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Sea Turtles, Light Pollution, and Citizen Science: A Preliminary Report

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Introduction

Sea turtles are an important ecological resource for Gulf Islands National Seashore's (Gulf Islands) waters and shorelines. Regionally, sea turtles face anthropogenic threats from situations such as entanglement in fishing gear and ingestion of marine debris, as well as possible changes in sex ratios due to increasing temperatures related to human-induced global warming. Locally, light pollution from residential, commercial, and industrial neighborhoods from nearby cities impacts the entirety of Gulf Islands, which spans 160 miles along the Gulf Coast, from Florida to Mississippi, and includes critical habitat for threatened and endangered sea turtles. Because light pollution has been hypothesized to negatively impact sea turtle nesting and hatchling survival, Gulf Islands undertook an effort to understand the relationship between light pollution and sea turtles and create unique educational and outreach opportunities by launching a citizen science program called Turtle Teens Helping in the Seashore (Turtle THIS). At the onset, the Turtle THIS program had two primary goals: quantify the association between light pollution and sea turtle nesting and hatching events using rigorous scientific methods; and initiate a citizen science volunteer program to provide youth with hands-on science and environmental stewardship roles, where they also gain employable skills and career opportunities. With multiple scientific hypotheses to consider, the development of a citizen science program became crucial. Such circumstances allowed Turtle THIS to grow a volunteer and intern program, quantify hypothesized light effects on sea turtles through developed methods, and begin to gather preliminary findings.

Citation: Weber, Samantha, ed. 2017. *Connections Across People, Place, and Time: Proceedings of the 2017 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites*. Hancock, Michigan: George Wright Society.

Hypothesized light effects on sea turtles

Sea turtles are important contributors to Gulf Island's barrier island and salt water ecosystems. They maintain healthy seagrass beds, which serve as fish nurseries, and entire food webs by controlling populations such as jellyfish. Most critical to the barrier island are the benefits gained when sea turtles lay nutrient rich eggs into nutrient depleted dune systems. Nest remains help contribute to the overall ecosystem, but also promote vegetation growth which strengthens shoreline protection (Bouchard and Bjorndal 2000; STC 2015; Pries, Miller, and Branch 2008).

The importance of sea turtles to the area, and their status as federally protected species, has created concern among park biologists at Gulf Islands as they have noticed certain factors affecting sea turtle reproductive success. For example, many adult female sea turtles lay their nests in close proximity to Gulf waters, at low elevations, where inundation by seawater can reduce hatchling survival rates. Although Gulf Islands is relatively undeveloped, the occurrence of low profile dunes permits the trespass of two types of light sources onto nesting beaches: sky glow, a form of indirect light from sources miles away, and direct light from nearby developed areas. The light from these sources is hypothesized to interfere with selection of nest sites higher on the beach and at higher elevations. One study determined that light does affect nesting sea turtles; specifically, direct light reduces the number of emergences (Witherington 1992). Although some studies discuss the relationships between light, dunes, and site selection (Salmon et al. 1995; Witherington 1992), we are aware of none that discuss the relationship between indirect light or nest site selection (i.e., proximity to water or low elevation) and light pollution. The understanding of light effects on nesting sea turtles is still in its infancy, but there is enough evidence to suggest that Gulf Islands hypotheses are worth investigating.

Since the 1950s, studies have confirmed hatchling disorientation from light pollution along shorelines affects survivability (Verheijen 1985; Witherington, Martin, and Trindell 2014). Hatchlings observed at Gulf Islands are frequently disoriented or travel toward the lights of a nearby city rather than toward the natural moonlight and starlight reflecting off the waters of the Gulf. In 2016, 71% of nests, where hatching observances took place, were classified as disoriented. This disorientation effect from artificial light is well understood and documented in sea turtle hatchlings, but recent studies indicate that blue wavelengths of light tend to affect disorientation in hatchlings more substantially (Witherington and Bjorndal 1991). This information led park biologists to hypothesize that blue light in Gulf Island's lightscape may intensify disorientation in hatchlings, as well as adults.

In an effort to obtain corroborating evidence that light pollution, specifically blue wavelengths, was contributing to the observed adult sea turtle nesting behavior and hatchling disorientation, Gulf Islands initiated the Turtle THIS program. The program conducts scientific research through a team of citizen science volunteers responsible for carrying out the many tasks required for success.

