variation may have on visitation rates (higher on weekends), observation session nights in 2016 were matched to occur on the same nights of the week on which they were conducted in 2015. For example, if an observation session in 2015 occurred on the Monday of the 27th week of the year, then the 2016 observation occasion was set to also be on the Monday of the 27th week of the year. We systematically chose the nights in 2016 (the control year) to match those in 2015 (the treatment year) to avoid a potential skew towards high-occupancy weekends, or vice versa and to minimize that potential variation across years. Finally, as hotel guests on vacation often reside in the same hotel room over multiple consecutive nights, we included in our analysis counts only from those observation occasions separated by at least four nights to minimize bias associated with potential independence between observations ("sampling nights").

During each observation session, all windows on beach-facing sides of the hotel were counted as either having "no light visible" (lights off and/or blinds completely closed) or having a "light visible" (lights on and blinds fully or partially open; Figure 3.3). Any light emerging through blinds (even partial light) could impact turtle behavior and would suggest that visitors were not complying with the rack card instructions. In hopes of having a maximum number of hotel guests present in their rooms and still awake in the hours after sunset, surveys began at approximately 2100 hrs. As it was not completely dark outside during the summer months before 2100 hrs, we also selected this time to ensure we were collecting observations during a period where emanating light was visible and potentially impactful to the nocturnal turtles. Last, because environmental conditions could impact a guest leaving their lights on or blinds open, data on environmental conditions were collected, including: whether it was raining (yes/no), estimated percentage of cloud cover (0-24%, 25-49%, 50-74%, or 75-100%), and air temperature.

Analysis Methods

To account for hotel occupancy rates, the estimated number of beachfront rooms occupied (i.e., occupancy rate) at the time of an observation was determined by multiplying the number of available beachfront rooms (n = 151) by the corresponding monthly occupancy rate (0-100%) of the hotel (note: daily occupancy rates could not be obtained). The final step in estimating the proportion of occupied beachfront rooms with visible lights was to divide the number of rooms counted with lights visible by the estimated number of beachfront rooms occupied at the time of sampling (as calculated above using monthly occupancy rates). This method of adjusting the proportion of visible lights for occupancy rates likely led to an underestimation of occupied rooms during peak visitation days (e.g., Saturday nights), therefore resulting in an overestimation of the proportion of visible lights; the inverse of this pattern also holds true (i.e., nights with lower-than-monthly occupancy rates likely resulted in an underestimated proportion of visible lights).

All statistical tests were conducted using SPSS Version 21.0. We used a 2x7x6x3 factorial analysis of covariance (ANCOVA) with one continuous covariate (temperature) to evaluate how our independent variables influenced the mean proportion of occupied rooms with visible lights. Independent variables included in the model were treatment group (i.e., year), day of the week, month, and cloud cover class (0-24%, 25-74%, and 75-100%). Interaction effects between treatment and other variables in the model were additionally examined. Interactions that were not statistically significant were dismissed and not included in our final model. We conducted preliminary checks to ensure the assumptions of the ANCOVA model were not violated; these included: 1) that the covariate was linearly related to the dependent variable, 2) homogeneity of regression slopes, 3) an approximately normal distribution of the dependent variable for each level of the independent variables, 4) homoscedasticity, 5) homogeneity of variances, and 6) no significant outliers present. Where a variable was found to be a significant predictor in the model, a *post hoc* Bonferroni multiple comparisons test was used to further examine the results. A significance threshold of $p = 0.05$ was set for all analyses unless otherwise stated.

Results

We had a combined total of 137 observation sessions for the two years (73 nights in 2015 and 64 nights in 2016). From the observation sessions, 58 sampling nights were used in analysis (29 nights from each year). In our treatment year (2015), the mean proportion of occupied guest rooms with visible light was 0.61, with a standard deviation of 0.21 ($n = 29$). Surprisingly, the mean proportion of occupied rooms with visible light during the control year was lower at 0.53 ($n = 29$), with a standard deviation of 0.11. By month within the treatment year, the mean proportion of visible light varied from a low of 0.36 (August) to a high of 0.91 (May). In the control year, monthly mean proportions ranged from 0.49 (August) to 0.59 (June; Figure 3.4).

Controlling for temperature as a covariate, the ANCOVA model found a statistically significant effect of treatment ($F_{1,37} = 14.30$ $p = 0.001$, $\eta^2 = 0.28$), day of week ($F_{6,37} = 2.45$, $p = 0.04$, $\eta^2 = 0.28$), month ($F_{5,37} = 8.00$, $p < 0.001$ $\eta^2 = 0.52$), and an interaction effect between treatment and month ($F_{5,37} = 4.49$, $p = 0.003$, $\eta^2 = 0.38$; Table 3.1).

Pairwise comparisons between days of the week indicated that Saturdays had a significantly higher proportion of rooms with visible light than both Mondays ($p = 0.001$) and Wednesdays ($p = 0.005$). Since the interaction term between month and treatment was significant, an analysis of simple main effects was performed with statistical significance receiving a Bonferroni adjustment, resulting in acceptance at the $p < 0.025$ level. A significant difference in the mean proportion of occupied rooms with visible light was found between treatment types for the months of May ($F_{1,37} = 20.14$, $p < 0.001$, partial $\eta^2 = 0.35$), June ($F_{1,37} = 6.99$, $p = 0.01$, partial $\eta^2 = 0.16$), and July ($F_{1,37} = 7.20$, $p = 0.01$, partial $\eta^2 = 0.16$), but not for August through October. May, June, and July each had a significantly lower mean proportion of visible lights in the control year than in the treatment year.

Finally, the GSTC had an educator present in the hotel on Fridays in June and July 2016 (the control year) during peak check-in hours. Despite this, a one-way ANOVA showed that there were no significant differences between months in the proportion of occupied hotel rooms with visible lights that summer ($F_{5,22} = 0.77$, $p = 0.58$). We therefore concluded that these relatively infrequent interpersonal education opportunities in 2016 did not significantly alter lighting choices and behavior within our control group.

Discussion

Our results suggest that: 1) fewer than half of all hotel guests in beachfront rooms abided by the recommended lighting regulations to protect nesting sea turtles, and 2) the educational treatment (rack card) failed to have a positive impact on visitors' sea turtle-friendly lighting choices and behaviors.

Temporal variations were also observed with respect to these behaviors. We found that May through July had significantly higher proportions of visible lights when the rack card was present in 2015. This is probably a function of the hotel's grand opening in April of that year. We believe that the hotel's staff were learning how to best operate in those initial months, resulting in fewer staff members being aware that: 1) sea turtles were nesting on the beach adjacent to the hotel beginning in May, and 2) that hotel guests' lights could pose a threat to sea turtles. As lighting issues were brought to the hotel's attention, staff were likely briefed on how to encourage guests to practice sea turtle-friendly lighting behaviors, leading to non-significant differences between the treatment group in the latter half of the nesting season (August through October) and the control group during that same period the following year. Although the non-personal rack card was ultimately ineffective at altering behaviors for many hotel guests, personal education-oriented interactions between hotel staff and guests might have gradually influenced visitors' behaviors as time progressed.

We found that the highest proportions of rooms with visible lights were observed during peak visitation times of Saturday evenings, and the lowest proportion of visible lights were observed on Monday and Wednesday nights when fewer guests were staying at the hotel. These findings could be attributed, in part, to our use of monthly hotel occupancy rates (rather than daily rates) to estimate how many beachfront rooms were occupied on any given night. But they could also reflect larger patterns in visitors' lighting choices and behaviors.

Regardless of the type of education intervention (non-personal vs. interpersonal) selected for conservation education, our findings suggest what one might already suspect from a management standpoint: the most important times to address beachfront lighting is during peak visitation days (e.g., weekends) and months (e.g., late spring/early summer) when more guests are present and a higher percentage of guests in beachfront rooms leave lights on with blinds open. A targeted management regime based on peak visible light ratios could prevent potential negative impacts on nesting sea turtles in the future and likely aid in the population recovery of the endangered animals. It could ultimately also cost hotel and wildlife managers less time and money in mitigating the issue. How, then, might managers effectively accomplish these goals to reduce this light pollution problem?

Our results appear to suggest that the rack cards, though relatively easy to produce and distribute, might not be the best solution. According to the elaboration likelihood model (ELM) of persuasion, our results might not be surprising. When people have the motivation, experience, ability, and predisposition to assimilate information about relevant issues, then persuasive communication can generate lasting outcomes (Ballantyne & Packer, 2011; Cacioppo & Petty, 1984). We presume, however, that many hotel guests on Jekyll Island do not possess inherent interest in or experience with sea turtles (Mascovich unpublished data). This would make them more likely to engage with information via peripheral pathways in the ELM, and it would make them less likely to respond voluntarily to non-personal messages that are not also accompanied by more direct personal experience (Gore, Knuth, Curtis, & Scherer, 2008). Research has shown that visitors to natural areas are most likely to alter their behavior and minimize ecological impacts following direct personal contact with guides or site staff (Kidd et al. 2015; Sharp et al. 2012). The enhanced educational value of personal and authentic animal encounters (relative to other forms of information distribution) for Jekyll Island visitors has been demonstrated with other reptile species (e.g., alligators; Skupien, Andrews, & Larson, 2016) to influence risk perceptions, and could lead to deeper message processing and subsequent action with respect to turtles as well. For instance, Disney's Vero Beach Resort in Florida integrates sea turtles into the resort's theme using both non-personal and interpersonal methods. Sea turtles are therefore part of the broader guest experience, thus keeping thoughts of them more prominent in guests' minds while in their hotel rooms (B. Witherington, personal communication, May 5, 2017).

Further, other non-personal approaches might yield better results. Some studies have shown that distribution method matters. Flyers obtained independently by park visitors at a brochure stand often have a weaker impact on visitor knowledge, attitudes, and behaviors than flyers that are personally delivered by staff members (Moscardo, 1999; Watson, Roggenbuck, & Oliver, 1985). Another study showed that the type of messaging was important: descriptive (what "everyone else" is doing), injunctive (what "should" be done), and economic messages influence guests differently based on demographics (Morgan & Chompreeda, 2015). The rack card was largely injunctive in its messaging; perhaps a switch to descriptive messaging would add the element of peer pressure needed for guests to respond with sea turtle-friendly behavior. A shift to a more coercive, regulatory, or incentive-based message might also have a greater impact on visitor behavior. A similar recommendation for incentive-based interventions was put forth in study by Dolcinar, Knezevic Cvelbar, and Grün (2017) in Slovenia after stickers failed to influence behavior change in the reduction of towel and electricity use.

