Quantifying injury rates on nesting leatherback turtles (*Dermochelys coriacea*) at Sandy Point National Wildlife Refuge, St. Croix

by

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April 27, 2017

Master's project submitted in partial fulfillment of the requirements for the Master of Environmental Management degree in the Nicholas School of the Environment of Duke University.

Executive Summary

Leatherback turtles are listed as Vulnerable globally, though the Atlantic and Caribbean nesting populations have been increasing. The St. Croix nesting population, which predominately nests at Sandy Point National Wildlife Refuge (SPNWR), is one of three leatherback nesting populations within US jurisdiction. This provides a unique opportunity to research an increasing population managed by the US, and it has been studied since the 1970s. Throughout the history of this long-term population study at SPNWR, injuries on nesting female leatherbacks have been observed, but have not been the focus of any quantified research.

The injuries observed on nesting female leatherbacks at SPNWR were the focus of this study. There were four main research objectives in order to assess injuries: the timing of injuries sustained during the nesting season, the trends in injury location on the body of females and in the characteristics of the injured females, the average healing rates for injuries, and the best practices for documenting and analyzing leatherback injuries.

During the 2016 nesting season at SPNWR, injuries observed on females were photo-documented and categorized on a scale of 1 to 5, ranging from a fresh injury (1) to a scar (5). The nesting population for this season consisted of 49 individuals, 24 of which were previously untagged neophytes and 25 were return nesters with preexisting PIT or flipper tags. Throughout the course of the nesting season, 37 individuals were observed with fresh injuries (anything that was a not a scar, thus a category 1-4 injury), which made up 75% of the total nesting population. Neophytes and return nesters were injured at similar rates, suggesting that there is not a behavioral difference between experienced and novice nesters to contribute to the likelihood of the individual becoming injured at some point during the nesting season.

Fresh injuries were observed consistently throughout the nesting season, with the greatest occurrence of injuries peaking alongside the greatest number of nesting turtles at SPNWR. The number of turtles that arrived at the nesting beach with injuries was similar to the number of turtles injured throughout the season, indicating that the cause of injuries is local to the Caribbean region where these females are likely spending time during the internesting period.

The most frequently observed injuries occurred on the shoulders of females, followed by carapace and head and neck injuries, then by front and rear flipper injuries. For the four most commonly observed injuries, the healing rates were estimated from a category 2 to 3 and from category 3 to 4. For all injury types, category 2 injuries progressed to category 3 faster than a category 3 injury to 4. To heal from a category 2 to 3 typically took one internesting period, 5-15 days, while healing from a category 3 to 4 injury typically took multiple internesting periods, anywhere from 18-25 days.

Extending this research to identifying the source of the injuries would greatly enhance the ability of injury studies to determine management priorities. Leatherbacks have previously been observed interacting with pelagic longline fisheries, and one of the leatherbacks in 2016 was attacked by sharks off SPNWR. These are likely the two main causes of injuries to the females nesting at SPNWR, but there is not enough literature and documentation at this point to confidently determine the cause of individual injuries.

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Introduction

Leatherback sea turtles (*Dermochelys coriacea*) are listed as Vulnerable globally (Wallace et al., 2013), while some populations (i.e., Pacific leatherbacks) are still quite endangered. Global populations have been estimated to have declined 40% in the past three generations (Wallace et al., 2013). In the Atlantic and Caribbean Sea though, leatherback populations have been increasing (Stewart et al., 2011; Rivas, Fernandez, & Marco, 2015; Dutton et al., 2005). This presents a unique opportunity to understand the mechanism of population increase for this species. While sensitive to long term threats from climate change, such as sea level rise that removes valuable nesting habitat (Fish et al., 2005), and increasing sand temperatures that may skew population sex ratios toward feminization (Gledhill, 2007), threats such as fishery interactions and bycatch require a more urgent evaluation. As leatherbacks are a slow growing species with a transboundary distribution throughout the Atlantic, assessing all threats to specific populations is important.

Sandy Point National Wildlife Refuge (St. Croix, USVI) is one of three critical US nesting aggregations under US jurisdiction. This important nesting habitat supports a unique population that has been studied intensively since 1977. However, current climate change predictions project that this critical habitat may disappear in the future, mainly due to sea level rise (USFWS, 2010). To manage this nesting population and maintain it, it is vital that we know as much about this population as possible to evaluate its resilience and to be able to predict how it may change and where it may move to.

Leatherback turtles are often observed on nesting beaches with injuries consistent with fishery interactions, as they are incidentally caught in longlines and other gear (Lewison et al. 2014;

Stewart et al., 2016). In this study, I evaluated the rate of injury found in St. Croix nesting leatherbacks during the 2016 nesting season. In particular, I assessed injuries seen on nesting females for degree of healing, as well as trying to identify the cause of injury. To date, very little about the impacts of injury to nesting females and their nesting behavior has been studied or published. Using data collected throughout the summer nesting season in 2016, I ranked the injuries exhibited by nesting females at Sandy Point by the degree of healing, noted whether they arrived injured or became injured through the nesting season, evaluated the level of healing over the season and photo-documented the types of injuries noted.