The need for citizen science

Citizen science is an important facet of the Turtle THIS program. Citizen science is a term that describes an everyday individual's contribution to scientific projects, particularly on a subject the individual values and wants to get involved in. A citizen scientist can provide data using their personalized skill sets, with data analysis conducted by a scientist (Bonney et al. 2009). The use of

citizen science is growing throughout the world in the natural science community as it contributes to large, long term scientific projects, engages communities in learning about the natural world, and provides benefits for the individuals involved (Bonney et al. 2009). Enabling individuals to participate in scientific projects enhances the ability of natural scientists to collect and analyze data that would otherwise be cost-inhibitive or difficult to acquire. Ideally, in such studies, data collection procedures are simple and easy, but require time and effort that citizen scientists are able to provide.

Turtle THIS first created a volunteer program to recruit citizen scientists, which has been vital to the success of the program. Program participants range from middle school, high school and college age students, families, park visitors, retired locals, and conservation groups. Although originally designed to promote future leaders through youth volunteers, the program found it necessary to diversify and further expand the program's reach while also keeping the original goal and name "Teens Helping in the Seashore." All volunteers aide in some portion of the data collection process (Figure 1). Turtle THIS utilizes individual skills to enhance the program and efficiently collect data, which has resulted in over three years of data collection for park sea turtle research.

Figure 1. A Turtle THIS volunteer team collects light data with equipment. During collection volunteers also learn about protecting sea turtles, such as how Turtle THIS only uses red light because red wavelengths are less likely to disorient sea turtles. Volunteers can then relay this information to stakeholders, decision makers, and members of the public they encounter in the field while collecting data. NPS Photo/Jeremy White.

Another objective of the program is to provide educational benefits. Turtle THIS helps volunteers grow into environmental stewards. By educating participants on sea turtles, conservation, and management, volunteers gain skills by providing this educational outreach to others (Figure 1). Additionally, Turtle THIS has set more prominent objectives for younger generations. The program allows youth to develop hands-on skill development in the fields of science, education, and management, and encourages participation through presentations, posters, and talks at regional and national scientific and interpretation conferences. Youth are also encouraged to attend community events or booth sessions to further their outreach skills in a professional setting. Additionally, Turtle THIS incorporates an internship program to serve as part of a career ladder into land management or education fields offering both year-long and summer internships to volunteers, which could grow to seasonal positions and eventually permanent positions.

Interns serve as important members of the team. Along with the skills and opportunities volunteers receive, interns are given other responsibilities such as helping with program management decisions, leading volunteers in the field, and using QA/QC procedures to ensure accuracy of data collection, recording, and data entry. A lead intern is employed to manage the overall data collection and volunteer program.

Program interns and volunteers are led by a team of scientists who provide oversight of lead interns who develop and teach protocol to achieve scientific goals. Turtle THIS was developed and is managed by a park biologist and the chief of resource education at Gulf Islands, a U. S. Geological Survey statistician, and a National Park Service Night Skies Team expert. While considering citizen science as the program's human resource base, these various backgrounds allow the program to utilize park resources, determine best equipment use, and create scientifically-informed project methods, thereby providing a scientific foundation for the program.

Developing project design

With hypotheses and the teams (e.g., scientists, interns, volunteers, etc.) in place, Turtle THIS identified a sampling design and methods to ensure robust scientific results. Turtle THIS encompasses a two-fold project design for understanding the effects of ambient light on sea turtles in the region; one study samples light at a fine scale and a second samples light at a large scale.

Fine scale light data are collected after two nesting events: when a sea turtle lays a nest and again when hatching occurs. The goal is to quantitatively measure the light conditions sea turtles experience during those events. Light data is collected each nesting season from May 1 to October 31. The fine scale data project began in 2014 and will continue annually through 2020 (Figure 2). The 2014 and 2015 seasons served largely as pilot studies to refine best practices for data collection and were necessary due to the novelty of the project questions, environmental complexities, and the expansive study area. Measurements were recorded within 20% of the lunar phase that occurred at the time of a nest event to maintain probable light conditions the sea turtles would have experienced. The 2016 nesting season procedure was refined to reduce variability in light conditions. Measurements are recorded within 72 hours of a nesting event.