Although many tourists are eager to absorb and apply new information about wildlife via free-choice learning opportunities during their trips (Ballantyne, Packer, & Hughes, 2009), few tourists may view hotel rooms as a setting where this type of learning can occur. Therefore, accessible placement of information within the room may be critical, generating subtle associations that impact visitor choices. For example, a placard near the light switch or window shades in hotel rooms (versus on the bed) would serve as an omnipresent reminder for guests to think about the implications of their decisions with respect to lights. However, as mentioned above, this type of permanent message positioning may not be not approved by corporate-level hotel managers concerned with brand and consistency. If beachfront hotels were to obtain corporate approval for a sea turtle-friendly lighting plaque, its use should be tested prior to full implementation to determine its effectiveness.

While our study suggests that rack cards are not effective in modifying hotel guest behavior, it also highlights the need for more research that addresses limitations of the current study and assesses the efficacy of various communication and outreach tools on specific visitor behaviors. Estimation of behavioral change linked to educational interventions is inherently difficult (Hungerford & Volk, 1990; Kollmuss & Agyeman, 2002), particularly when behaviors are measured at aggregate scales (i.e., block of hotel guests vs. individual visitors). In this case, the only hotel occupancy rates available to us were grouped by month rather than day and did not differentiate beachfront rooms (which are typically filled first) from others at the hotel. This average affected our ability to precisely control for daily variations in occupancy that might have influenced our visible light count, but relative differences across similar sampling days likely remained comparable.

Finally, another major limitation that we encountered was that in June and July 2016 (the control year), the hotel requested to have a GSTC educator present during peak check-in hours on Fridays to educate guests about sea turtles, lighting issues they face, and to promote a field-based education program. These personal interactions could have introduced additional educational content (at least for some guests) into our control group. However, analyses of variance checking for differences in visible light counts across months in 2016 suggested this impact might be negligible.

Despite these limitations, our study adopted the relatively novel approach of assessing conservation education outcomes by assessing an overt behavior (in this case, lighting choices and behaviors of hotel guests) rather than relying exclusively on potentially biased self-reported measures (Heimlich & Ardoin, 2008; Munro et al., 2008). Future studies could examine impacts on the actions of specific visitors – offering a more precise and potentially more accurate scale of resolution. Regardless of analytical scale, it is likely that a single message or platform will not lead to impactful behavior change. The most effective conservation campaigns typically connect with visitors in multiple ways at multiple times, reinforcing key messages (Ardoin & Heimlich, 2013; Ballantyne, Packer, & Falk, 2011). Rather than spending money on communication strategies hoping that they work, conservation managers and partners should work together to develop solutions for a sustainable coexistence between humans and wildlife at popular and ecologically sensitive tourist destinations. Once implemented, evaluation should take place to determine whether any impacts to people's conservation attitudes and behavior actually result in tangible biological outcomes (Veríssimo et al., 2018).

Considering our findings and the current literature, we believe that a diverse toolkit is likely needed for delivering important messages that inspire conservation behavior. With recent technological advances and cultural transitions, the way in which news and information is being consumed has changed (Choi, 2015). This shift makes it difficult for managers to be assured that messages broadcast via conventional media sources will reach target audiences. In the digital age, conservation managers must be able to identify centralized, broad-reaching tactics through which they can succinctly disseminate important information (Marion & Reid, 2007). Furthermore, these messages must resonate with people from diverse backgrounds, with unique interests and passions, and with different learnings styles (Cassidy, 2004).

Collaborations between tourism industry partners (e.g., hotel chains), conservation managers, and tourists are an important piece of this puzzle, helping to ensure appropriate and consistent communication of information that helps to maintain enjoyable visitor experiences while achieving conservation goals (Ballantyne et al., 2009). Interpersonal interactions may be an effective means of accomplishing this goal, but managers cannot rely exclusively on these strategies because they reach only a fraction of the target audience. For example, studies suggest that formal sea turtle programming on Jekyll Island has been successful at conferring changes in participants' behaviors regarding use of sea turtle-friendly lights, as well as other behaviors which can negatively impact nesting sea turtles such as littering (Mascovich, Larson, & Andrews, 2018). However, this type of formal programming is an intense resource investment (e.g., personnel time and costs) and may prohibit certain nesting beaches from implementing similar programs in the hopes of better protecting sea turtles from light pollution. Additionally, beachfront hotels might consider investments in technological fixes to conservation problems (Heberlein, 2012) that accomplish goals irrespective of visitor behavior. For example, by tinting beachfront windows, the impacts of artificial lights on turtles could be minimized even if guests and maintenance personnel did not know or comply with lighting regulations.

When dealing with situations involving endangered or threatened species such as the loggerhead sea turtle, conservation managers and their industry partners must be able to communicate quickly and effectively with the public; if they fail to do so, it is possible that the negative consequences conferred by (often unintentional) behaviors could result in regulatory violations and further decline of the species' population. Conservation managers must be able to find cost-effective and time-efficient methods through which they can broadcast their messages.

Acknowledgments

We would like to thank the management team and staff of The Westin Jekyll Island, especially Kevin Baker, for working alongside us to design a study which could quantitatively measure the effectiveness of education materials. Additionally, we would like to extend our appreciation to employees of the Jekyll Island State Park Authority and Georgia Sea Turtle Center for their assistance and support in implementing the study. Specifically, Dr. Terry Norton, Katie Higgins, Ben Carswell, and Jones Hooks, helped make this study possible. Mark Dodd from the Georgia Department of Natural Resources also provided us with valuable feedback. We additionally thank two anonymous reviewers for their constructive feedback. This publication is supported in part by an Institutional Grant (NA10OAR4170084) to the Georgia Sea Grant College Program from the National Sea Grant Office, National Oceanic and Atmospheric Administration, United States Department of Commerce.

Literature Cited

Ardoin, N.M., & Heimlich, J.E. (2013). Views from the field: Conservation educators' and practitioners' perceptions of education as a strategy for achieving conservation outcomes. *Journal of Environmental Education*, *44*, 97-115.

Ardoin, N.M., Heimlich, J., Braus, J., & Merrick, C. (2013). Influencing conservation action: What research says about environmental literacy, behavior, and conservation results. *National Audubon Society Report*. Retrieved from http://web4.audubon.org/educate/toolkit/pdf/Influencing%20Conservation%20Outcomes%20Module%202013_National%20Audubon%20Society.pdf

Bagwell, T.E. (2001). *Images of America – Jekyll Island, a State Park*. Charleston, SC: Arcadia Publishing.

Ballantyne, R., & Packer, J. (2011). Using tourism free-choice learning experiences to promote environmentally sustainable behaviour: the role of post-visit "action resources." *Environmental Education Research, 17,* :201–215.

Ballantyne, R., Packer, J., & Falk, J. (2011). Visitors' learning for environmental sustainability: Testing short- and long-term impacts of wildlife tourism experiences using structural equation modelling. *Tourism Management, 32*, 1243–1252.

Ballantyne, R., Packer, J., & Hughes, K. (2009). Tourists' support for conservation messages and sustainable management practices in wildlife tourism experiences. *Tourism Management 30*, 658–664.

Cacioppo, J.T., & Petty, R.E. (1984). The elaboration likelihood model of persuasion. *Advances in Consumer Research*, *11*, 673–675.

Cassidy, S. (2004). Learning styles: An overview of theories, models, and measures. *Educational Psychology, 24*, 419–444.

Choi, J. (2015). Why do people use news differently on SNSs? An investigation of the role of motivations, media repertoires, and technology cluster on citizens' news-related activities. *Computers in Human Behavior, 54*, 249–256.

Dolnicar, S., Knezevic Cvelbar, L., & Grün, B. (2017). Do pro-environmental appeals trigger pro-environmental behavior in hotel guests? *Journal of Travel Research, 56*, 988-997.

Fielding, K., Spinks, A., Russell, S., McCrea, R., Stewart, R., & Gardner, J. 2013. An experimental test of voluntary strategies to promote urban water demand management. *Journal of Environmental Management, 114*, 343–351.

Gore, M.L., Knuth, B.A., Curtis, P.D., & Scherer, C.W. (2008). Evaluating a conservation investment designed to reduce human-wildlife conflict. *Conservation Letters, 1*, 136–145.

Hailman, J.P., & Elowson, A.M. (1992). Ethogram of the nesting female loggerhead (*Caretta caretta*). *Herpetologica, 48*, 1–30.

Ham, S.H. (1992). Environmental Interpretation: A Practical Guide for People with Big Ideas and Small Budgets. Golden, CO: North American Press.

Heberlein, T. A. (2012). Navigating environmental attitudes. New York, NY: Oxford University Press.

Heimlich, J.E., & Ardoin, N.M. (2008). Understanding behavior to understand behavior change: A literature review. *Environmental Education Research, 14*, 215-237.

Henker, K.B., & Brown, G. (2011). As good as the real thing? A comparative study of interpretive podcasts and traditional ranger talks. *Journal of Interpretation Research, 16,* 7–23.

Hughes, M. (2004). *Influence of varying intensities of natural area on-site interpretation on attitudes and knowledge* (Unpublished doctoral dissertation). University of Notre Dame Australia, Fremantle, Australia.

Hungerford, H.R., & Volk, T.L. (1990). Changing learner behavior through environmental education. *The Journal of Environmental Education, 21*, 8–21.

Kaska, Y., Başkale, E., Urhan, R., Katış, Y., Gidiş, M., Sarı, F., Sözbilen, D., Canbolat, A.F., Yilmaz, F., Barlas, M., Özdemir, N., & Özkul, M. (2010). Natural and anthropogenic factors affecting the nest-site selection of Loggerhead Turtles, Caretta caretta, on Dalaman-Sarıgerme beach in South-west Turkey. *Zoology in the Middle East, 50*, 47–58.

Kidd, A.M., Monz, C., D'Antonio, A., Manning, R.E., Reigner, N., Goonan, K.A., & Jacobi, C. (2015). The effect of minimum impact education on visitor spatial behavior in parks and protected areas: an experimental investigation using GPS-based tracking. *Journal of Environmental Management*, *162*, 53–62.

Knudson, D.M., Cable, T.T., & Beck, L. (2003). Interpretation of Cultural and Natural Resources. State College, PA: Venture Publishing.

Kollmuss, A., & Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research, 8*, 239–260.

LeTallec, T., Théry, M., & Perret, M. (2015). Effects of light pollution on seasonal estrus and daily rhythms in a nocturnal primate. *Journal of Mammalogy, 96*, 438–445.

Levenson, D.H., Eckert, S.A., Crognale, M.A., Deegan, J.F., II, & Jacobs, G.H. (2004). Photopic spectral sensitivity of green and loggerhead sea turtles. *Copeia, 2004*, 908–914.

Marion, J.L., & Reid, S.E. (2007). Minimising visitor impacts to protected areas: The efficacy of low impact education programmes. *Journal of Sustainable Tourism, 15*, 5–27.

Mascovich, K.A., Larson, L.R., & Andrews, K.M. (2018). *Talking turtles: Exploring the relative efficatcy of different visitor education programs at Jekyll Island, Georgia*. Manuscript in preparation.

