INJURY ASSESSMENT OF SEA TURTLES UTILIZING THE NERITIC ZONE OF THE SOUTHEASTERN UNITED STATES

By

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To my parents, Jim W. Norem and Kay J. Hall.

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Natural and anthropogenic factors regulate the long-term survival of sea turtles. To gain further understanding of the injury condition and possible effects of non-lethal injuries on sea turtles utilizing the neritic zone of the southeastern United States, a systematic Sea Turtle Injury Identification System (STIIS) was developed and applied to the turtles entrained at the St. Lucie Nuclear Power Plant (SLNPP). Physical cues (injuries) resulting from past interactions between turtles and the abiotic/biotic factors within their environment were quantified and statistically compared for the time period May 2000 through July 2005.

Data were collected on anthropogenic (fishing, oil/tar, boat propeller strikes, and SLNPP intake pipes) and natural sources (shark, social interactions among turtles, and barnacles). This information was compared among species, size class (life stage), and sex class. Unfortunately, the size class distribution of turtles captured during the study period limited analyses. Green turtles were predominantly within the small juvenile size classes, whereas the loggerhead turtles were large juvenile/transitional and adult turtles.

It was determined that within recent years, significantly more turtles incurred fresh scrapes while traveling through the intake pipes at the SLNPP. An increase of fresh scrape records within the eye and head region is an indicator of plant-related impacts to the sea turtles entrained at the SLNPP. Overall, the data suggests increased fouling inside the intake pipes and supports cleaning of the intake pipes.

The data suggests that significantly more loggerhead turtles are traumatized by boat propellers than green turtles. Additional data should be collected to elucidate if this is a species and/or size class effect. Loggerhead turtles were traumatized significantly more within the posterior subregion 2a of the carapace compared to green turtles (70.7% compared to 28.6%, respectively).

No significant differences were found between the number of loggerhead and green turtles with flipper amputations. However, significant differences were found between life stages and sex class. The rear flippers accounted for 78% of the amputations found in green turtles. The front right flipper accounted for the highest number (35%) of flipper amputations in loggerhead turtles. While, this was statistically non-significant, there may be a biological significance.

Overall, the data supported the idea that the types and causes of injury may vary across species, size class and sex class. The STIIS created in this project can be applied globally by researchers and volunteers across research and stranding projects assessing both live and dead turtles.

CHAPTER 1
INTRODUCTION AND BACKGROUND

Introduction

Sea turtles exhibit slow growth and late sexual maturation, traits typically found within long-lived wildlife species (Dennis et al. 1991). Unfortunately, such demographic factors make sea turtles particularly vulnerable to biotic and abiotic factors that could potentially decimate their populations (Zug et al. 2001). In order for resource managers to take the necessary steps in protecting sea turtles, basic biological and ecological life history information must be collected and made available (Witzell et al. 2002; Witherington 2003). For example, it has become increasingly clear that sea turtles face many threats in their marine environments, particularly along migratory routes, foraging grounds and nesting beaches. Clear identification and quantification of such threats has been minimal due to the difficult nature of obtaining such information on a group of organisms that spend the majority of their lives in the sea.

Since 1976, the St. Lucie Nuclear Power Plant (SLNPP) has maintained a database of all sea turtles inadvertently captured at the electric generating facility, which includes detailed injury records. This project utilized both new and historical data (May 2000 through July 2005) collected at the St. Lucie Power Plant to quantify primary types and causes of injuries, and to further identify regions of the body that may sustain significantly higher rates of injury (e.g., posterior versus anterior regions of the carapace, front and rear flippers, and the head region). This was accomplished by studying physical injuries (e.g., wounds, oil, fishing line) left from past interactions among turtles and abiotic/biotic factors. A primary objective of this project was to gain insight into many types of sea turtle species interactions (i.e., both anthropogenic and natural sources) that may allow for understanding into how these interactions are influencing survival rates, as well as how non-lethal injuries may be affecting their ability to function (both biologically and ecologically) throughout their lives. In general, this project provides basic biological and ecological information to agencies working to develop conservation and management plans, particularly within nearshore systems. Numerous gaps remain within sea turtle life histories that are prohibiting the development of sound long-term management plans. This project attempts to bridge such gaps.

Background

Population Ecology

Fluctuations within wildlife populations are a result of a multitude of abiotic and biotic factors that both positively and negatively affect long-term species viability (Congdon 1989). Parameters such as growth, reproduction, and survivorship play fundamental roles in shaping species' populations (Werner and Caswell 1977). For example, survival rates can substantially fluctuate between age and sex classes within a species (Chaloupka and Limpus 2001). Higher rates of mortality are frequently observed within younger cohorts than in the older generations of the same wildlife species (Jorgenson et al. 1997). Due to the multiple factors impacting populations, wildlife ecologists must strive to understand as much about species of concern and their ecological systems as possible (Jorgenson et al. 1997).