This research is essential to identifying and quantifying threats gaps for an important Atlantic leatherback population. In order to make this population resilient and robust to withstand any future threats posed by climate change, it is critical that we quantify and mitigate as many anthropogenic effects as possible. By quantifying the number of injuries on nesting female leatherbacks and evaluating the healing over time, I can determine the impacts of fishery interactions or threats from other causes on this population. This information will better inform both management practices and future research on leatherbacks.

My Master's Project aimed to answer four main questions to understand injuries on leatherbacks and how to most effectively study them: are nesting females arriving at Sandy Point with injuries or are they sustaining injuries during the nesting season; what are the trends in type of injuries; how long is the typical healing rate for leatherbacks; and what is the most effective methodology to use to document and categorize injuries?

Materials & Methods

The data were collected from March to July during the 2016 nesting season at the Sandy Point National Wildlife Refuge (SPNWR) in St. Croix. Each night during the nesting season, a team of at least four people conducted patrols that covered the three kilometer span of nesting beach every 45 minutes, with the assumption that this time interval would capture every nesting event on the beach given the amount of time it takes a typical female to nest.

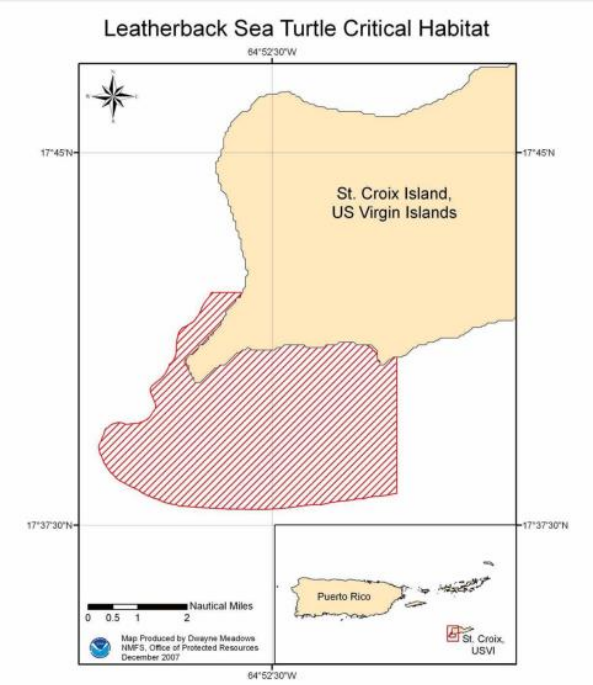

Figure 1. The study site, Sandy Point National Wildlife Refuge, and corresponding critical habitat for leatherback turtles. Map produced by NOAA NMFS Office of Protected Resources.

When a female arrived and began to nest, a datasheet was created to record the observed activities and diagnostics. Basic information was gathered, including the flipper tag number, the PIT tag number, date and time, her carapace width and length, and the GPS location of the nest.

Figure 2. From left to right, the healing stages 1-3 on the top row, and 4-5 on the bottom row. For photo quality purposes, these are different injuries on different turtles, all located in a roughly similar position.

When a neophyte nested, a turtle without a flipper or PIT tag or nesting history, these tags were applied to the female. The tags were provided by US Fish and Wildlife. Additionally, sketches of the observed injuries for each female were drawn on the data sheet, and photographs were taken when possible. For each photograph taken, an index card including the date and the flipper tag number was included for both reference and scale. On the datasheet, the degree of healing observed for each injury was recorded, then cross-referenced against the photos taken. The degree of healing is categorized on a scale of 1 to 5, with a category 1 injury being a fresh, bleeding wound and a category 5 injury being a pink scar (Table 1). For reference purposes, photo examples for each healing stage can be seen in Figure 2. Any females that remained on the beach at dawn were watched until they returned to the water to ensure that they made it back to the water and did not become overheated.

Table 1. The healing stage of injuries used to describe the injuries observed on nesting females. This table was taken from the 2015 Sandy Point National Wildlife Refuge Leatherback Project Report (Valiulis, 2015).

Healing Stage	Wound Description
Stage 1	Fresh and still bleeding
Stage 2	Fresh and no apparent signs of healing, but no bleeding
Stage 3	Yellow flesh but no pink edges
Stage 4	Yellow flesh with pink edges
Stage 5	Pink scarring

Following data collection during the nightly patrols, the photographs were uploaded to a folder for each individual turtle, labeled by the flipper tag number, the date, and the location of the injury on the turtle's body. The injuries were also recorded in a data file, noting the flipper tag number, date, the visit number for that individual, where the injury was located, what stage of healing the injury was observed at, the type of injury (gash, scrape, scar, or missing chunk), and any pertinent notes. With this data, the trends for the nesting season was determined for peak injury time, common injury types and locations, and an estimate of the amount of time needed for an injury to heal.