McFarlane, R.W. (1963). Disorientation of loggerhead hatchlings by artificial road lighting. *Copeia, 1963,* 153.

Morgan, M., & Chompreeda, K. (2015). The relative effect of message-based appeals to promote water conservation at a tourist resort in the Gulf of Thailand. *Environmental Communication, 9*, 20–36.

Moscardo, G. (1999). Communicating with two million tourists: A formative evaluation of an interpretive brochure. *Journal of Interpretation Research, 4*, 21–37.

Mrosovsky, N. & Shettleworth, S.J. (1968). Wavelength preferences and brightness cues in the water finding behaviour of sea turtles. *Behaviour, 32*, 211–257.

Munro, J.K., Morrison-Saunders, A., & Hughes, M. (2008). Environmental interpretation evaluation in natural areas. *Journal of Ecotourism, 7*, 1–14.

Oliver de Esperanza, A., Arenas Martínez, A., Tzeek Tuz, M., & Pérez-Collazos, E. (2017). Are anthropogenic factors affecting nesting habitat of sea turtles? The case of Kanzul beach, Riviera Maya-Tulum (Mexico). *Journal of Coastal Conservation, 21*, 85–93.

Ondich, B.L., & Andrews, K.M. (2013). A history of sea turtle tagging and monitoring on Jekyll Island, Georgia, USA. *Marine Turtle Newsletter, 138*, 11–15.

Philibosian, R. (1976). Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights. *Copeia, 1976*: 824.

Raap, T., Casasole, G., Pinxten, R., & Eens, M. (2016). Early life exposure to artificial light at night affects the physiological condition: An experimental study on the ecophysiology of free-living nestling songbirds. *Environmental Pollution, 218*, 909–914.

Rodríguez, A., Burgan, G., Dann, P., Jessop, R., Negro, J.J., & Chiaradia, A. (2014). Fatal attraction of short-tailed shearwaters to artificial lights. *PLoS ONE, 9*, e110114.

Sharp, R.L., Larson, L.R., Green, G.T., & Tomek, S. (2012). Comparing interpretive methods targeting invasive species management at Cumberland Island National Seashore. *Journal of Interpretation Research, 17*, 23–43.

Silverman, L.H., & Barrie, E.R. (2000). Determining social science research needs in interpretation: A case study. *Journal of Interpretation Research, 5*, 35–44.

Skupien, G.M., Andrews, K.M., & Larson, L.R. (2016). Teaching tolerance? Effects of conservation education programs on wildlife acceptance capacity for the American alligator. *Human Dimensions of Wildlife, 21*, 264–279.

Taylor, A., Curnow, R., Fletcher, T., & Lewis, J. (2007). Education campaigns to reduce stormwater pollution in commercial areas: Do they work? *Journal of Environmental Management, 84*, 323–335.

Veríssimo, D., Bianchessi, A., Arrivillaga, A., Ceasar Cadiz, F., Mancao, R., & Green, K. (2017). Does it work for biodiversity? Experiences and challenges in the evaluation of social marketing campaigns. *Social Marketing Quarterly, 24*, 18-34.

Warren, C., Becken, S., & Coghlan, A. (2018). Using persuasive communication to co-create behavioural change–engaging with guests to save resources at tourist accommodation facilities. *Journal of Sustainable Tourism, 25*, 935-954.

Washburn, J. (2007). A summary of the National Park Service Interpretation and Education Evaluation Summit. *George Wright Forum, 24*, 91–98.

Watson, A.E., Roggenbuck, J.W., & Oliver, S.S. (1985). Education to reduce impacts in forest campgrounds. *Journal of Forestry, 83*, 234–236.

Wearing, S., & Neil, J. (1999). Ecotourism: Impacts, Potentials, and Possibilities. Boston, MA: Butterworth-Heinemann.

Widner, C.J., & Roggenbuck, J.W. (2000). Reducing theft of petrified wood at Petrified Forest National Park. *Journal of Interpretation Research, 5*, 1–18.

Witherington, B.E. (1992). Behavioral responses of nesting sea turtles to artificial lighting. *Herpetologica,, 48*, 31–39.

Witherington, B.E., & Bjorndal, K.A. (1991a). Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta*. *Biological Conservation, 55*, 139–149.

Witherington, B.E., & Bjorndal, K.A. (1991b). Influences of wavelength and intensity on hatchling sea turtle phototaxis: Implications for sea-finding behavior. *Copeia, 1991*, 1060–1069.

Table 3.1. Factorial ANCOVA examining main effects and interactions of treatment (rack card vs. no rack card) and temporal/environmental variables on the proportion of visible lights after controlling for the covariate temperature (n = 58).

Source	df	Type III SS	F	p	η^2
Intercept	1	0.001	0.113	0.739	
Treatment	1	0.190	14.301	0.001	0.279
Day of week	6	0.195	2.449	0.043	0.284
Month	5	0.530	7.999	<0.001	0.519
Cloud cover	2	0.008	0.309	0.736	
Temperature	1	0.042	3.169	0.083	
Treatment*Month	5	0.298	4.492	0.003	0.378
Error	37	0.491			

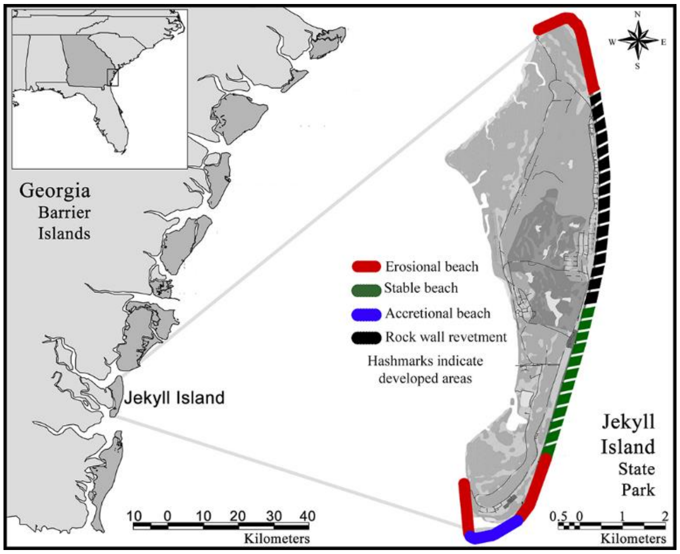

Figure 3.1. The study site, Jekyll Island, Georgia, USA. Portions of the beach are categorized as erosional, stable, accretional or having a rock wall revetment. Sections of the beach are additionally classified as being developed or undeveloped (indicated by the hashmarks). Image adapted by K. Mascovich with base layers credited to the Jekyll Island Sea Turtle Project, Georgia Department of Natural Resources, and Breanna Ondich.

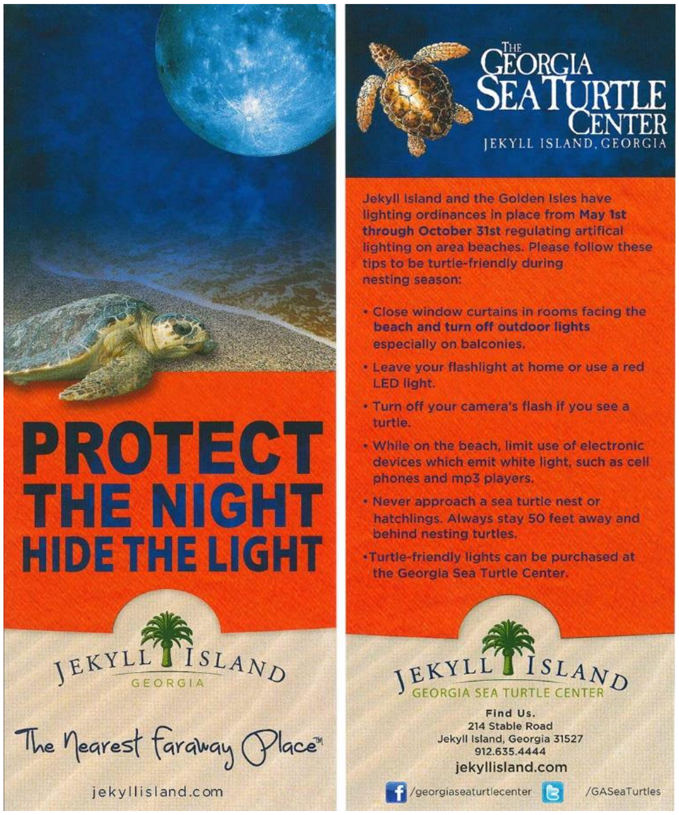

Figure 3.2. The “Protect the Night, Hide the Light” rack cards which were placed in all guest rooms of a local hotel in 2015. The front of the card is pictured on the left and the back of the card, which describes sea turtle-friendly behaviors, is pictured on the right. Image credit: Jekyll Island Authority Georgia Sea Turtle Center.

Figure 3.3. Beachfront rooms were assessed during each observation occasion to determine whether there was “no light visible” or “light visible.” In this image, circled windows were coded as “light visible,” while the rest were coded as “no light visible.” (Note that rooms on the first floor are all common spaces and therefore were not included in analysis.) Image credit: K. Mascovich.

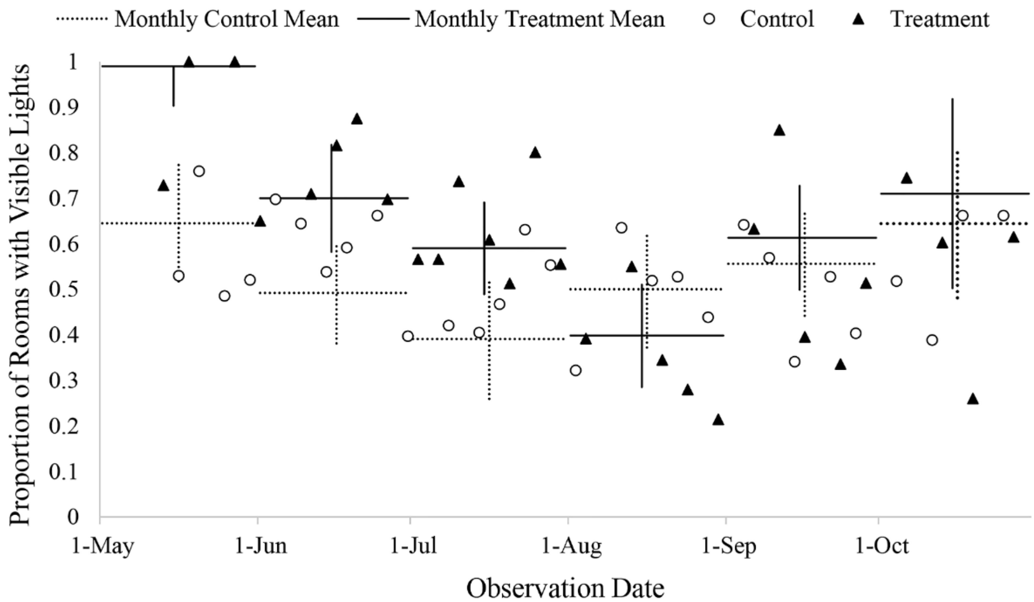

Figure 3.4. Proportion of occupied rooms with visible lights for sampling nights (points representing actual counts/ratios) and month (horizontal lines representing estimated marginal means and vertical lines representing 95% confidence intervals). Solid points and lines represent the treatment year and dashed points and lines represent the control year.