Spatial and temporal factors often limit the amount of information obtainable by ecologists (Akcakaya et al. 1995). This is most critical when the information is needed to determine long-term survival of a species and the development of recovery plans for threatened or endangered status. In the development of long-term population models it is insufficient to only consider such factors as birth and deaths when immigration and emigration can markedly affect the population size, which inherently molds the genetic and evolutionary change within the system (Werner and Caswell 1977). Predation and competition are examples of factors that cannot be ignored to simplify the process of understanding complex relationships shaping species populations. Wildlife populations can be strongly influenced by a multitude of demographic parameters (e.g., survivorship, growth, and reproduction) that can directly shape the viability of a species and therefore determine the species' long-term survival (Beddington and May 1977). Maturation within some long-lived species may take more than a decade [e.g., the gray whale *Eschrichtius robustus* may delay maturation up to 11 years of age (Beddington and May 1977)]. Serious problems arise when entire reproductive cohorts, especially the individuals that have the highest reproductive success (i.e., usually the older or larger individuals) are removed from the population (Doak et al. 1994). This makes species protection (e.g., classifying a population as threatened or endangered), necessary to prevent extinctions.

Vital Rates in Long-Lived Species

Further complications arise when attempting to understand the complexities controlling long-lived species populations. As previously mentioned, it is not uncommon for survival rates to be higher among older cohorts within a population. Such life history traits can have severe impacts within long-lived species that characteristically exhibit slow growth and delayed maturation (Dennis et al. 1991). The California condor (*Gymnosyps californianus*) is a prime example of such a species that underwent a severe population decline. The traits of longevity and delayed maturation coupled with low reproductive rates exposed the species to a severe risk of extinction (Dennis et al. 1991).

The example of *G. californianus* further demonstrates long-lived species' vulnerability to both natural and human-induced mortality. A crucial component in long-lived species conservation is the protection of the older cohorts (generally the key producers) (Jorgenson et al. 1997).

Wildlife populations are naturally regulated via various non-anthropogenic methods (e.g., weather, temperature, competition), but the resulting survivorship rates are in turn negatively affected by anthropogenic factors (e.g., encroachment, fishing, and environmental pollutants). For the most part, it is unclear to what level humans are impacting wildlife populations because of the difficulty associated with assessing population abundance and survivorship within some species. Marine organisms living part or their entire lives within ocean systems are among those species whose life histories in large part, remain a mystery. This makes it difficult to accurately assess the toll that humans are inflicting on oceanic systems. The lack of understanding within marine systems demonstrates the need for more research and protection of such systems.

Threats to Sea Turtles

Natural and anthropogenic factors within marine and terrestrial environments regulate the long-term survival of sea turtle species. Sea turtle survival probabilities are significantly influenced by human induced-mortality, such as fisheries interactions involving trawling, longlines, gill/entanglement, hook and line (Hilburn et al. 1995; Oravetz 1999), marine pollution (McCauley and Bjorndal 1999; Bugoni et al. 2001), and may be significantly influenced by natural sources such as disease [e.g., fibropapillomatosis, FP (Smith and Coates 1938) and predation such as birds, crabs, and sharks (Stancyk 1981; Marquez 1990)].

Each factor may impose a different level of threat to sea turtle survival, but assessing this can be difficult in a group of animals largely inaccessible for most of their lives. However, there are opportunities for researchers to gain insight into factors that may be affecting sea turtle survival probabilities (e.g., inferring threats from injury identification). This method has been applied in studies examining predator-prey interactions across several taxa (e.g., reptiles, zooplankton, and marine mammals) by inferring interactions and relative predation rates from new and healed inflicted injuries (Schoener 1979; Murtaugh 1981; Heithaus 2001a; Heithaus et al. 2002; Shimada and Hooks III 2004). Although inferences that can be made from such methodologies are limited, they can prove to be useful in providing information when other methods are unavailable.

Study Objectives

A primary objective of this project was to gain insight into many types of sea turtle species interactions (i.e., both anthropogenic and non-anthropogenic sources) that may allow for understanding of how these interactions are influencing survival rates, as well as how non-lethal injuries may be affecting their ability to function (both biologically and ecologically) throughout their lives (e.g., affecting vital rates such as reproductive success). Physical cues (injuries) left from past interactions among turtles and the abiotic and biotic factors within their environment were quantified, but before doing so it was first necessary to develop a standardized Sea Turtle Injury Identification System (STIIS) that would aid in reducing observer error when categorizing injury types, causes and locations. The use of this systematic injury identification system is not limited to this project, but can be applied globally by researchers and volunteers across research and stranding projects assessing both live and dead turtles.

As previously discussed, several anthropogenic and natural factors regulate sea turtle populations. However, the focus of this project is limited to the types and causes of injuries present on the sea turtles utilizing the neritic zone of the southeastern United States and entrained at the SLNPP. These include the following injury sources 1) shark, 2) social interactions among turtles, 3) barnacles, 4) fishing (hook, entanglement), 5) oil/tar, 6) boat propeller strikes, and 7) SLNPP intake pipes.

Two primary objectives were identified:

OBJECTIVE 1. Develop a systematic Sea Turtle Injury Identification System (STIIS), which researchers could use to determine types and causes of injuries and consistently record injury location.