Results

During the nesting season, photographs of injuries and scars were collected for 38 turtles. A total of 49 individuals were observed during the season at SPNWR, and diagnostics were recorded for each individual. Of the 49 individuals, 24 were neophytes. This means that this was the first time that they were observed at a monitored nesting beach and tagged, and it is typically presumed that this is their first season nesting. The remaining 25 females had nested in past seasons and had previously been flipper and/or PIT tagged.

Timing of injuries

To answer my first question, whether turtles are arriving with injuries or becoming injured during the season, I compared the number of turtles with injuries on their first visit to the number of turtles that had fresh injuries on any subsequent visit that were not noted when she first nested (Figure 3). An injury for these purposes was considered anything from a category 1-4, excluding healed scars. There were 24 individuals who had injuries on their first visit, and 23 turtles became injured during the season. These are not mutually exclusive categories, so the same female could have arrived with injuries on her first visit, but may have sustained new injuries later in the season and therefore been included in both categories. During the season, 37 individual turtles were injured.

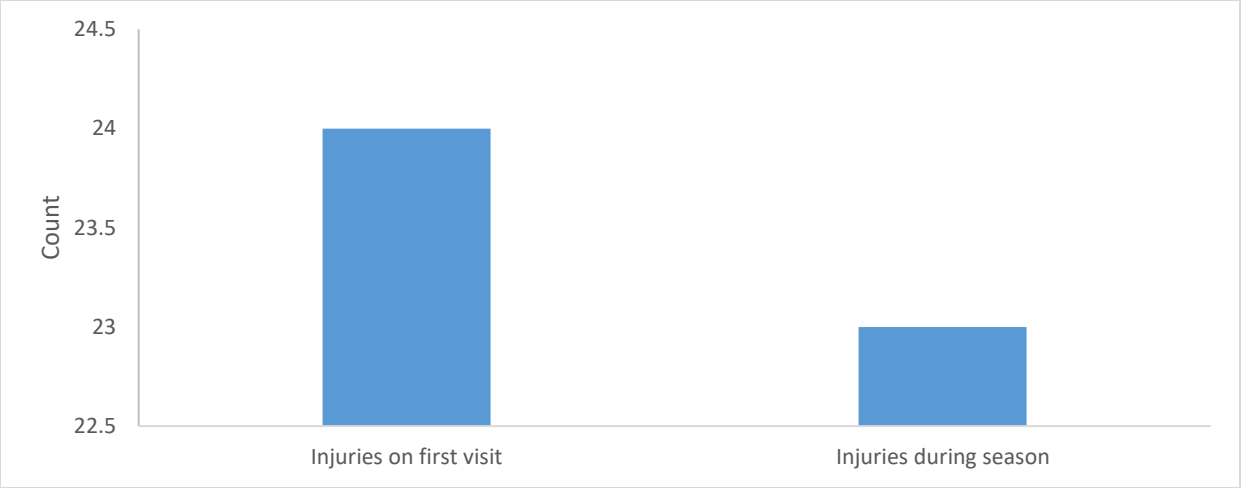

Figure 3. The observed count of female leatherbacks injured on their first visit to SPNWR and the count of females who arrived to SPNWR with fresh injuries on any subsequent visit. The same individual could be included in both categories if she arrived initially with injuries and became injured again during the nesting season. In total, 37 individual females sustained injuries at some point during the nesting season.

In Figure 4, the rate of injury throughout the season can be observed. The ten-day intervals of this figure are meant to reflect the amount of time typically between leatherback nesting events, though this can vary (anywhere from 8-12 days). As the season began at the end of March and beginning of April, there were only 3 turtles that arrived to the nesting beach with fresh injuries. However, the number of freshly injured turtles peaked at 11 in the following ten days, from early to mid-April, coinciding with the range of time during which we saw a large number of females arriving to nest for their first time at SPNWR this season. The number of injuries observed ranged from 7 to 9 turtles from the end of April to the beginning of June, with injury rates dropping off after the first week of June. This decline in the rate of fresh injuries on nesting females corresponds with the end of the nesting season and the overall rate of turtle nesting events.