CHAPTER 4

TALKING TURTLES: EXPLORING THE RELATIVE EFFICACY OF DIFFERENT VISITOR EDUCATION PROGRAMS AT JEKYLL ISLAND, GEORGIA[3]

[3] Mascovich, K.A., L.R. Larson and K.M. Andrews. To be submitted to *Journal of Environmental Education*.

Abstract

Wildlife tourism experiences provide educators with opportunities to relay important conservation messages about the wildlife and habitats seen on a tour. Past research has shown that these wildlife education programs can increase visitors' knowledge and the frequency with which they practice environmentally friendly behaviors. However, few studies have directly compared the efficacy of education programs with different structures. Here, we sought to evaluate learning and behavioral outcomes associated with two different programs focused on nesting sea turtles in coastal Georgia, USA: one was a high-capacity, low-interaction program (LIP) and the second, a lower capacity, high-interaction experiential program (HIP). We found that both increased participants' knowledge of sea turtle natural history and willingness to participate in sea turtle-specific and general environmental behaviors. Effects on attitudes and emotional responses to sea turtles were minimal. We did not observe significant differences between the two program types, with both leading to similar changes in participants. Results suggest that wildlife managers and educators can effectively employ different program delivery methods to achieve similar conservation-oriented learning and behavioral outcomes.

Introduction

Wildlife tourism, defined as tourism undertaken to view or encounter wildlife, is popular throughout the world (Ballantyne, Packer, & Falk, 2011). Such nature-based experiences provide people with the chance to witness natural phenomena, species, and habitats that are uncommon, rare, unique, threatened, or endangered. Tourists are often eager to learn more about these species and what they can do to protect them (Ballantyne, Packer, & Hughes, 2009; Ham & Weiler, 2012). Research has begun to demonstrate that positive wildlife tourism experiences have the capacity to influence visitors' knowledge and attitudes, as well as increase appreciation and awareness (Ballantyne & Packer, 2005; Lee & Moscardo, 2005). In some cases, these experiences can even promote ecologically sustainable actions and environmental stewardship behavior (Ballantyne et al., 2011; Kim, Airey, & Szivas, 2011; Powell & Ham, 2008; Powell, Vezeau, Stern, Moore, & Wright, 2017).

However, wildlife tourism can also negatively affect animal behavior, health, and habitats – especially in marine areas (Herrera-Silveira, Cebrian, Hauxwell, Ramirez-Ramirez, & Ralph, 2010; Trave, Brunnschwiler, Sheaves, Diedrich, & Barnett, 2017). This consequence is particularly true in destinations where sea turtles are a focal attraction. Due to turtles' predictable use of nesting beaches, there is high potential for human-turtle interactions that negatively impact sea turtles (Meletis & Harrison, 2010). For example, human beachgoers often scare off nesting turtles and prevent them from laying eggs. Human objects left on the beach can also obstruct the passage of nesting and hatchling turtles (Hailman & Elowson, 1992; Oliver de la Esperanza, Martínez, Tuz, & Pérez-Collazos, 2017). Additionally, visitors using artificial lights (e.g., buildings, flashlights) may cause light-sensitive nesting and hatchling turtles to alter their movements (Esperanza et al., 2017). In cases where human-wildlife conflicts have been documented, minimizing impacts by enhancing visitors' ecological awareness through active education programs could be beneficial (Tisdell & Wilson, 2005; Trave et al., 2017; Zeppel et al., 2008). But what types of education programs create actual changes in people's behaviors, and what types of short- and long-term impacts might they generate? Answers to such questions about program structure remain elusive in the environmental education literature, which historically has focused more heavily on program impacts than on delivery methods (Stern, Powell, & Hill, 2014).

The environmental education community emphasizes the importance of active and experiential learning that typically involves direct engagement with authentic conservation problems (Hungerford & Volk, 1990; Volk & Cheak, 2003; Stern et al., 2014). Educational experiences associated with wildlife tourism provide opportunities where such authentic connections can occur (Ballantyne, Packer, & Sutherland, 2011). The experiences become even more valuable when educators or tour guides model effective stewardship behaviors linked to specific places and issues (Stern, Powell, & Ardoin, 2010), especially when those behaviors can be integrated into tourists' daily lives or routines (Newsome, Dowling, & Moore, 2004). When carefully managed and instructed, guided eco-tours might impact individual behavior beyond the specific site in which the experience occurs (García-Cegarra & Pacheco, 2016). In addition to offering ways for visitors to acquire knowledge and skills in real-world settings, wildlife tourism experiences create unique opportunities for fostering emotional connections with wildlife species through direct observations and live animal encounters (Skibins, Powell, & Stern, 2012). For example, research suggests that direct contact with animals elicits powerful affective responses and subsequent attitudinal or behavioral change (Ballantyne, Packer, Hughes, & Dierking, 2007; Ballantyne et al., 2011), particularly in cases involving reptiles (Ballouard, Provost, Barré, & Bonnet, 2012; Hassan et al., 2017; Morgan & Gramann, 1989; Skupien, Andrews, & Larson, 2016). Such positive encounters also enhance visitors' satisfaction with their overall trip experience (Ballantyne et al., 2007; Ballantyne & Packer, 2011).

Considering the trends noted above, it is not surprising that personal forms of education and interpretation such as face-to-face programs and guided tours typically have a strong influence on visitors' knowledge (Ren & Folta, 2016; Sharp, Larson, Green, & Tomek, 2012) and may have pronounced effects on their attitudes and behaviors (Hughes & Morrison-

Saunders, 2005; Weiler & Ham, 2010). Guided eco-tours are a popular programming approach in the wildlife tourism context due to this educational potential and their ability to adaptively influence visitor interactions with important wildlife species and habitat. But guided programs vary substantially in their duration, location, focus, audience, and intensity of experience, all of which could produce different types of learning outcomes (Ballantyne & Packer, 2009; Powell & Stern, 2013). For example, visitors might respond very differently to a short, guided program with a large group than they would to a small-group program of longer duration with more experiential elements. Studies that suggest group size, program duration, and program type might not be important predictors of interpretive outcomes also highlight the unique benefits of intimate programs in outdoor settings (Powell & Stern, 2013). To date, few studies have specifically compared the effect of different types of programs – particularly wildlife education programs – on learning outcomes (Stern et al., 2014).

We had the opportunity to study the differences between participants' responses to field-based sea turtle education programs that differed in delivery method and were offered by the Georgia Sea Turtle Center (GSTC) on Jekyll Island, GA, USA. Specifically, one program type had a higher guest capacity, was shorter in duration, and involved a more limited level of interaction with both sea turtles and the biologists studying them; the other program type was more intimate, with a longer duration and more turtle and human interactions. Educating the public about native wildlife species and conservation is one of the GSTC's core mission goals, so quantifying the impacts of these programs was of particular importance to the organization – especially given the relative absence in the literature regarding the differences in programmatic impacts. Some research shows that classroom-based sea turtle education modules can succeed in transferring knowledge to students, corresponding with increased concern for sea turtles

(Dimopoulos, Paraskevopoulos, & Pantis, 2008). While the literature on field-based programs is limited, there is evidence that even short, direct interactions with sea turtles can result in significant pro-environmental behavior changes (Hassan et al., 2017). We sought to extend these studies by exploring to what extent the GSTC's field-based sea turtle education programs were influencing participants' knowledge, attitudes, and behaviors. Based on the literature and our personal observations, we expected to find significant increases in participants' knowledge, positive attitudes, and engagement in environmentally friendly behaviors following both programs. Furthermore, we expected these increases to be significantly higher for participants attending longer, more intimate programs incorporating a higher level of interaction with both sea turtles and sea turtle biologists.

Methods

Study Site

Jekyll Island is a barrier island located in southeastern Georgia, USA. Of the state's 14 barrier islands, Jekyll is just one of four islands accessible by car via a causeway. Hence, it receives high levels of visitation and supports a thriving tourism industry. The island is designated as a state park, although it is financially self-sufficient. Therefore, the island's managing entity, the Jekyll Island State Park Authority (JIA), is heavily reliant on revenues generated from tourism to maintain park operations. With approximately two-thirds of the island being undeveloped, many people visit for the abundant nature opportunities. The main natural attraction for visitors and residents is the 15.3 km of beachfront available for recreation. This beach habitat is additionally valuable for sea turtles that nest and hatch there from May through October (Ondich & Andrews, 2013). Witnessing this natural phenomenon is a popular attraction for visitors and residents alike. However, sea turtle-human conflicts occur each summer. The issues often involve beachgoers using improper artificial light at night, leaving belongings and debris on the beach, and – often unintentionally – scaring away nesting turtles (Georgia Sea Turtle Center, unpublished data).

Education Programs

The GSTC is an additional nature-based attraction on Jekyll Island managed by the JIA. This rehabilitation, education, and research facility houses a museum, wildlife hospital, and a research department. Education and research related to the island's sea turtles has been ongoing since 1972, when the Jekyll Island Sea Turtle Project (JISTP) was initiated. The GSTC has been the managing entity for these projects since it opened in 2007 (Ondich & Andrews, 2013). In peak sea turtle season, the GSTC's Education Department offers nighttime Turtle Walks (June-July, corresponding with peak nesting) and early morning Sunrise Walks (August-September, corresponding with peak hatching). Some form of these programs has been in existence as far back as 1978 (Ondich & Andrews, 2013). Turtle and Sunrise Walks currently have a maximum guest capacity of 25 people per program and run for approximately two hours. Turtle Walks begin with a short (approximately 30 minute) presentation in the GSTC's educational gallery. After this introduction to sea turtles, the program relocates to the beach where participants walk with guides in hopes of finding a nesting sea turtle. Participants on Sunrise Walks receive this basic sea turtle information on their beach walk, as there is no presentation component of the program. In the event that these programs encounter a nesting or hatchling sea turtle, visitors' interaction with the animal is limited primarily due to the time constraints of the programs and the large number of attendees. Most Turtle and Sunrise Walk guides are trained volunteers, although a small number of GSTC staff members also act as guides. Program costs have varied slightly over the years, but were $25 per person (children and adults) per program and included general admission to the GSTC during the 2017 nesting season. Given the nature of these two programs offered by the GSTC Education Department, we have classified them as “low-interaction” programs (LIP) since they have reduced probabilities of seeing a turtle and reduced intimacy in their interactions with the researchers. These programs differ from the newer “high turtle-interaction” programs (HIP) now offered by the GSTC.