OBJECTIVE 2. Apply the STIIS created in Objective 1 to new and historical sea turtle capture data at the SLNPP in order to quantify types, causes, and locations of injuries found on the sea turtles entrained at SLNPP.

A. Compare types and causes of injuries among species, size classes and gender.
B. Examine the frequency of intake pipe related scrapes on the turtles entrained at SLNPP. Provide the findings to Florida Power & Light (FP&L) and Quantum Resources.

CHAPTER 2
SEA TURTLE INJURY IDENTIFICATION SYSTEM

Introduction

Attempting to identify sources of injury in wildlife populations is not a new endeavor. Injury identification has been used across several taxa (e.g., reptiles, zooplankton, and marine mammals) to gain insight into threats that may be impacting imperiled wildlife populations (Schoener 1979; Murtaugh 1981; Heithaus 2001a; Heithaus et al. 2002; Shimada and Hooks III 2004). However, one question that has rarely been researched is the effects of non-lethal injuries on an organism's ability to function and reproduce (Nakaoka 2000) throughout its' lifetime. This is an especially important concern when individuals in early life stages sustain permanent injuries that may reduce their reproductive success.

With the vast number of sea turtle research programs being implemented globally, data sharing can sometimes be a trivial objective. Methodological and observer differences can thwart the regional data sharing process. In this study, a standard injury identification system that could be applied across research projects was identified as a crucial missing component in the field of sea turtle injury assessment. Thus, the creation of such a systematic Sea Turtle Injury Identification System (STIIS) was a primary objective in this project.

Obtaining standardized data is not the only obstacle when attempting to optimally utilize injury data. An additional source of concern is the task of formatting the data in a way in which it can be statistically analyzed. For example, many researchers are vigilant and meticulous data collectors, however, it is not uncommon for the injury data to become embedded and subsequently lost in the "comments column" of an extensive spreadsheet (e.g., a database spanning several years or decades). The comments column often contains such information as recapture data, animal behavior observations such as aggression or lethargy, and injury or abnormality data such as missing flippers or embedded fishing hooks. Unfortunately, many of the details explaining such data are often lost in the transferring of data from field datasheet to electronic spreadsheet, further underscoring the need for a standardized method of entering consistent and quantifiable data.

Methods

Study Area

The St. Lucie Nuclear Power Plant (SLNPP) is located on Hutchinson Island (a 36 km long barrier island) in St. Lucie County on the east coast of Florida, USA (lat 27°20'N, long 80°13'E). The island is bordered by the Atlantic Ocean on the east, the Indian River Lagoon on the west, St. Lucie Inlet on the south, and the Ft. Pierce Inlet on the north (Figures 2-1 and 2-2). The adjacent beach is composed of sand and shell hash. The littoral benthic community consists of a sandy-shell hash substrate that supports large worm-rock reefs consisting of sabellarid worms (*Phragmatopoma caudata*). The worm-rock reefs support high levels of fast-growing macroscopic algae (e.g., red algal species such as *Bryothamnion, Botryocladia, Solieria and Gracilaria*) (Ecological Associates 2000).

The continental shelf margin is approximately 30 km offshore from the power plant. The Florida Gulf Stream flows parallel to the shelf margin, and contributes water to the nearshore system during the summer season. The annual coastal water temperatures range from approximately 14 to 31° C (Ecological Associates 2000).

Study Site

The SLNPP, which opened in 1976, is an electric power generating facility operated by Florida Power and Light (FP&L). Water drawn from the Atlantic Ocean maintains the plant's two nuclear fueled units (i.e., condensers and cooling systems) in a circulating seawater cooling system (Ecological Associates 2000)

Intake system

The intake system for the two nuclear units is composed of 1) three ocean intake structures, their associated vertical openings, velocity caps and pipelines, 2) a common canal system, 3) individual unit intake and discharge structures, 4) and a common discharge canal leading to a shared discharge pipeline, which branches to a 3.65 m pipeline conveying water approximately 365 m offshore or a multiport diffuser approximately 4.9 m in diameter conveying water approximately 365-730 m offshore (Ecological Associates 2000).

Ocean intake structures

The three ocean intake structures are located approximately 365 m offshore. Each offshore structure is composed of a velocity cap and vertical shaft that serve to reduce the vertical entrainment of marine organisms (flora and fauna) and debris, however, no screen or grates are in place that would deny access to the intake pipes. The velocity cap for each intake pipe is located approximately 2.1 m below the water surface at mean low water. One intake pipe is 4.9 m in diameter with a 1.5 m thick velocity cap measuring 6.5 m^2 and a vertical shaft opening of 1.9 m. The second and third intake pipes are 3.65 m in diameter, with 1.5 m thick velocity cap measuring 4.8 m^2 and a vertical shaft opening of

2.0 m. Water entering under the velocity caps shifts to a vertical flow pattern with water flow velocities of 40.2cm/sec for the 3.65 m pipe, and 206 cm/sec for the 4.9 m pipe. Flow velocity inside each of the pipes range from 127-206 cm/sec and the estimated time for an object to travel the offshore pipeline to intake canal distance of 365 m ranges from 3-5 minutes. This varies depending on the intake pipe and degree of fouling inside the pipes. Water passes into each intake pipe's vertical shaft and enters a horizontal intake pipe, which is buried under the plant's adjacent beach and dune system (Ecological Associates 2000).