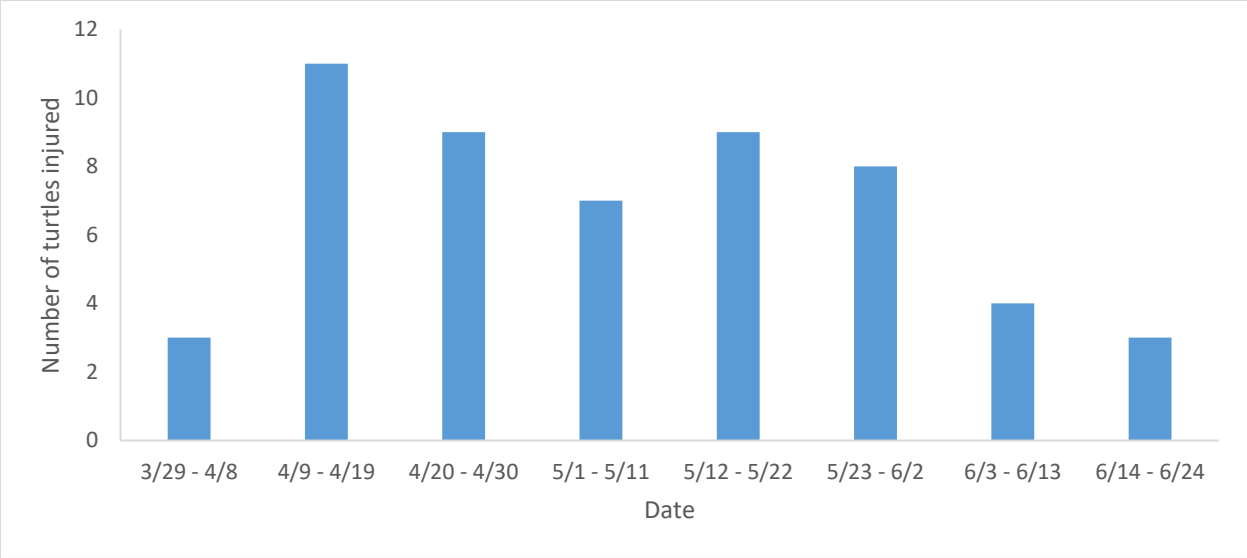

Figure 4. The count of injured females every ten days during the 2016 nesting season. It is possible for the same individual to be included multiple times in this figure, as they may have sustained additional injuries since their previous visit.

In Figure 4, the same turtle can be present multiple times if she arrived to the nesting beach with fresh injuries since her last visit. The individual turtles observed with injuries can be seen in Appendix A, with several becoming injured multiple times during the season.

The trends seen in Figure 4 hold true when evaluating the number of turtles injured as a percent of turtles that nested within each ten-day period (Figure 5). During the second interval, April 9 to April 19, the 11 turtles observed with fresh injuries comprised of 52.4% of the turtles that nested in that period. The main difference between the two figures is that the first time period, March 29 to April 8, comprises a greater percentage of the total number of turtles observed nesting during that time period. Following the peak in the second ten-day time interval, the percent of turtles observed with injuries ranged from 23.5-40%.

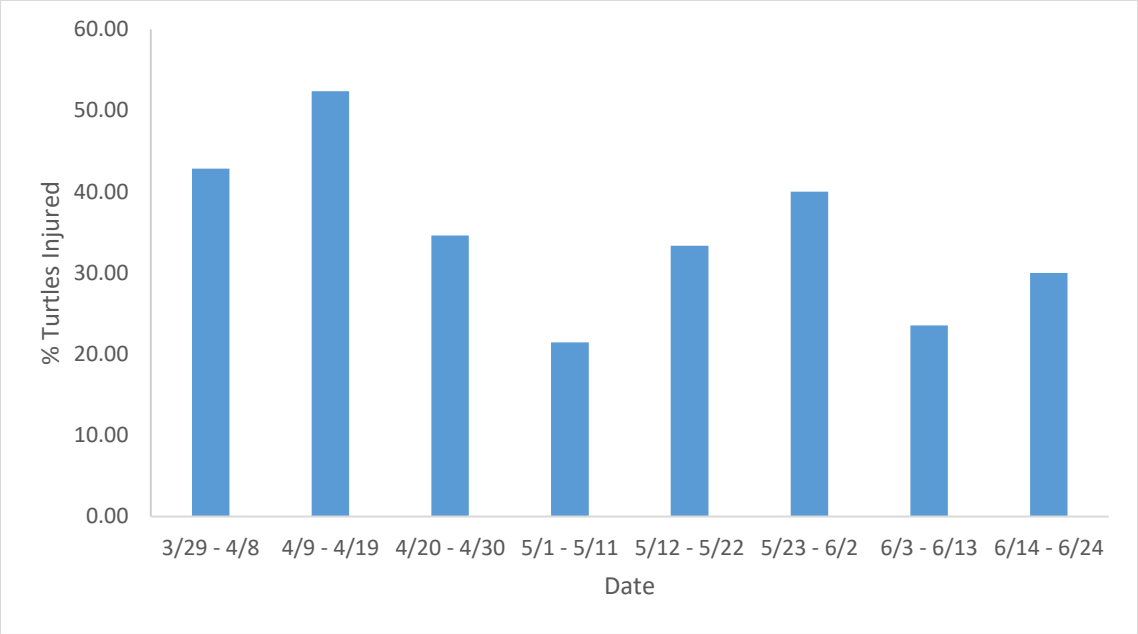

Figure 5. The percent of turtles injured of the total number of turtles observed at SPNWR for each ten day time period throughout the 2016 nesting season.