In 2012, the GSTC Research Department saw the opportunity to initiate more intimate and experiential education programs. These were designed to give participants an idea of what it is like to be a sea turtle biologist. These high-interaction programs were branded as Ride with Night Patrol and Egg-sperience Dawn Patrol. Ride with Night Patrol is offered at night in peak nesting season (June-July) and Egg-sperience Dawn Patrol is offered in the early mornings during peak hatching season (August-September). In both cases, participants ride with the sea turtle patrol team and programs may last up to five hours. To ensure that participants receive the same basic sea turtle natural history and threat information as did those on the LIPs, the patrol team follows a checklist of facts and talking points to be covered throughout unscripted conversation during each program. Due to the space limitations in the patrol team’s vehicles, each program’s maximum capacity is limited to four people. All programs are conducted by GSTC sea turtle researchers. Ride with Night Patrol is currently priced at $100 per person, while Egg-sperience Dawn Patrol costs $50 per person, with kids as young as four years in age being allowed to participate. In the event that a sea turtle is encountered on a HIP, participants have more extended interaction with the animal and can assist the researchers in recording data for the JISTP. It is important to note that *only* indirect interaction with sea turtles (i.e., looking but not touching) is allowed on these programs due to their being a federally threatened species on the Endangered Species Act.

Survey Distribution

To gain a better sense of how these two types of education programs (LIP and HIP) might differentially impact participants' knowledge, attitudes, and behaviors related to sea turtles, we designed a pre-post survey assessment. After visitors made reservations for one of the LIPs or the HIPs during the 2016 program season, the GSTC provided us with the prospective attendee's email address, program type, and reservation date. Soon after signing up for a program, participants received an email with a link to the pre-program survey asking them to complete it if they were 18 years or older in age. For LIP, only those individuals who selected to receive promotional emails from the GSTC could be contacted for participation in the survey. If guests had not filled out the survey at least three days prior to their program, they received a reminder email to complete the optional survey before attending. Completion of the pre-program survey was incentivized with a discount coupon code to the GSTC Gift Shop or Jekyll Island's "Life is Good" Store (either 10% off in-store purchases or 15% off online purchases).

One week after attending the program, all participants who completed the pre-program survey were sent a follow-up post-program survey. This survey was incentivized with a coupon for 10% off a GSTC Nest Tracker package (a nest adoption program). In the event a participant had not completed the one-week post survey, a reminder email was sent approximately one week after they received the first request. All surveys distributed to program participants were completed using Qualtrics® software.

To determine if program participants were representative of the general public visiting Jekyll Island, we also distributed hard-copy surveys to Jekyll Island beachgoers over the age of 18 from August to September 2015 and May to September 2016. We used a convenience sampling method in which all people or groups were approached and asked to complete the survey. Most people were sitting on the beach when approached. If an individual declined to take the survey, then the response was recorded and the interaction ended. If an individual agreed to take the survey, then they were given a clipboard with the survey attached and a pencil to complete the self-administered survey. Upon completion, the survey was collected and the respondent received the same coupon incentive that the pre-program survey respondents were given. No additional follow-up with the beachgoers occurred since they did not receive any intervention.

Survey Instruments

The survey instruments were designed to assess thematic areas related to sea turtle knowledge, attitudes, and behaviors: (1) prior exposure to sea turtles; (2) knowledge about sea turtles; (3) attitudes toward sea turtle conservation; (4) emotional dispositions toward sea turtles; and (5) sea turtle- and environmentally friendly behaviors. A description of the questions on the survey instruments are listed below.

- *Prior exposure to sea turtles* was determined via 11 questions about respondents' previous exposure to sea turtles via popular media platforms (e.g., television), in-person experiences in the wild or a zoo setting, and whether they had visited popular attractions on Jekyll Island that are known display information regarding sea turtles.
- *Knowledge of sea turtle* natural history and threats was assessed via 16 questions. These questions were designed to assess a range of knowledge, from relatively well-known natural history facts (e.g., that sea turtles can live for many decades), to specific knowledge of the status of Georgia's nesting population (e.g., it is increasing). Questions about the threats that sea turtles face included items that pose threats to sea turtles (e.g., boats), as well as items

that pose relatively little-known harm to the animals (e.g., swimming in the ocean). Participants had the option to answer these questions as “True,” “False,” or, “Unsure.”

- *Visitors’ attitudes toward sea turtles* were assessed using eight questions on a Likert scale ranging from a value of 1 (strongly disagree) to 5 (strongly agree). During analysis, answers were recoded to be on a scale from -2 (strongly disagree) to 2 (strongly agree). These questions measured items such as a participant’s feelings of personal responsibility to protect sea turtles, and whether the JIA was doing enough to protect sea turtles on the island. Any question in which a negative attitude corresponded with a positive point value was reverse coded such that positive attitudes received the highest score.
- *Emotional dispositions of participants toward sea turtles* was measured through four questions. These temperaments gauged if they felt fear, excitement, joy, and amazement toward sea turtles. Similar to the attitude questions above, these were asked on a scale of 1 to 5 (strongly disagree to strongly agree, respectively) and recoded during analysis to range from -2 (strongly disagree) to 2 (strongly agree). Point values were reverse-coded as necessary such that positive emotions toward sea turtles received the highest point values.
- *Environmentally friendly behavior* questions were divided into two categories, low-effort behaviors and high-effort behaviors, to assess actions that support coastal conservation with a particular emphasis on sea turtles and were based on a similar approach taken by Larson, Usher, and Chapmon (2017). We asked nine low-effort behavior questions that generally focused on behaviors that were specific to protecting sea turtles during their visit to the beach. For example, these behaviors could include limiting their use of non-sea turtle-friendly lighting near the beach at night, or not walking in the sand dunes where sea turtles nest. We asked eight additional high-effort behavior questions. These behaviors typically

require a larger time and/or monetary investment, such as willingness to donate money to conservation organizations and participation in cleaning up natural areas like beaches or parks. Behavior questions in the pre-survey were posed regarding the respondent's behaviors over the past year. In the one-week post survey, we asked the behavior questions regarding how the respondent planned to behave in the next year (i.e., behavior intentions). All behavior questions were asked on a Likert scale regarding how often they practiced or intended to practice the behaviors, ranging from 1 (never) to 5 (always). Similar to above, answers were reverse coded as needed such that sea turtle- and environmentally friendly behaviors received the highest scores.

- *Demographic questions* were posed at the end of the survey. We asked respondents for their gender, year of birth, zip code of their permanent address, employment status with the JIA, highest level of education achieved, and affiliation with Jekyll (tourist or resident).

The pre-program and beachgoer survey instruments were nearly identical, facilitating comparisons between both groups of visitors. Post-program surveys included identical questions to allow for detection of treatment effects. Additional questions regarding the participant's experience and satisfaction with the program were asked on the post-program survey. Pre- and post-program survey responses were matched via the email address provided on the survey.

Data Analysis

We created five indices to assess our variables of interest: (1) knowledge; (2) attitudes; (3) emotions; (4) low-effort behaviors; and (5) high-effort behaviors. The knowledge index was developed by adding together the number of correct answers to the knowledge questions (answers of "unsure" were coded as incorrect). The theoretical range of this index was from 0 to 16, and this scale had a moderate level of internal consistency with a Cronbach's alpha of 0.518.

The attitude index was similarly calculated, with the recoded answers to attitude questions being summed. The theoretical range of this index was from -16 to 16. The attitude index questions were also moderately consistent, as assessed by a Cronbach's alpha of 0.532. The emotion index was calculated by summing the recoded values to the emotional response questions (theoretical range was -8 to 8). The scale of these questions was internally consistent with a Cronbach's alpha of 0.727. The two behavior indices were calculated by summing the recoded values within each category. The theoretical range of these indices was from 9 to 45 (low-effort behavior), and from 8 to 40 (high-effort behavior). The low-effort behavior questions had a relatively low internal consistency with the Cronbach's alpha value being at 0.394, but we continued to group these items together due to their similar content, scope and scale. The high-effort behavior questions were highly consistent with a Cronbach's alpha value of 0.837.

Data analysis was completed using SPSS version 21. We explored baseline comparisons of the three groups (LIP participants, HIP participants, and the general public) as well as specific comparisons on program-related effects for LIP and HIP participants on the outcome variables of interest. For analyses involving a categorical dependent variable, we used a chi-square test of homogeneity with post-hoc analyses using the z-test of two proportions with a Bonferroni correction. Analyses in which the dependent variable was continuous in nature, we used either the independent samples t-test (if assumptions of parametric data distribution for that test were met) or a Mann-Whitney U test (for non-parametric data) with post-hoc pairwise comparisons using Dunn's (1964) procedure with a Bonferroni correction.

Results

Demographics and Baseline Group Differences

Of the 219 pre-program surveys that were distributed to LIP participants, 82 (37.4%) completed the survey. Of those 82 pre-program respondents, 56 (68.3%) people completed the post-program survey. We saw similar response rates for the HIP participants, with 46 of the 95 (48.4%) completing the pre-program survey, and 36 of those 46 (78.3%) HIP participants also completing a post-program survey. Surveys distributed to the general public (GP) on the beach totaled 295, with 229 individuals (77.6%) consenting to fill it out.

For each group, a majority of survey respondents were female (Table 4.1). Low-interaction programs had a significantly higher proportion of female survey respondents than the GP. Similarly, LIP respondents were significantly older than GP respondents (Table 4.1). Finally, the only other demographic difference between groups was that a significantly higher percentage of LIP participants had a higher education degree than the GP (Table 4.1). There were no significant differences between groups in regard to their prior exposure to sea turtles or whether they lived in a US coastal county where sea turtles might nest (Table 4.1).

In regard to the Mann-Whitney U test to compare the various indices of interest for this study, there were no significant differences between groups for the baseline (i.e., pre-program) emotion index and low-effort behavior index scores (Figure 4.1). However, the GP had a significantly lower median knowledge index score (9) than both the LIP (10) and HIP (11) respondents (Figure 4.1). Additionally, both LIP and HIP participants scored significantly higher in median attitude index scores (9 and 12, respectively) than the GP (7), indicating that the GP had less positive attitudes toward sea turtles (Figure 4.1). Finally, the median high-effort behavior index score for HIP participants (24) was significantly higher than those of LIP (20) and GP (20) respondents (Figure 4.1).