Intake canal and discharge system

The water from each horizontal intake pipe empties into a shared canal system (approximately 450 m behind the primary dune line), which carries the water 1,525 m before it reaches one of the two nuclear unit intake structures. The canal is 91 m wide and approximately 7.6 m maximum depth with a flow rate of 27-32 cm/sec depending on tidal stage. The incoming water passes through the plant's cooling system, and the resulting heated water is then released back into the ocean via two separate pipes, located 365 m and 730 m offshore (Ecological Associates 2000).

Barrier net implementation and modification program

A series of barrier nets have been erected, modified, and replaced at various locations along the canal system since 1978 in efforts to accomplish two primary purposes: 1) to restrict turtles (in addition to other floating debris) from moving down the canal system towards the plant's intake wells and 2) to establish an efficient netting turtle capture program to minimize the residency time of the turtles in the canal. In addition to turtle entrapment within the canal, other marine organisms and debris are entrained within the intake pipes and discharged into the canal, such as jellyfish, seaweed and flotsam (Ecological Associates 2000, Quantum Resources 2004).

The size of the mesh of each barrier net erected since 1978 has been dependent on the size frequency of the turtles captured at the plant prior to each net's construction. In 1978, a large barrier net (20.3 cm^2 mesh) was erected at the A1A bridge in an attempt to limit 95% of the sea turtles to the canal section east of the A1A bridge. However since 1993, a significant increase in the number of juvenile green turtles (<30 cm carapace width) have been entrapped within the canal. A large percentage of the juvenile green turtles were able to pass through the 20.3 cm mesh net and subsequently carried down the canal system to the plant intake wells, where they were later removed (e.g., in 1995, 673 green turtles were captured in the canal, 14.4% (n=97) passed the 20.3 cm net and 7.2% (n=7) were recovered dead from the intake wells. The 20.3 cm net was deemed insufficient after continued increases in turtle entrapment rates. In 1996, an additional barrier net (12.7 cm^2 mesh) was erected east of the 20.3 cm barrier net, while the 20.3 cm barrier net was left in place. The 1996 net reduced residency times for the turtles in the canal, but proved to be unsuccessful when its design was compromised by large amounts of seaweed and jellyfish. In 2002, a new barrier net was constructed using stronger material and increased structural support. This net has been able to withstand high pulses of seaweed and jellyfish, and has significantly reduced the likelihood of turtle mortality in the canal (Ecological Associates 2000, Quantum Resources 2004, 2005).

Procedures

Sea turtle capture program

Since 1976, an estimated 10,500 sea turtles (including recaptures) of five species (*C. caretta*, *C. mydas*, *D. coriacea*, *E. imbricata*, and *L. kempii*) have become entrained in the water entering the plant's canal system. All sea turtle species are listed as threatened or endangered in the U.S. Endangered Species Act of 1973. In order to reduce impacts by canal entrainment (injuries, residency time in canal, mortality), FP&L has maintained a sea turtle monitoring and review program with two biological contracting companies since opening in 1976, Applied Biology, Inc. (1976-1994), and Quantum Resources, Inc. (1994-present) . The sea turtle monitoring program involves a proficient daily observation, netting and removal program. Large-mesh tangle nets (30-37 m length and 2.7-3.7 m deep) with large floats attached to the top line (bottom line is not weighted) are set in the morning when the staff arrives, and are monitored throughout the day. Nets are removed before the staff leaves to eliminate the possibility of entanglement and drowning of animals within the canal. Dip nets and SCUBA are employed in addition to set-netting to further reduce the residency time of turtles entrained in the canal (Quantum Resources 2004, Quantum Resources 2005).

Captured turtles are individually processed, which includes: 1) species identification, 2) obtaining several morphological measurements (e.g., carapace lengths and widths, head width, and weight), 3) application of external and internal tags [i.e., Inconel flipper tags and Passive Integrated Transponder tag (PIT)], 3) full assessment and notation of any injuries, abnormalities, parasites and, 4) photo documentation. Photographs are filed according to capture date and data is recorded on a standardized datasheet in the field and later entered into a Microsoft Access database. The relative condition of each turtle is assigned (i.e., good, fair, poor or dead) based on a multitude of factors such as weight, activity, parasite load, barnacle coverage, injuries and other factors that may affect the overall condition of the turtle (Quantum Resources 2005).

Each turtle is assigned a turtle identification number (Turtle ID), which corresponds to the code of the first tag (a combination of letters and numbers) applied to the turtle. The presence or absence of a tag on a turtle is the primary indicator used in determining whether or not the turtle has previously been captured at the SLNPP or elsewhere. A turtle is categorized as a recapture if previously captured at SLNPP and a new capture if it has not been captured at SLNPP. One internal PIT tag (inserted in the front right flipper) and two external Inconel tags are applied to new captures > 30 cm straight-line standard carapace length (SSCL). Turtles <30 cm SSCL receive only a PIT tag in the front right flipper. After processing, healthy turtles are released back into the adjacent coastal waters ~800 m from the intake sites on the day of capture (Bresette et al. 1998). Turtles that are sick or injured are treated, and when necessary are held for observation before being released (Quantum Resources 2005). Turtles requiring further medical evaluation/treatment are sent to an approved rehabilitation facility after contact with the Florida Fish and Wildlife Conservation Commission (FFWCC) (Quantum Resources 2005).