Trends in injuries

Two main trends were examined in order to answer my second research question. First, I looked at any trends in the locations of injuries on the turtles (Figure 6). For each injury location, I have totaled the number of injuries over all turtles, with some turtles having multiples injuries to the same location during the season. To account for the fact that an individual may have multiple injuries of each injury type, the total number of individual females was also included. The count of injuries to both front and rear flippers was similar to the count of individuals, meaning most females with flipper injuries only had a single injury in those locations. Flipper injuries were also the least frequently observed. The injuries to flippers were most often missing chunks of the flipper, from small notches out of the edge of the flipper to almost the entire flipper missing. Injuries to the carapace were more common in both counts than flipper injuries. The most common injuries were to the shoulders for both counts, with 58 injuries observed on 33 turtles. Shoulder

injuries were typically gashes of varying sizes and depths (see Appendix B for example photographs of injuries).

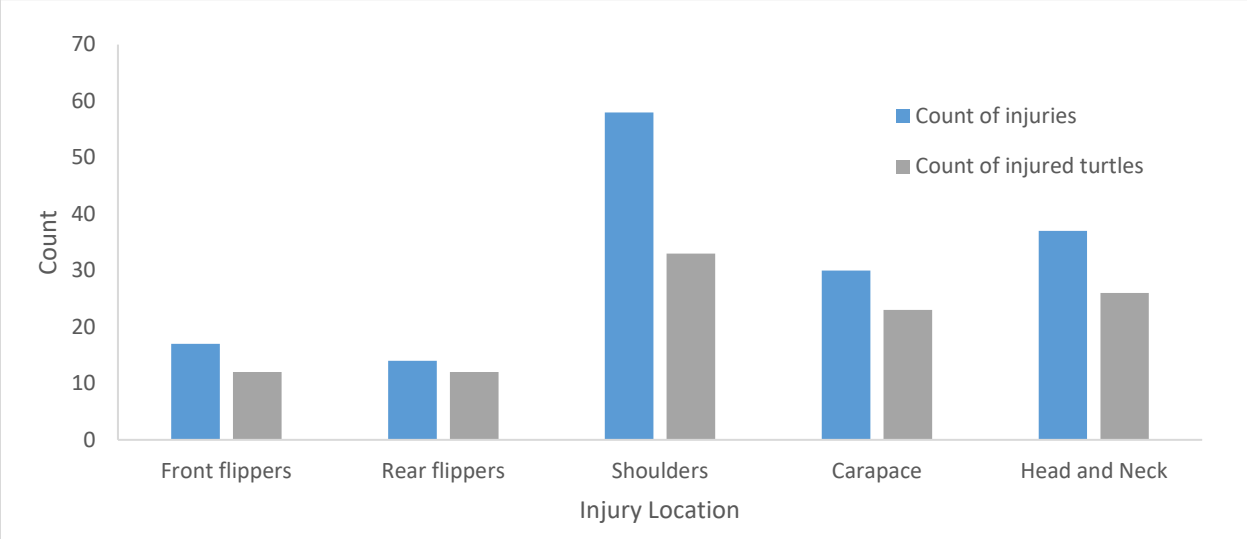

Figure 6. The counts of five injury locations on the bodies of nesting females (blue) and the counts of individuals with each injury type (grey).

In addition to the location and general type of injuries, trends in the characteristics of injured turtles were examined (Figure 7). Of the 49 individuals who nested on SPNWR over the course of the season, 24 were neophytes. Of the neophytes, 16, or 66.67%, were injured at some point during the season (injuries do not include scars, only recent injuries under categories 1-4). The remaining 25 individuals had previously nested and been tagged, and of those, 21 individuals, or 84% were injured at some point during the season. Neophytes consisted of 43% of the 37 turtles injured during the season. In sum, the 37 injured females consisted of 75.5% of the nesting population that season.