Effect of Programs on Participant Responses

In general, we saw positive effects of the programs on our key metrics. Within LIP, participants showed a significant median increase in their knowledge index score from the pre-program survey (10) to the post-program survey (12; $z = 5.122$, $p < 0.0005$). Similarly, the median knowledge index score on the post-program survey (12) was significantly higher for the HIP group when compared to the pre-program survey (11; $z = 2.783$, $p = 0.005$). In comparing the gain scores (i.e., the difference between pre- and post-program survey scores), there was not a significant difference between program type in terms of knowledge gain ($U = 837$, $p = 0.224$; Figure 4.2). Neither LIP nor HIP participants exhibited a significant change in mean attitude scores between their pre- and post-program surveys (gain score = 0, $z = 0.310$, $p = 0.757$) There was no significant difference in how program type affected participants' attitudes ($U = 913$, $p = 0.644$; Figure 4.2).

With respect to the emotion index, the median score for LIP participants was 6.00 on the pre-program survey and 6.50 on the post-program survey, representing a significant increase ($z = 2.136$, $p = 0.033$). The median HIP emotion index score on the pre-program survey was already relatively high at 7.00; however, it did increase to 8.00 (the maximum value attainable) on the post-program survey. While we did see an increase in the score, the difference was not significant ($z = 1.533$, $p = 0.125$). In comparing the two program types, HIP and LIP median gain scores did not differ significantly for the emotion index ($U = -0.127$, $p = 0.899$; Figure 4.2).

Significant program-mediated changes for the low-effort behavior index scores were observed. The median pre-program score for LIP was 32.00 and increased to 37.00 on the post-program survey ($z = 5.057$, $p < 0.0005$). Very similar scores were seen in the HIP group, with the median pre-program score being 32.00 and the post-program score increasing to 36.00 ($z = 3.390$, $p = 0.001$). The median gain score for LIP (4.00) was not significantly different from that of HIP (3.00; $U = 589.00$, $p = 0.257$; Figure 4.2).

Finally, we saw increases in the high-effort behavior index scores for each program. The median post-program survey score for LIP guests (30.00) was significantly higher than the pre-program survey score (20.00; $z = 6.260$, $p < 0.0005$). Similarly, the median post-program survey score for HIP participants (32.00) was significantly higher than that of the pre-program survey (24.00; $z = 4.901$, $p < 0.0005$). The gain scores did not differ significantly between LIP (7.00) and HIP (6.00; $U = 734.50$, $p = 0.099$; Figure 4.2).

Impacts of other Characteristics on Index Scores

For each of our five indices, we additionally tested gain scores against five characteristics that may have had an impact on the scores: age (whether an individual was over 40 years old), residency (whether an individual lived in a coastal county where sea turtles might nest), education level (whether an individual had a higher education degree), prior exposure to sea turtles (yes/no), and whether the individual saw a sea turtle on their program (yes/no). No characteristics except for prior exposure to sea turtles had a significant impact on the index scores. Individuals with no prior exposure to sea turtles prior to their program saw significantly higher increases in their attitude index score (median gain score = 1.00 for no prior exposure; median gain score = 0.00 for prior exposure; $U = 533.50$, $p = 0.035$). Additionally, individuals with no prior exposure to sea turtles had a significantly higher median gain score for the high-effort behavior index (11.50) relative to individuals who had prior exposure to turtles (6.00; $U = 341.50$, $p = 0.001$).

Discussion

Results suggested that both programs effectively increased the sea turtle-related knowledge and engagement in environmentally friendly behaviors of program participants, with smaller effects on emotional responses and minimal effects on attitudes. Contrary to our hypotheses, we found that program delivery method had little effect on the strength of gains in the outcome variables. The LIP gain scores were higher than the HIP gain scores for most variables, though these differences were not significant.

Although both programs led to gains in knowledge about sea turtle natural history and conservation threats, one program did not outperform the other despite different methods of information delivery. Most LIP participants (i.e., Turtle Walk participants) were provided with information about sea turtle natural history and threats via a scripted slideshow presentation, while HIP participants received this information solely via unscripted conversation with the patrol team biologists. Based on previous research highlighting the benefits of personal education programs (Ren & Folta, 2016; Sharp et al., 2012), these results were expected. However, we thought that higher levels of interaction during a longer duration program might lead to even more pronounced gains. This null result does not align with some other studies, indicating that program duration and level of interaction may not have a major influence on certain outcomes (Powell & Stern, 2013).

Given past research suggesting that increases in knowledge can improve attitudes toward wildlife conservation (Dimopoulos et al., 2008), we were surprised to find that neither program influenced participants' attitudes toward sea turtle conservation. It is possible that our survey instrument was designed in such a way that we encountered a ceiling effect with respect to the attitude index, in which guests self-selecting to attend either type of turtle program already expressed very positive attitudes regarding sea turtle conservation. Comparisons with the beachgoers sample of other Jekyll Island visitors supports this assertion. Similarly, we suspect that the emotion index may have also been impacted by the ceiling effect. While we saw significant gains in the scores for LIP participants, we did not see a significant increase in the median emotion index scores for HIP participants – perhaps because the pre-program median emotion index score for HIP participants was already close to the maximum value attainable on the survey. Similar ceiling effects have been proposed to explain a lack of observed statistical significance in other environmental education evaluations (Eagles & Demare, 1999; Ernst & Theimer, 2011; Leeming, Dwyer, Porter, & Cobern, 1993). Alternative survey designs (e.g., structured interviews) may have allowed us to detect whether our results were a product of the ceiling effect and should be considered in future studies with self-selecting participants.

Finally, we did not find evidence to reject our hypothesis that the behavior index scores would increase after a participant attended a program. However, as with the knowledge index, we were incorrect in predicting that HIP behavior gain scores would be significantly higher than LIP gain scores. This may be due, in part, to the fact that HIP participants had higher baseline scores for the high-effort behavior index. Although we did not consider it as such in our analysis, the act of attending a high-interaction program in and of itself can be seen as a high-effort conservation behavior. The higher cost of these programs is advertised as a way to directly support the research being conducted on Jekyll Island's nesting sea turtles.

We believe that one reason we saw such high increases in behavioral responses was because participants on both LIP and HIP were given the opportunity to transfer their knowledge into direct behavioral actions during their program (Newsome et al., 2004; Stern et al., 2010). This is particularly true of the low-effort behaviors which focus primarily on being sea turtle-friendly. On LIP, guides carried with them a reusable bag in which they could deposit debris found on their walk. For HIP participants riding with the patrol team, each patrol vehicle contained a trash bucket for the same purpose of picking up garbage along the beach as it was encountered. Similarly, any holes or sandcastles that were encountered on the beach by both program types were filled in or knocked down. Although participants were not required to join in these behaviors during their program, the act of guides leading by example (or other program participants choosing to engage) was likely a powerful tool for implementing these environmentally friendly behaviors for the group as a whole (Stern et al., 2010). Future research should explore the causal mechanisms driving this behavior change, perhaps focusing on elaboration likelihood (Powell et al., 2017) or qualitative data collection that reveals why certain approaches were effective (Ballantyne et al., 2011; Stern et al., 2014).

An additional factor that may impact participants is their prior exposure to sea turtles. For individuals with no prior exposure, we found a significant increase in the gain scores for their attitudes and willingness to practice high-effort conservation behaviors. One possible reason for the significant gains in these areas is due to the “wow” factor or the awe-inspiring experience of seeing and learning about sea turtles for the first time, a factor that has proven to be significant in other studies of wildlife tourists (Hicks & Stewart, 2017; Pearce, Strickland-Munro, & Moore, 2017). Conservation managers hoping to create the significant changes in sea turtle-related attitudes and behaviors could focus on this particular subset of the general public, helping many visitors appreciate the value of turtles for the first time.

When interpreting results, there are several limitations of our study that should be acknowledged. First, as completion of the survey was optional with small incentives, many program participants did not respond to our requests. This resulted in a smaller-than-anticipated sample, making it more difficult to detect program effects. This also introduces two forms of potential bias: self-selection and non-response bias (Duda & Nobile, 2010). Evidence suggests that individuals who opt out of a survey are often different from their counterparts who opt in (Vaske, 2008). In our case, it is plausible that people who elected to participate in the survey had a greater interest in the subject of sea turtles than those who did not participate, thereby skewing results. However, the pre-post research design still enabled us to detect program-mediated score changes, even if baseline values differed. Expectancy bias, introduced when survey respondents report what they believe survey administrators would like to hear, is another potential limitation (Leeming et al., 1993).

Additionally, self-reported, short-term cognitive and behavioral outcomes do not always result in long-term action. For example, Hughes (2013) found that in a majority of cases, survey participants that self-reported an intention to increase their conservation-related behaviors did not follow through on that intent over a longer period of time. Long-term follow-ups (i.e., longitudinal studies) are therefore ideal mechanisms for assessing the sustainability of program outcomes over time (Bogner, 1998; Powell et al., 2017; Stern et al., 2014); however, such an approach is typically financially or logistically difficult to implement. In this study, we attempted a follow-up online survey with all participants approximately six months after each program, but we did not receive enough responses (fewer than 20 to achieve a sample size sufficient for analysis. A successful longitudinal study might reveal lasting differences between low- and high-interaction program types.

Another limitation we encountered was that participants of both program types were generally more educated and typically expressed more positive attitudes toward sea turtles relative to the average Jekyll Island visitor. These differences suggest that people self-selecting to participate in sea turtle education programs may exhibit responses to outcome metrics that differ from those of the typical Island visitor.

Further, while we controlled what information was delivered to program guests, we were not able to account for how the level of knowledge, delivery style, or personality of the different program guides impacted guests in the various indices (there were approximately 30 LIP and 15 HIP guides for the whole season). This is important because the charisma of a guide is one of the best predictors of positive outcomes in interpretation programs (Stern & Powell, 2013). Controlling for this variable in an experimental design would require either the same person to present many programs to guests (see Skupien et al., 2016) or a lower number of guides to present enough programs to allow for comparisons of instructor effects.

Finally, there was no way for us to control for whether participants in a program actually saw a sea turtle (36% of LIP respondents and 77% of HIP respondents saw a turtle on their program). While the results of our study did not find that seeing a turtle was an important predictor variable, past research and our personal experience has shown that direct encounters with wildlife in their natural habitat can be powerful motivators for attitude and behavioral change (Hassan et al., 2017). Often after a program group encounters a sea turtle, guests ask educators and biologists many questions they were previously not prompted to ask – questions that may not be adequately captured on standardized survey instruments. Future qualitative research could explore the impacts of this experiential learning in more detail.

Another important consideration for educational programming focused on wild animals is the potential costs and negative impacts for both visitors and the focal wildlife species. There is risk of human injury when leading beach walks at night due to the low-light environment (LIP guests were not allowed to use any lights of their own, but rather followed guides with sea turtle-friendly red lights; HIP guests were provided their own red lights for the evening). There is also a high likelihood of stressing animals like sea turtles when allowing people to interact closely with them (Johnson, Bjorndal, & Bolten, 1996). The organization hosting the program runs the risk of not encountering a sea turtle and leaving guests feeling dissatisfied in their experience. Given the potential drawbacks for both humans and animals, more research is needed to determine if field-based programs are more beneficial than captive-animal programs with respect to both program implementation and conservation outcome considerations (Skupien et al., 2016).