Description and Discussion

Sea Turtle Injury Identification System (STIIS)

This project utilized both historical and new data collected from SLNPP during the period of May 2000 through July 2005. This decision was based on the knowledge that the core sea turtle research staff (those employed year-round) at the SLNPP has remained stable from May 2000 through July 2005 with the exception of one new hire during 2005. The new hire was considered ‘in-training’ and was largely overseen by senior research members. Furthermore, data collected during late summer/fall of 2004 (August to December) was not used because of the disruption of normal plant operation due to the hurricanes that occurred in Florida during 2004. Data collected May through December 2000 was used as a baseline year from which the STIIS was developed. Injury types and causes were determined for all captures in the 8-month period.

In order to consistently identify injuries within each categorical region, a film transparency was produced containing the corresponding sea turtle diagram found on the field datasheet. Diagrams (n=4) from each of the 5 years were scanned on an IMAX flatbed scanner (original scale maintained) and printed on a standard sheet of white paper (20 cm X 28.75 cm). Each diagram was sectioned based on biological and ecological criteria. The same principals were applied when sectioning the flippers into four subsections. Biological and ecological information used included: 1) bone and joint location, 2) the location of the claws on the front flippers and the scooping portion of the rear flippers, and 3) the standardized placement of both internal tags (PIT) and external tags (Inconel flipper tags). Sectioned diagrams were scanned using the IMAX flatbed and printed on a clear transparency. This transparency sheet was instrumental in recording consistent injury location data from the standard SLNPP datasheets throughout the project.

Turtle captures were evaluated for types, causes, and locations of injuries by close examination of each turtle's corresponding field datasheet and photographs. Photographs were available in slide and/or digital formats. More than 2,000 slide photographs were examined utilizing a Logan Tru-View light box (Logan Electric, Chicago, Illinois, USA) and a Carson 10X-magnifying lens. Injury causes were identified by characteristic markings/wounds (cues) of each injury type. Injury location was assigned by placing the diagram transparency (described in the previous section) over each of the corresponding datasheet's dorsal/ventral diagram. Injury information recorded included: 1) the anatomical region (general body region), 2) numerical region which is a single number and series of letters corresponding to subsections within a general body region (some anatomical regions were not subsectioned and thus only consisted of a single number), 3) the view of the injury (i.e., dorsal, dorsal/ventral, and ventral), 4) injury type, 5) injury depth (superficial or deep), 6) injury condition which describes the temporal occurrence (recency) of the injury (i.e., fresh, partial, or healed) by the presence/degree of wound closure and fibrin deposition (Table 2-1), and 7) injury cause. If the same injury (identical in injury location, type, depth, condition, and cause) occurred more than once within the same body region, it was recorded as a single record. For example, a turtle with five fresh scrapes on the head would be recorded as a single fresh scrape record on the head region.

Attention was given to field notations on each datasheet describing the turtle's condition/injury. Non-descriptive injuries were classified as unknown. Discrepancies between datasheets and photographs were corrected, ensuring the robustness of injury identification within this study.

Each injury should be recorded using the diagram and fields found in Fig. 2-3. Researchers should first begin by identifying the anatomical region location of the injury. This should be followed by determining the numerical region and subregion (when applicable). The injury view should be identified by the corresponding dorsal and/or ventral diagrams (dorsal/ventral) of which the injury is located. Missing portions of the carapace or flippers would be classified as dorsal/ventral. The type of injury should be closely evaluated, as certain types (cues) are indicative of certain sources of injury. The depth of injury should also be strongly evaluated. Superficial wounds are generally defined as those removing only minor amounts of scute/scale/tissue, which does not result in exposure of bone, muscle, internal viscera, or moderate to extreme blood loss. Deep wounds are generally defined as those of which moderate to extreme tissue/blood loss may occur, which may require medical attention. Injury recency should be determined by the criteria outlined in Table 2-1. The cause of the injury should be determined by the injury types (cues) (refer to the text and photographic descriptions in the following sections for further details). If the type of injury is non-descriptive, then it is appropriate to categorize the injury as unknown. Some projects may experience injury types and causes that are not represented in Fig. 2-3, in such cases, project personnel should make the appropriate additions to meet their project needs.

During the initial application of such an identification system, one could argue that time constraints (i.e., handling and processing) in the field would not allow for such detailed record keeping of each observed injury. However, consistent use of such an identification system does have practical application, and may prove to be extremely efficient and valuable now and in the future. For example, by keeping organized records of what are referred to as ‘unknown’ injuries now, researchers may be able to detect trends in injuries, which may aid in identifying potentially rising and serious threats to sea turtle populations in the near future.