At the larger scale, ambient light data is collected along the shoreline from the west end of Perdido Key to the east end of Santa Rosa Island (Figure 2). The goal is to create a light profile of the beach, which documents artificial light within the entire study area. Data are collected on transects spaced every 400 m (1312 ft). The light sensor has an approximate viewing range of 10 degrees in either direction, allowing for overlap between points so no light sources are missed. Light

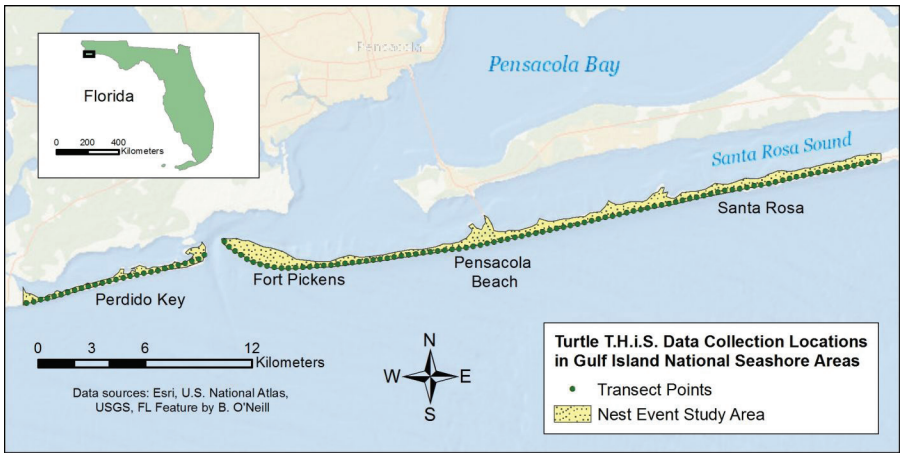

Figure 2. Data collection locations throughout Gulf Islands National Seashore and Pensacola Beach areas for Turtle THIS projects. Citizen science sampling activities are confined to the shoreline, where transect survey points have been marked by GPS, and where turtle nesting activity has been identified by Gulf Islands park biologists. Points on the figure represent transect line locations.

samples are recorded at three points along each transect: the mean high tide line, the toe of the dune, and the top of the dune. Because light conditions can change rapidly due to environmental conditions, sampling conditions are standardized. Sampling only occurs when the moon is absent and twice at each transect location when cloud cover is either greater than 20%, or equal to or less than 20% (cloud reflectivity strongly influences light measurements). Project samples consist of 121 transects, yielding a sample size of 242 when measured under two cloud conditions.

Sampling at both the fine scale and large scale utilize the same equipment, which includes a tripod and mount, two sky quality meters (SQM) for measuring light, and a laser pointer. The tripod and mount combination is adjustable in a circular horizontal plane and a vertical plane. The two SQMs, one of which measures white light and the other which measures blue light, attach to the mount in a fixed position. By systematically varying the altitude and azimuth of the mount, a hemispheric profile of white and blue light over the entire night sky is sampled. The laser pointer is used to determine the altitude of the horizon line. All measurements are standardized to true north to facilitate comparisons among sites. Equipment is easy to use and assemble. The overall equipment design was developed to quantify light visible at about 50 cm (20 in) above the surface of the sand to approximate a sea turtle's perspective, and from a scientific viewpoint not previously studied.

Preliminary project analysis

Turtle THIS has successfully collected 26.9% of beach transect data and completed three seasons of data collection at nest events. Transect data collection is an ongoing process and is in its third year with the bulk of the data collected during the 2016/2017 winter season. Thus far data have been collected at 52 transects during low cloud conditions and 13 transects during high cloud conditions yielding a total sample of 65 of the 242 transects (Figure 3). Turtle THIS will to continue data collection past the original 242 transects to document spatio-temporal variation in light conditions under a variety of environmental conditions.

Preliminary observations show that maximum vertical illuminance, the maximum amount of light striking a vertical surface, is greatest on the dune top and mean high tide and lowest at the dune toe. This suggests that a sea turtle will experience higher intensity light pollution when an adult exits the Gulf to nest or a hatchling enters the Gulf. This also suggests that dune structure may be