While our study found a significant increase in intended behavioral changes, it is unclear what impact this might have on actual conservation outcomes. Do these changes in individual actions have a tangible positive effect on the reproductive success of sea turtles on Jekyll Island? Do they reduce sea turtle mortality in some way, for example through a reduction in debris consumption or entanglement? Such questions, which were beyond the scope of this study, can only be answered through comprehensive social-ecological assessments that integrate human behavior and environmental impacts in a wildlife tourism context (Meletis & Harrison, 2010).

Conclusion

Ultimately, our study suggests that a larger-capacity, low-interaction program with volunteer guides and a lower-capacity, high-interaction experiential program with a trained patrol team can *both* be effective tools for increasing knowledge of sea turtle natural history and the frequency with which participants practice environmentally friendly behaviors. This finding can help organizations with limited resources decide how to best allocate those programming resources to achieve education and conservation goals that impact both humans and wildlife. If the organization has a field team already deployed with space available for visitors, then the additional costs of implementing and promoting a HIP are minimal. Additionally, the intimate experience of a HIP allows for a relatively high program fee to bring in revenue (the GSTC grossed $18,100 from HIPs in 2016) to support local conservation efforts. However, organizations operating under a different scenario may find LIPs more appealing. These programs have higher organizational costs to operate (e.g., staff would otherwise not be on the beach as a patrol team would), but with a higher group capacity, revenues generated often exceed those made by low-capacity HIP (gross revenue for the LIPs in 2016 was $36,897). If outcomes, at least in the short term, are comparable, then costs and the feasibility of implementation should therefore be key considerations when selecting an education program structure.

Interestingly, we observed minors (<18 years of age) to be a driving force in program attendance, but they could not be captured in this survey design. As there are survey limitations in measuring the behaviors of minors, we feel we may be missing a part of our audience that contributes productively to conservation in direct and secondary manners. Where possible, we encourage future studies to incorporate means to include minors in their experimental design. In closing, future research is needed to determine the extent to which our findings translate to other sea turtle nesting beaches, programmatic models, and audiences, including youth. Further research on the subject could additionally shed light on whether our findings apply to other species of conservation concern – especially those that are less charismatic than sea turtles.

Acknowledgements

This study was made possible thanks to the support of the Jekyll Island Authority and Georgia Sea Turtle Center staff. Specifically, we would like to thank Dr. Terry Norton, Katie Higgins, Nicki Thomas, Brian O'Neal, Lori Hunt, Breanna Ondich, Alison Ballard, the 2016 GSTC sea turtle patrol team, the 2016 GSTC Education Department, and the 2016 GSTC Turtle Walk and Sunrise Walk guides. This publication is supported in part by an Institutional Grant

(NA10OAR4170084) to the Georgia Sea Grant College Program from the National Sea Grant Office, National Oceanic and Atmospheric Administration, United States Department of Commerce. Research was carried out with permission from the University of Georgia Institutional Review Board under Study #00003362.

Literature Cited

Ballantyne, R., & Packer, J. (2005). Promoting environmentally sustainable attitudes and behaviour through free-choice learning experiences: what is the state of the game? *Environmental Education Research, 11*, 21-35.

Ballantyne, R., & Packer. (2009). Introducing a fifth pedagogy: experience-based strategies for facilitating learning in natural environments. *Environmental Education Research, 15,* 243-262.

Ballantyne, R., & Packer, J. (2011). Using tourism free-choice learning experiences to promote environmentally sustainable behaviour: the role of post-visit 'action resources'. *Environmental Education Research, 17,* 201-215.

Ballantyne, R., Packer, J., & Falk, J. (2011). Visitors' learning for environmental sustainability: Testing short-and long-term impacts of wildlife tourism experiences using structural equation modelling. *Tourism Management, 32,* 1243-1252.

Ballantyne, R., Packer, J., & Hughes, K. (2009). Tourists' support for conservation messages and sustainable management practices in wildlife tourism experiences. *Tourism Management, 30,* 658-664.

Ballantyne, R., Packer, J., Hughes, K., & Dierking, L. (2007). Conservation learning in wildlife tourism settings: lessons from research in zoos and aquariums. *Environmental Education Research, 13,* 367-383.

Ballantyne, R., Packer, J., & Sutherland, L.A. (2011). Visitors' memories of wildlife tourism: Implications for the design of powerful interpretive experiences. *Tourism Management, 32*, 770-779.

Ballouard, J.M., Provost, G., Barré, D., & Bonnet, X. (2012). Influence of a field trip on the attitude of schoolchildren toward unpopular organisms: an experience with snakes. *Journal of Herpetology, 46*, 423–428.

Bogner, F.X. (1998). The influence of short-term outdoor ecology education on long-term variables of environmental perspective. *The Journal of Environmental Education*, *29*, 17-29.

Dimopoulos, D., Paraskevopoulos, S., & Pantis, J.D. (2008). The cognitive and attitudinal effects of a conservation education module on elementary school students. *Journal of Environmental Education, 39*, 47-61.

Duda, M.D., & Nobile, J. L. (2010). The fallacy of online surveys: no data are better than bad data. *Human Dimensions of Wildlife*, *15*, 55-64.

Eagles, P.F., & Demare, R. (1999). Factors influencing children's environmental attitudes. *The Journal of Environmental Education*, *30*, 33-37.

Ernst, J., & Theimer, S. (2011). Evaluating the effects of environmental education programming on connectedness to nature. *Environmental Education Research*, *17*, 577-598.

García-Cegarra, A.M., & Pacheco, A. S. (2016). Whale-watching trips in Peru lead to increases in tourist knowledge, pro-conservation intentions and tourist concern for the impacts of whale-watching on humpback whales. *Aquatic Conservation: Marine and Freshwater Ecosystems, 27,* 1011-1020.

Hailman, J.P., & Elowson, A. M. (1992). Ethogram of the nesting female loggerhead (*Caretta caretta*). *Herpetologica*, *48*, 1-30.

Ham, S.H., & Weiler, B. (2012). Interpretation as the centerpiece of sustainable wildlife tourism. In *Sustainable Tourism* (pp. 35-44). Oxford: Butterworth-Heinemann.

Hassan, R., Yahya, N.K., Ong, L.M., Keng, L.K., Abidin, Z.Z., Ayob, A., & Jainal, A.M. (2017). Public awareness program and development of education toolkit for green sea turtle conservation in Sarawak, Malaysia. *International Journal of Environmental & Science Education*, *12*, 463-474.

Herrera-Silveira, J.A., Cebrian, J., Hauxwell, J., Ramirez-Ramirez, J., & Ralph, P. (2010). Evidence of negative impacts of ecological tourism on turtlegrass (Thalassia testudinum) beds in a marine protected area of the Mexican Caribbean. *Aquatic Ecology*, *44*, 23-31.

Hicks, J.R., & Stewart, W.P. (2017). Exploring potential components of wildlife-inspired awe. *Human Dimensions of Wildlife*, 1-3.

Hughes, K. (2013). Measuring the impact of viewing wildlife: do positive intentions equate to long-term changes in conservation behaviour? *Journal of Sustainable Tourism*, *1*, 42-59.

Hughes, M., & Morrison-Saunders, A. (2005). Interpretation, activity participation, and environmental attitudes of visitors to Penguin Island, Western Australia. *Society & Natural Resources*, *18*, 611–624.

Hungerford, H.R., & Volk, T.L. (1990). Changing learner behavior through environmental education. *Journal of Environmental Education*, *21*, 8–21.

Johnson, S.A., Bjorndal, K.A, & Bolten, A.B. (1996). Effects of organized turtle watches on loggerhead (*Caretta caretta*) nesting behavior and hatchling production in Florida. *Conservation Biology*, *10*, 570-577.

Kim, A.K., Airey, D., & Szivas, E. (2011). The multiple assessment of interpretation effectiveness: promoting visitors' environmental attitudes and behavior. *Journal of Travel Research, 50*, 321-334.

Larson, L.R., Usher, L.E., & Chapmon, T. (2017). Surfers as environmental stewards: understanding place-protecting behavior at Cape Hatteras National Seashore. *Leisure Sciences*, DOI: 10.1080/01490400.2017.1305306.

Lee, W.H., & Moscardo, G. (2005). Understanding the impact of ecotourism resort experiences on tourists' environmental attitudes and behavioural intentions. *Journal of Sustainable Tourism, 13*, 546-565

Leeming, F.C., Dwyer, W.O., Porter, B.E., & Cobern, M.K. (1993). Outcome research in environmental education: a critical review. *The Journal of Environmental Education*, 24, 8-21.

Meletis, Z.A., & Harrison, E.C. (2010). Tourists and turtles: searching for a balance in Tortuguero, Costa Rica. *Conservation and Society, 8*, 26-43.

Morgan, J.M., & Gramann, J.H. (1989). Predicting effectiveness of wildlife education programs: a study of students' attitudes and knowledge toward snakes. *Wildlife Society Bulletin, 17*, 501–509.

Newsome, D., Dowling, R.K., & Moore, S.A. (2004). Wildlife Tourism. Clevedon/Buffalo: Channel View Publications.

Oliver de la Esperanza, A., Martínez, A.A., Tuz, M., & Pérez-Collazos, E. (2017). Are anthropogenic factors affecting nesting habitat of sea turtles? The case of Kanzul beach, Riviera Maya-Tulum (Mexico). *Journal of Coastal Conservation, 21*, 85-93.

Ondich, B.L. & Andrews, K.M. (2013). A history of sea turtle tagging and monitoring on Jekyll Island, Georgia, USA. *Marine Turtle Newsletter, 138*, 11-15.

Pearce, J., Strickland-Munro, J., & Moore, S.A. (2017). What fosters awe-inspiring experiences in nature-based tourism destinations?. *Journal of Sustainable Tourism, 25*, 362-378.

Powell, R.B., & Ham, S.H. (2008). Can ecotourism interpretation really lead to pro-conservation knowledge, attitudes and behaviour? Evidence from the Galapagos Islands. *Journal of Sustainable Tourism, 16*, 467-489.

Powell, R.B., & Stern, M.J. (2013). Speculating on the role of context in the outcomes of interpretive programs. *Journal of Interpretation Research, 18*, 61-78.

Powell, R.B., Vezeau,, S.L., Stern, M.J., Moore, D.D., & Wright, B.A. (2017). Does interpretation influence elaboration and environmental behaviors? *Environmental Education Research, 2017*, 1-14.

Ren, Q., & Folta, E. (2016). Evaluating environmental interpretation with mixed method. *Journal of Interpretation Research, 21*, 5-19.