Injury Types/Causes

Flipper amputation

Flipper amputation was defined as a continuous missing portion beginning on one margin of a flipper and following through to the opposite margin, as opposed to a missing section from one margin (crescent-shaped, v-shaped, and u-shaped notches). Flipper amputations were categorized according to the percentage of flipper missing: 1) less than half (<50%), 2) half (~50%), 3) over half (51-80%), and 4) entire (81-100%) (Fig. 2-4).

Barnacle

Injuries related to barnacles were determined by superficial to deep depressions, generally found on the carapace or plastrons region (Fig. 2-5).

Shark-related

Shark-inflicted injuries were determined by the criteria outlined in Table 2-2. Only flipper amputations coupled with apparent punctures and/or missing crescent-shaped sections with tooth impressions were classified as shark-related injuries. Once the healing process has commenced, the ability to identify shark-related injuries may become less obvious and therefore less indicative of a shark-turtle interaction. Fig. 2-6 contains photographs of sea turtles with shark-related injuries.

Social interactions

Indicators of social interactions among turtles include 1) circular bites on the neck region of females, 2) symmetrical abrasions on the trailing edges of the flippers in males indicative of reproductive activity (Fig. 2-7), 3) symmetrical creases on the plastron of males (Fig. 2-7), and 4) symmetrical scars under the front flippers on females.

Boat propeller

In this study, identification of boat-related injuries was limited to propeller strikes (Fig. 2-8). Carapace cracks were not identified as boat-related because of the inability to distinguish hull strikes from other high-impact injury sources (Fig. 2-9). Cracks in the carapace are often assumed to be boat-related, however, within the scope of this project causality was not assigned without additional indicators such as lacerations. Propeller strikes were identified by one to several lacerations found on the head, carapace, flipper, and plastron regions. Boat propeller lacerations differ from other slices or cuts typically by the severity of the wound, including the length, width and depth. It is not uncommon for such lacerations to be grouped in a parallel configuration showing the rotational movement of the boat propeller that struck the turtle.

Fishing interactions

Injuries categorized as fishing related included: 1) monofilament entanglement, 2) embedded fishing hooks (generally found in soft tissue areas such as the neck, flipper, mouth or eye region), and 3) strangulation wounds (superficial to deep scars) around the base of the flipper or neck region (Fig. 2-10). Turtles found with attached fishing line and/or hooks were closely evaluated. If the line or hook was found to be superficial it was removed and the turtle was released, however, if the line was deeply embedded the turtle was sent to a rehabilitation facility.

Intake pipe

Intake pipe related injuries were identified by fresh scrapes on the body (lack of observable fibrin deposition) resulting from entrainment through one of the three intake pipes at the SLNPP (Fig. 2-11).

Oil/tar

Oil/tar related injuries were identified by the presence of oil or tar on the body (Fig. 2-12).

Unknown

Unknown injuries were classified as such when no distinguishable cues (injury was non-descriptive) were present that would indicate a known injury source (Fig. 2-13).