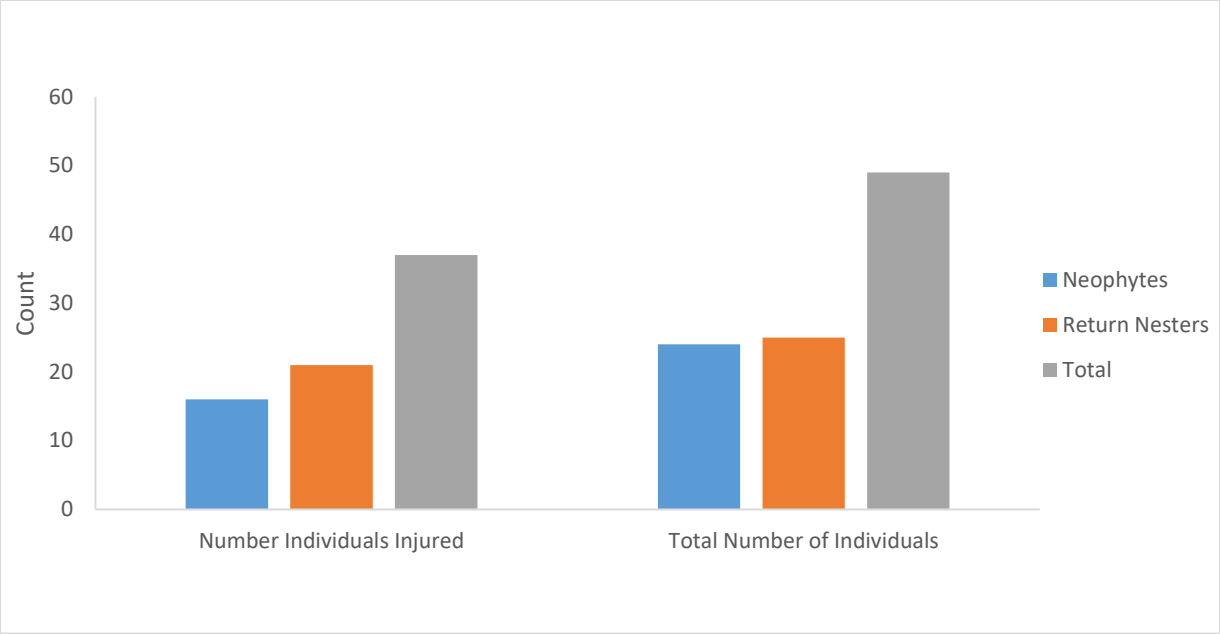

Figure 7. The count of injured individuals for neophytes, return nesters, and the total population at SPNWR the 2016 nesting season, and the total count of neophytes, return nesters, and the entire nesting population.

Healing rate

My final research objective was to estimate the typical healing rate for injuries on leatherbacks. This was determined by looking at the four most common types and locations of injuries: shoulder gashes, neck gashes, carapace scrapes, and neck scrapes. Then, for each turtle with that type of injury, the length of time between each category for each individual injury was determined. This was limited by the available data, and only the average healing rate from category 2 to 3 and 3 to 4 were consistently available for each of the four injury types (Figure 8). The scrapes typically took less time to heal than the gashes. Head scrapes went from category 2 to 3 on an average of 6 days, with a range of 5.5-7 days and n=2. Head scrapes went from category 3 to 4 on an average of 10 days, with a range of 5.5-17 days and n=4. Carapace scrapes healed from 2 to 3 in an average of 12.2 days (range=8.5-19, n=3) and from 3 to 4 in an average of 18.1 days (range=8.5-33, n=4). Neck gashes healed from 2 to 3 in an average of 16 days (range=10-25, n=4) and from 3 to 4 in an

average of 16.4 days (range=9-31, n=5). Shoulder gashes healed from 2 to 3 in an average of 11.75 days (range=11-13, n=4) and from 3 to 4 in an average of 25.75 days (range=19-41, n=4). For each injury type and location, the healing time from category 2 to 3 was shorter than the healing time from category 3 to 4.

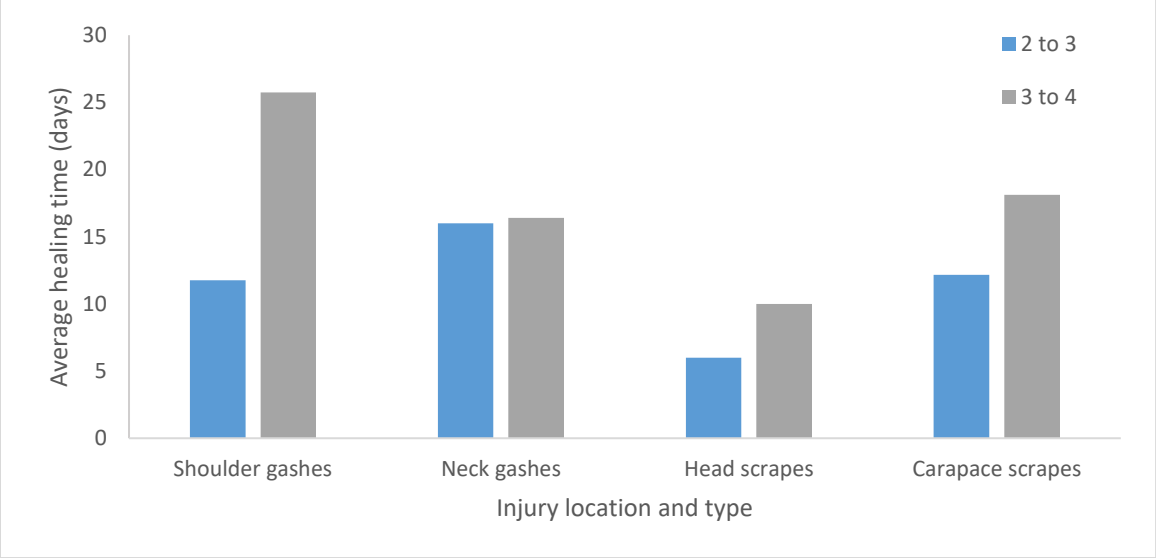

Figure 8. The average healing rate for four types of injuries observed on nesting females for the 2016 season. In blue, the average time to heal from a category 2 to 3, and in grey, the average time to heal from a category 3 to 4.

Discussion

Injury timing and trends

Injuries to female leatherbacks nesting at SPNWR are happening throughout the entire nesting season, though the occurrence peaks towards the beginning of the season when the greatest number of females were observed. The number of recent injuries for the first nesting event and the frequency of injuries during the season indicates that these females are sustaining injuries in the local Caribbean region during the internesting period, which can last from 8 to 12 days.