Sharp, R.L., Larson, L.R., Green, G.T., & Tomek, S. (2012). Comparing interpretive methods targeting invasive species management at Cumberland Island National Seashore. *Journal of Interpretation Research, 17*, 23-43.

Skibins, J.C., Powell, R.B., & Stern, M.J. (2012). Exploring empirical support for interpretation’s best practices. *Journal of Interpretation Research, 17*, 25–44.

Skupien, G.M., Andrews, K.M., & Larson, L.R. (2016). Teaching tolerance? Effects of conservation education programs on acceptance capacity for the American alligator. *Human Dimensions of Wildlife, 21*, 264-279.

Stern, M.J., & Powell, R.B. (2013). What leads to better visitor outcomes in live interpretation? *Journal of Interpretation Research, 18*, 9-44.

Stern, M.J., Powell, R.B., & Ardoin, N.M. (2010). Evaluating a constructivist and culturally responsive approach to environmental education for diverse audiences. *Journal of Environmental Education, 42*, 109–122.

Stern, M.J., Powell, R.B., & Hill, D. (2014). Environmental education program evaluation in the new millennium: what do we measure and what have we learned? *Environmental Education Research, 20*, 581-611.

Tisdell, C., & Wilson, C. (2005). Perceived impacts of ecotourism on environmental learning and conservation: turtle watching as a case study. *Environment, Development and Sustainability, 7,* 291-302.

Trave, C., Brunnschweiler, J., Sheaves, M., Diedrich, A., & Barnett. (2017). Are we killing them with kindness? Evaluation of sustainable marine wildlife tourism. *Biological Conservation, 209*, 211-222.

Vaske, J.J. (2008). Survey research and analysis: application in parks, recreation and human dimensions. State College, PA: Venture Publishing.

Volk, T.L., & Cheak, M.J. (2003). The effects of an environmental education program on students, parents, and community. *Journal of Environmental Education*, *34*, 12–25.

Weiler, B., & Ham, S.H. (2010). Development of a research instrument for evaluating the visitor outcomes of face-to-face interpretation. *Visitor Studies*, *13*, 187–205.

Zeppel, H. (2008). Education and conservation benefits of marine wildlife tours: developing free-choice learning experiences. *The Journal of Environmental Education, 39*, 3-18.

Table 4.1: The percentage of survey respondents falling into each demographic category based on group type: low-interaction programs (LIP), high-interaction programs (HIP), and the general public (GP). Where applicable, significant post-hoc analysis results are given.

Variable	LIP	HIP	GP	Difference Tests	Post-hoc result
Gender (% female)	84.7	80.0	64.0	$\chi^2(2) = 11.515$ $p = 0.003$	LIP > GP
Higher education degree (% yes)	83.1	71.4	62.9	$\chi^2(2) = 8.975$ $p = 0.011$	LIP > GP
Age (% over 40)	84.5	74.3	41.0	$\chi^2(2) = 14.721$ $p = 0.001$	LIP > GP
% Live in Coastal County	23.2	31.3	23.6	$\chi^2(2) = 0.941$ $p = 0.625$	N/A
% with Prior Exposure to Sea Turtles	67.8	27.1	78.6	$\chi^2(2) = 4.683$ $p = 0.096$	N/A

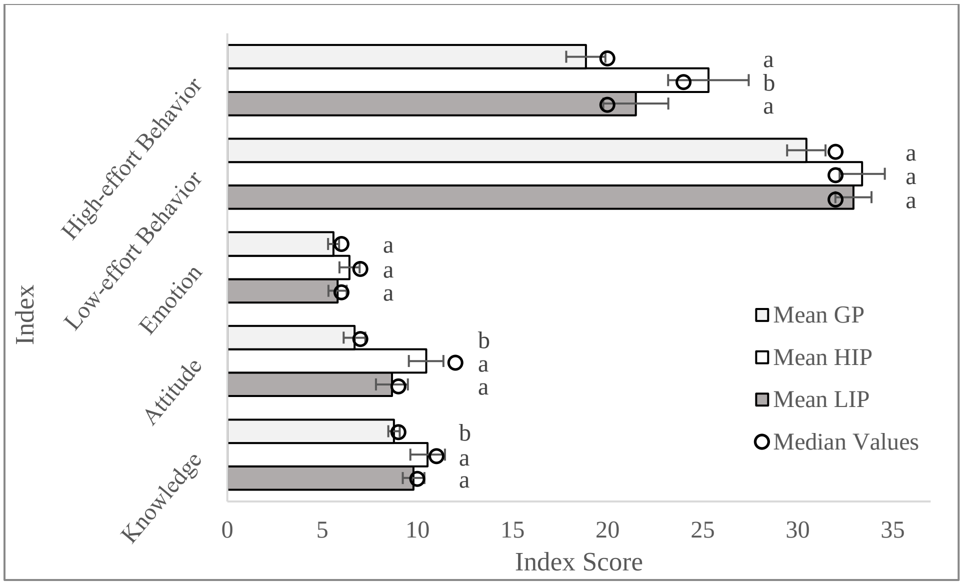

Figure 4.1: Mean scores for each of the five indices by group for pre-program baseline surveys: Low-interaction programs (LIP), High-interaction programs (HIP), and the general public (GP). Means are represented by the bars with 95% confidence intervals shown. The dots and letters aligning with each bar indicate the median score and significance category for that given index and group, respectively. Bars with different letters indicate that there is a significant difference (p < 0.05, with a Bonferroni correction) between groups for that given index.

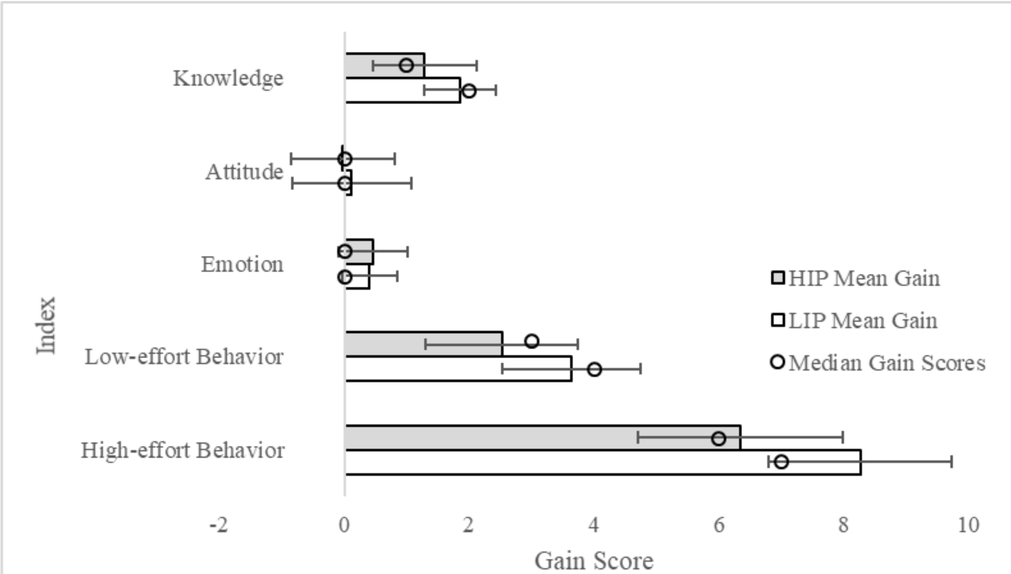

Figure 4.3: Between program differences in the gain scores. Means for each index are represented by the bars with 95% confidence intervals shown. Median scores for each program are represented by the open dots on each index's corresponding bar. There were no significant differences in gain scores for any of the five indices.

CHAPTER 5

SYNTHESIS AND RECOMMENDATIONS

In order to effectively manage a beach for wildlife conservation purposes, a beach management plan (BMP) can be crafted as a guidance document that considers management actions directed at the habitat, beachfront infrastructure, and people that use the beach. Ignoring just one of these areas of conservation and management need could result in negative consequences for sea turtles or an ineffective management approach.

In Chapter 2, we learned that there are many habitat variables – both naturally and anthropogenically influenced – that can affect sea turtle nest success. The GLM showed us some unexpected results regarding the maximum temperatures experienced within a nest and the frequency with which a nest is washed over. Further, our results indicated that many of the hatchlings produced on Jekyll Island may be female due to the relatively high temperatures during the thermosensitive period in the middle third of incubation. We found that simulating various hatch success rates for relocated nests had they been left to incubate *in situ* led to significant differences in hatch success between our shoreline classification categories.. Nests laid in erosional habitats fared the worst, which could mean that nest relocations will increase as sea levels rise and erosion increases along barrier island shorelines. Managers of sea turtle nesting beaches should therefore prepare for more nest relocations as environmental conditions shift to warmer climates.

In Chapter 3, we learned how infrastructure poses a threat to nesting and hatchling sea turtles via light pollution and one way in which natural resource and hotel managers attempted to mitigate the issue. The lack of a positive impact of the educational rack card led us to the conclusion that a different messaging tool or approach is needed to persuade hotel guests to abide by sea turtle-friendly lighting regulations during nesting season. Alternatively, in light of our findings, beachfront businesses could seek out solutions to mitigate lighting issues that do not rely on humans behaving in a conservation-minded manner. These interventions could include tinting windows, installing sea turtle-friendly light bulbs, and ensuring that non-sea turtle-friendly lighting is properly shielded from the nesting beach.

Finally, in Chapter 4 we learned that education programs were effective at imparting sea turtle knowledge and increasing participation in environmentally friendly behaviors. This finding was encouraging, but longitudinal studies are needed to assess the long-term impacts of these programs. If the behavioral intentions from our one-week post-program surveys hold true over longer time periods, then education programs provide potentially large benefits to conservation practitioners. With our results indicating that the delivery method of programs does not yield significant differences in short-term knowledge and behavioral outcomes, organizations should consider the cost and feasibility of implementation when wanting to begin an ecotourism program.

An effective BMP will provide natural resource managers with specific tools and methodologies with which to manage habitat, infrastructure, and people. The findings from the research conducted here, as well as what is available in the literature, will be synthesized into a document from which beach and natural resource managers can take away concrete recommendations. These may include suggestions on what is and is not effective when it comes to implementation. For example, the educational rack card did not alter hotel guests' lighting choices and other avenues to mitigate infrastructure impacts on sea turtle nesting beaches should be taken. On the other hand, behavioral changes can be seen through the use of low- or high-interaction beach education programs. Recommendations such as these can help save managers valuable time and money while working toward conservation efforts.

Managing each of these aspects of the beach – habitat, infrastructure, and people – requires significant collaborative efforts between conservation and research organizations, industry partners, the public, residents, and governmental organizations. Between these stakeholders, conflicts over management styles and actions will arise. Compromise will be the key to successfully ensuring that conservation goals are met while keeping the needs of people living or visiting coastal regions in mind.