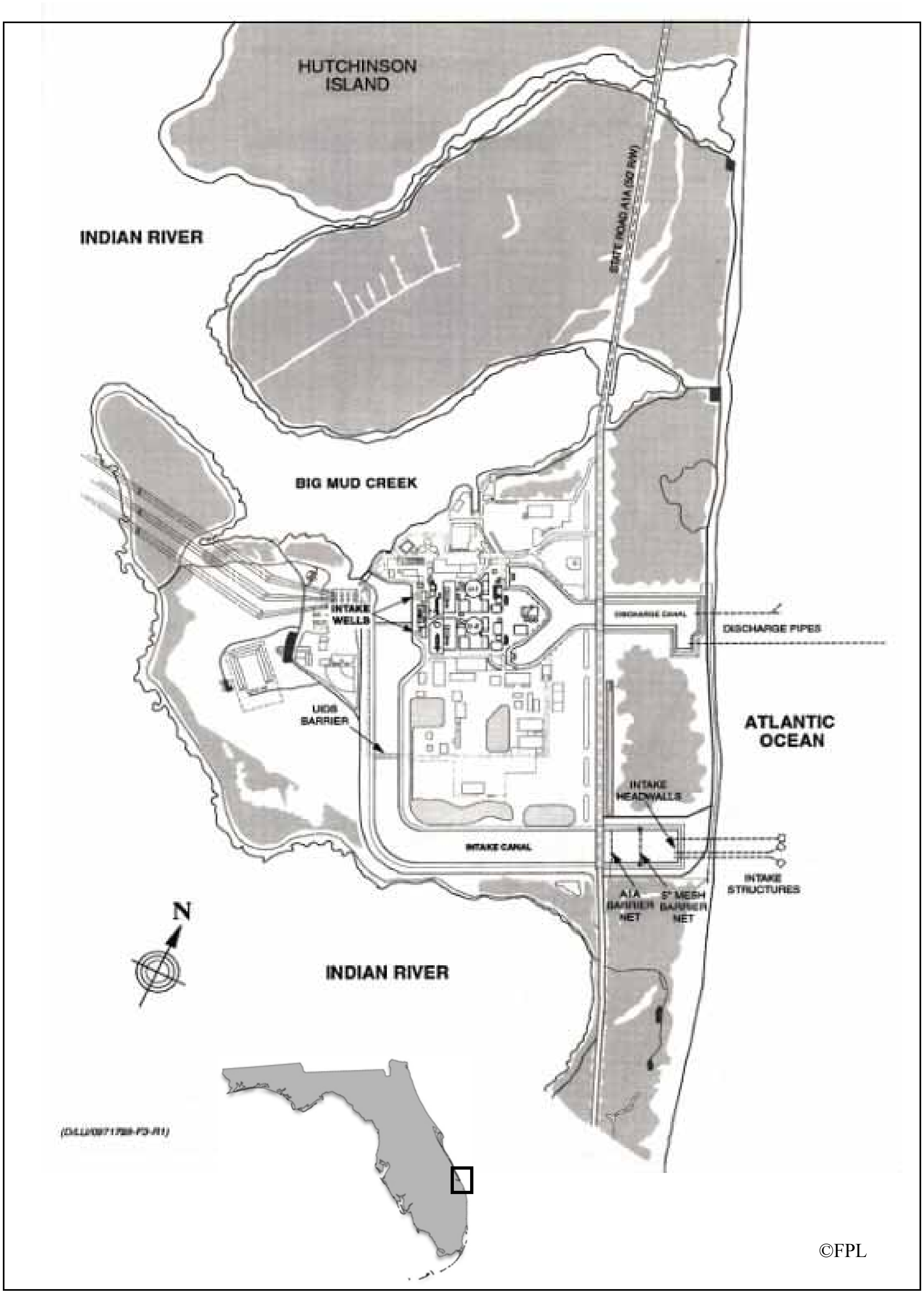

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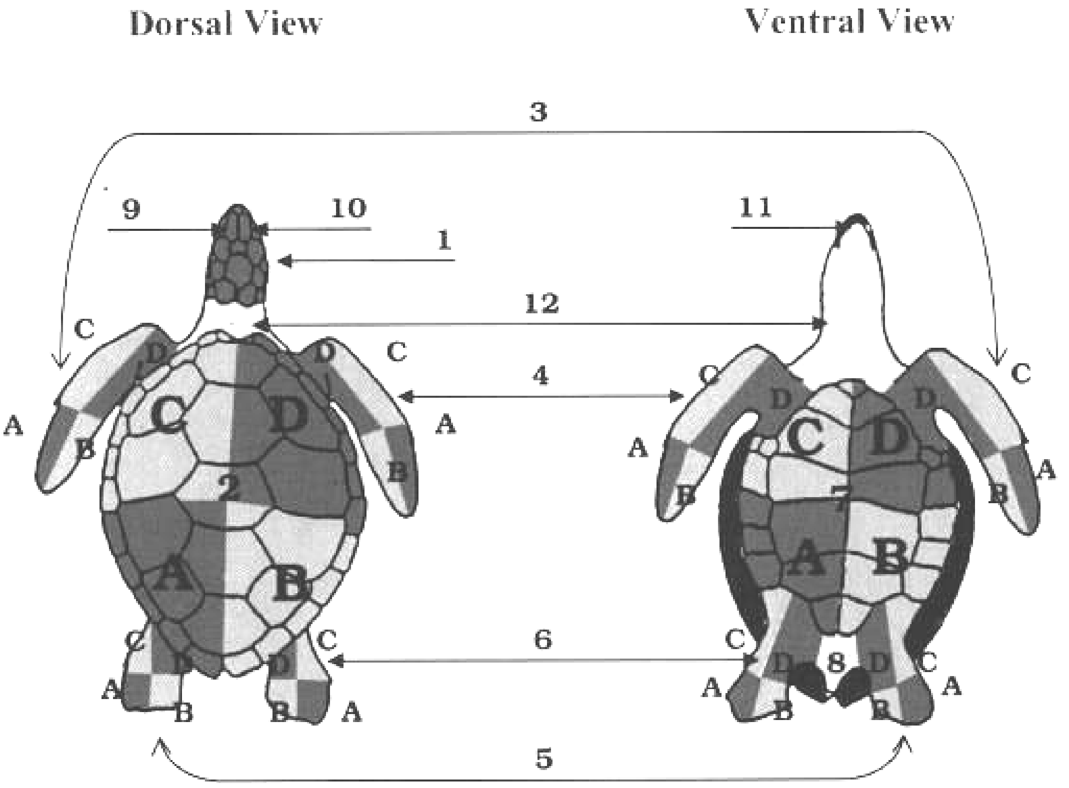
Figure 2-1. St. Lucie Nuclear Power Plant located on Hutchinson Island, Florida, USA.

Figure 2-2. Aerial view of the St. Lucie Nuclear Power Plant and nearshore reef system. The barge was present in 1991 during the reconstruction of the intake pipe's velocity caps.