However, about a quarter of this season's nesting females did not sustain any injuries during the season. Both neophytes and return nesters were injured, with just five more return nesters injured than neophytes. Overall, a greater proportion of return nesters were injured than of neophytes. Additionally, as seen in the Appendix Table 1, there were several females who were injured multiple times during the season. These differences in which individuals were injured does not appear linked to whether or not they have previously nested at SPNWR. Therefore, there may be differences in individual behaviors after leaving the nesting beach or in where they choose to go during the internesting period. Some individuals may travel to places with a greater amount of fishing activity or where they are more likely to interact with predators, particularly sharks.

Shark predation on the leatherbacks at SPNWR was witnessed first-hand by the research team during one night patrol. The turtle, Rapunzel (SPP056), stayed on the beach until dawn on the morning of 17 April, and had bleeding injuries that were likely sustained shortly before her coming onshore to nest. When she returned to the water at dawn, the research team noticed that she

breached roughly ten meters offshore and was rolling to attempt to shake off a shark that was attacking her. She struggled with the shark for about 25 minutes and continued to move further offshore throughout the attack, and at times a second shark was also observed. This direct observation of shark attack just off Sandy Point indicates that interactions with predators may be one of the leading causes of injuries to this nesting population. From the photos of injuries to Rapunzel shortly before arriving to nest on 17 April that we assume are from sharks, we can have a rough idea of what injuries due to shark attack are likely to look like (see Appendix C for these images). Unfortunately, following the shark attack that was observed, Rapunzel did not return to nest in the 2016 season, thus we were not able to document injuries that we could be positive were due to predation. However, Rapunzel has returned to SPNWR and has already nested three times since the 2017 season began in March. The attack observed last season has not left any apparent damage on her, and exemplifies the resiliency of this species to attack and their ability to heal from injuries in order to continue to successfully nest.

Shark predation on sea turtles has been observed previously, but there is little documentation about shark predation on leatherback turtles. Green and loggerhead sea turtles are often observed with injuries due to interactions with sharks, and these injuries provide sufficient evidence to identify the species of shark preying on these turtles (Heithaus, Frid, & Dill, 2002). Unfortunately, no such research exists for leatherbacks and sharks, so definitively identifying which injuries observed during the 2016 nesting season at SPNWR are a result of interaction with sharks is difficult.

Additionally in St. Croix, leatherback interactions with longline fisheries has also been observed (Tobias, 1991). The instance observed by Tobias (1991) concluded with the hooked leatherback

being released alive from the hook that was under the front flipper in March of 1989. However, this injury was not photo-documented and therefore does not provide an example of what characteristics may identify this kind of injury. Incidental capture of leatherbacks in longlines has been documented in other places around the world (Kotas et al., 2004), and the extensive number of hooks deployed for each longline makes it plausible that these types of fishery interactions are occurring during the nesting season for leatherbacks nesting at SPNWR.

Overall, having the ability to determine the cause of the injuries would be ideal in identifying the specific threats facing this nesting population and how acute these threats are. As mentioned above, predation on this population seems to one of the main causes of injury to leatherbacks observed during the 2016 nesting season at SPNWR. However, data and photographs on what injuries due to interaction with predators and fisheries look like on leatherbacks is severely lacking. Unless the fishing gear is still entangled or embedded in the turtle, it is difficult to determine if injuries are a result of fishery interaction or predation.

Injury healing rates

Overall, the current healing rate results show that the healing rate from category 2 to 3 is faster for all injury types included in the analysis than the healing rate from category 3 to 4. For injuries to heal from a category 2 to 3, it took an average of 5-15 days, which is about one internesting period. Based on these results, an observed category 2 injury will likely have progressed to category 3 by the following nesting event at SPNWR. These results do not hold for healing timelines from category 3 to 4, in which the healing rate is much longer and more variable. These injuries took from 18 to 25 days to progress from one category to another, indicating that it will take multiple

nesting events for healing progress on a category 3 injury to be observed. However, the average healing rates for the four most common injuries were widely varied and had small sample sizes. The rates were also constrained by the internesting intervals, and therefore do not fully reflect the amount of time it takes for injuries to heal from one category to another. Additionally, there was not enough data available to get a full idea of how long a fresh injury takes to heal and become a scar.

It is interesting to note, however, that the healing of several injuries observed throughout the season seemed to stall at a stage 3. Once they reached the point of having yellow flesh, it seemed to take an extended amount of time for pink edges to develop on the injuries to indicate it had moved to stage 4 of the healing process. Many of the turtles seen with shoulder injuries at stage 3 could not be included in the estimate of the healing rate from stage 3 to 4 because the injury did not show signs of healing over several nesting events. If this data collection continues into the future, this would provide a larger sample size that could be used to further hone these estimates. This would help identify if this stalling in healing is common throughout the entire healing process or if it takes a longer amount of time for injuries to get past a certain point in the healing process.