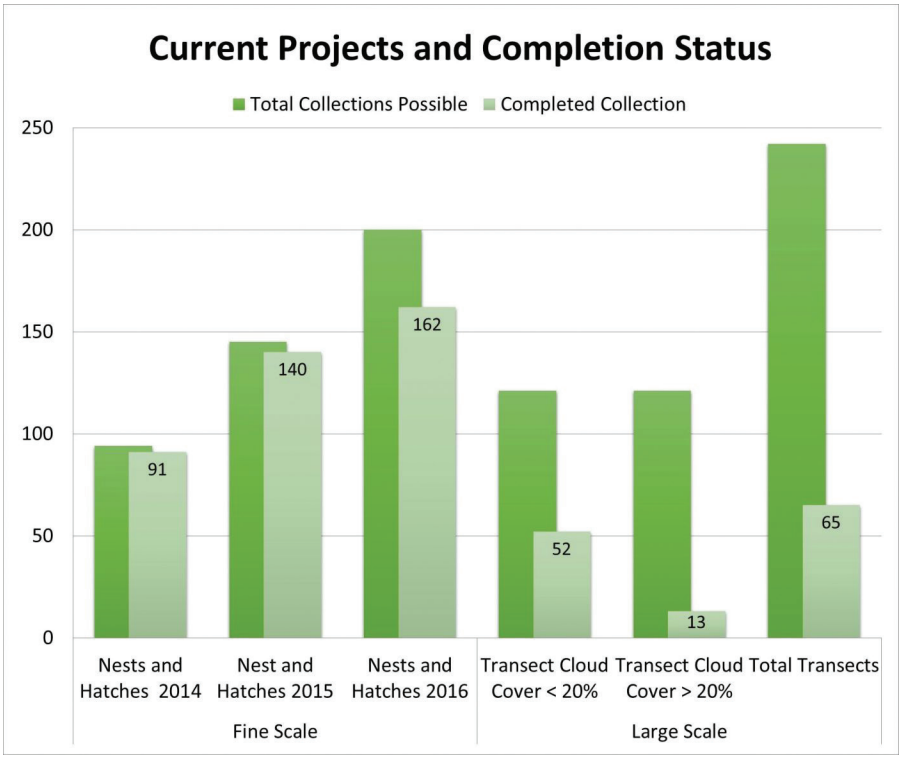

Figure 3. Current status of data collection for both fine scale and large scale projects. Fine scale project bars are organized annually, while large scale project bars are organized by cloud conditions and total transects collected. Last updated April 20, 2017.

an important factor in mitigating the effects of light pollution trespass into sea turtle habitat. Final results, with a higher, more refined sample size will provide more insight into this pattern.

Large scale beach profile results will allow Turtle THIS to create several products. This will include imagery to depict locations data were collected, analysis of the brightest and darkest light under different sky conditions and vertical illuminance analysis to depict light brightness at transect points.

Fine scale data collection and organization are complete for the 2014, 2015, and 2016 seasons. In 2014, there were a total of 94 nest events with data collection occurring at 91 of these sites. In 2015, nest events increased to 145, with a total of 140 samples collected (Figure 3). The total number of nest events does not include nests that failed to hatch a single individual. In 2016, the total of nest events increased to 200 resulting in data collection at 162 nests. Data not collected was due to limited available resources, timing of nest events, and environmental conditions.

These data subtly indicate that nests and number of hatches are increasing. However, when paired with disorientation and relocation data from park biologists, problems in survivability still exist. Preliminary observations of raw data and some initial analyses suggest light, specifically blue light, in Gulf Islands is influencing nest placement and continues to affect hatchling disorientation. However, more analysis is needed to confirm if and how light pollution significantly affects sea turtles in Gulf Islands.

Final analysis of light data collected at nest events will be used to decipher relationships between white light, blue light, horizon line, lunar phase, and other environmental data in comparison to locations of nesting and hatching occurrences.

Conclusion

Turtle THIS is a dynamic program which includes a core scientific component and invites youths and community members to assist with scientific research and promotes environmental stewardship for the national seashore and nature as a whole. The Turtle THIS program adapts as volunteers gain more skills and new volunteers join, interns transfer to permanent positions, new interns are hired, and seasons and conditions change. The program will continue to create new environmental stewards and future land managers, provide sound scientific findings to improve sea turtle management, and inform local populations of their role to help protect sea turtles and engage with Gulf Islands National Seashore.

Acknowledgements

Turtle THIS and this paper would not be successful if not for the help of countless other individuals. Special thanks to Brent Everitt, Cassidy Clements, and Steven Dubose for their dedication and contributions to the project. Extreme gratitude is also given to the Turtle THIS volunteers. Without our citizen scientists, this project would be incomplete, and for their help, the rest of the Turtle THIS team is grateful.

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