Future research directions

This review of the injuries seen on nesting female leatherbacks in St. Croix sets important groundwork for understanding the role injuries play in affecting the health and resiliency of this population. Since leatherbacks do not nest annually, it will be valuable to continue to collect data and photographs of the injuries on nesting females to better understand patterns that might exist

for different nesting cohorts. Furthermore, continuing to collect this data will allow for the evaluation of the health of females that had severe injuries this season.

One example of this in particular is Eleanor (AAR568), who had severe damage to her entire body that appeared to be infected (see Appendix D for photos). Eleanor only nested one time this season, so we were not able to see how the injuries changed over time. Hopefully Eleanor will return in 3-5 years and allow us to observe how these injuries healed over this time period and if they have had any lasting effects on her ability to successfully nest.

It would also be interesting to develop a classification scheme more focused on the severity of the injury than the degree of healing done. This is challenging for leatherbacks, because their large size makes these smaller injuries we typically observe non-lethal. Other resources that classify injury severity for different sea turtle species use probability of mortality as the main classifier (Upite, 2011). In the case of SPNWR turtles, this scale would not be useful to apply to this population. Despite sometimes having severe injuries or missing limbs, the females at SPNWR still successfully nested and often did so multiple times during the season. The return of Rapunzel the season following her witnessed shark attack provides more evidence that these turtles are more resilient to injury than perhaps other turtles and need a novel scale to estimate injury severity. Instead, possible characteristics to use to estimate severity could be the depth of the injury or the size, though this still has limitations to accurately conveying the severity of the injuries we observe.

One interesting extension of this research would be to satellite track the internesting movements and activities of females that are observed with injuries and females that are clean. By observing

their movements throughout the region between nesting events, we may be able to compare injured and non-injured turtle habits and identify if there are certain places or activities that increase the likelihood of the turtle interacting with a predator or fishing gear. Including video recordings with satellite tracking would provide the full picture of what behaviors and activities the turtles are engaging in between nesting events. With a better understanding of what turtles are doing and where they are going during internesting periods we may be able to identify where injury hotspots may be located or what is causing the injuries seen. Additionally, it would allow us to understand if the behavior and movement of turtles without injuries is different and to determine what makes a turtle more likely to arrive at SPNWR with injuries during the nesting season.

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Appendix

A. The individuals associated with Figures 4 & 5 that were injured for each 10-day period, along with that individual's tag number and the visit number.

Date Range	Turtles Injured	Tag Number	Visit Number
3/29 - 4/8	Catalina	SPP214	1
	Yonce	SPP327	1
	Pascal	UUK946	1
4/9 - 4/19	Uno	SPP216	1
	Ariel	SPP264	1
	Flounder	SPP254	1
	Ursula	SPP360	1
	Perdita	SPP204	1
	Bunny	SPP188	1
	Rapunzel	SPP056	2
	Crush	SPP400	2
	Big Mama	AAC385	1
	Lola	AAC358	1
	Fredrika	SPP329	1
4/20 - 4/30	Catalina	SPP214	3
	Nicole	WC10459	1
	Ducana	SPP394	1
	Yogi	SPP081	1
	Hedwig	SPP001	1
	Ursula	SPP360	3
	Pascal	UUK946	2
	Yonce	SPP327	2
	Purple Rain	SPP372	1
5/1 - 5/11	Queen	SPP051	2
	Nona	SPP287	2
	Nemo	SPP308	3
	Culebra	3015	2
	Abbi	SPP066	1
	Dumpling	SPP370	1
	Illana	SPP320	1
5/12 - 5/22	Dora	SPP322	1
	Galadriel	SPP395	1
	Uno	SPP216	3
	Ursula	SPP360	5
	Ariel	SPP264	4
	Crush	SPP400	4

	Flounder	SPP254	1
	Eleanor	AAR568	5
	Jasmine	SPP097	3
5/23 - 6/2	Leia	SPP248	5
	Abbi	SPP066	2
	Yogi	SPP081	5
	Elsa	SPP342	1
	Crush	SPP400	5
	Ariel	SPP264	5
	Gaia	SPP377	4
	Boo	SPP344	2
6/3 - 6/13	Perdita	SPP204	6
	Leia	SPP248	6
	Katara	SPP353	1
	Molly	SPP362	1
6/14 - 6/24	Nuria	UUK934	4
	Flounder	SPP254	8
	Molly	SPP362	2

B. Photograph examples of different injury types observed at SPNWR during the 2016 nesting season. In order: right front flipper, right rear flipper, left shoulder, carapace, neck, and head injuries.


126336737A
SPP081
4/25/2016


6-10-16
SPP254


151616641A
SPP214
4/20/16


151613345A
SPP051
5/2/16

C. Rapunzel's injuries (tag number SPP056), which are assumed to be due to shark attack. In order, the first two photos show the left shoulder and the final photo shows the left rear flipper.

D. Eleanor's injuries (AAR568) on her head in the first image and carapace in the following images. The source of these injuries is unknown, but they appeared to be infected.