Anatomical	Numerical	View	Injury Type	Depth	Injury Condition	Cause
Head	1	Dorsal	Abrasion	Superficial	Fresh	Barnacle
Carapace	2abcd	Dorsal/Ventral	Amputation	Deep	Partial	Shark
Front Left Flipper	3abcd	Dorsal/Ventral	Bite		Healed	Social
Front Right Flipper	4abcd	Dorsal/Ventral	Broken			Boat Propeller Strike
Rear Left Flipper	5abcd	Dorsal/Ventral	Crack			Fishing
Rear Right Flipper	6abcd	Dorsal/Ventral	Crease			Intake Pipe
Plastron	7abcd	Ventral	Cut			Tar
Cloaca/Tail	8	Dorsal/Ventral	Depression (pitted/indented)			Unknown
Left Eye	9	Dorsal	Discoloration			
Right Eye	10	Dorsal	Hole			
Mouth (Jaws/Esophagus)	11	Dorsal/Ventral	Missing			
Neck	12	Dorsal/Ventral	Missing (crescent-shaped)			
			Missing (marginal)			
			Missing (scalloped)			
			Missing (u-shaped marginal)			
			Missing (v-shaped)			
			Puncture			
			Raised			
			Rake Marks			
			Scrape			
			Slice			
			Other			

Figure 2-3. Sea Turtle Injury Identification System (STIIS) developed by A.D.Norem.

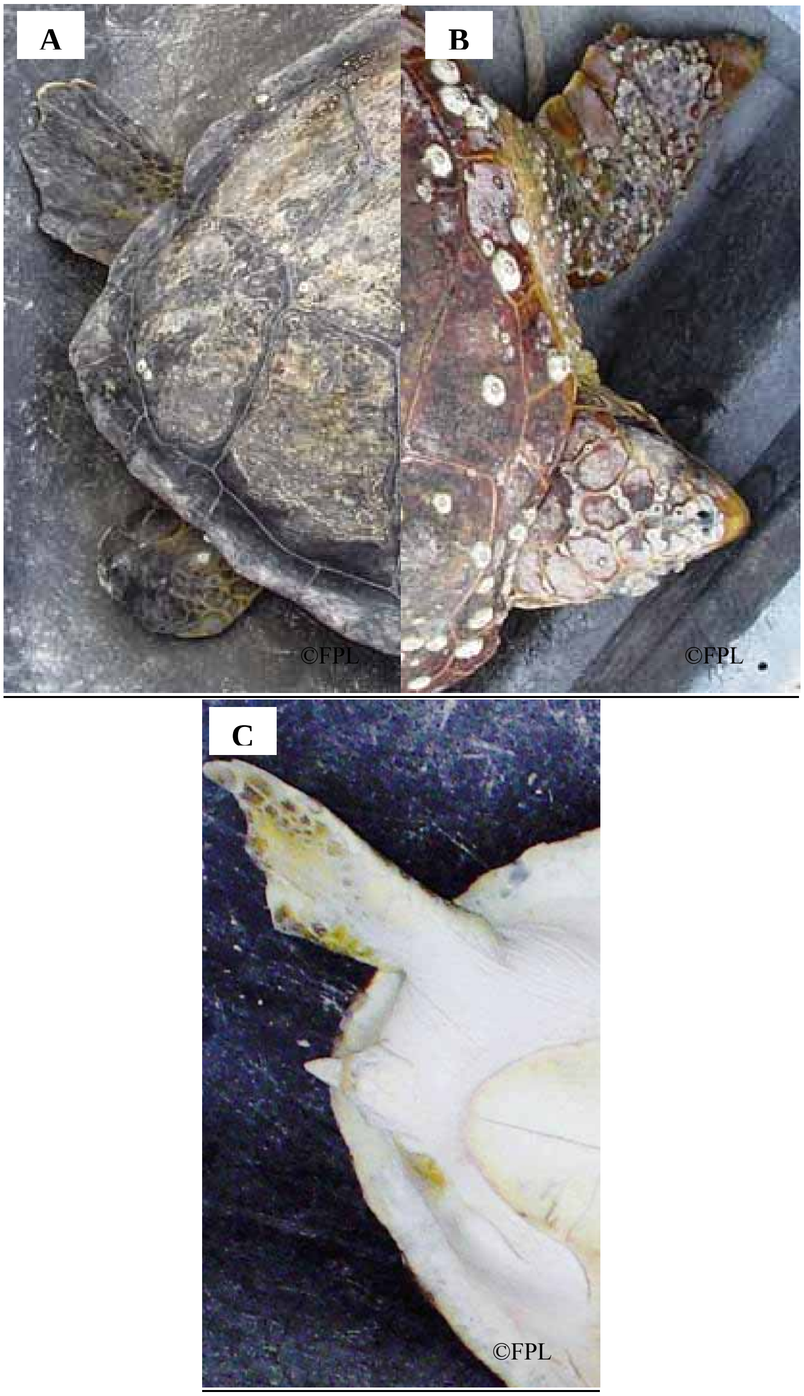


Figure 2-4. Flipper Amputations. A) *C. mydas* missing less than half of rear right flipper (numerical region 6ab). B) *C. caretta* missing half of front left flipper (numerical region 3ab). C) *C. mydas* missing entire rear left flipper (numerical region 5abcd).

Figure 2-5. Two deep barnacle depressions on the 3rd vertebral on the carapace of a juvenile *C. mydas* (numerical region 2abcd).

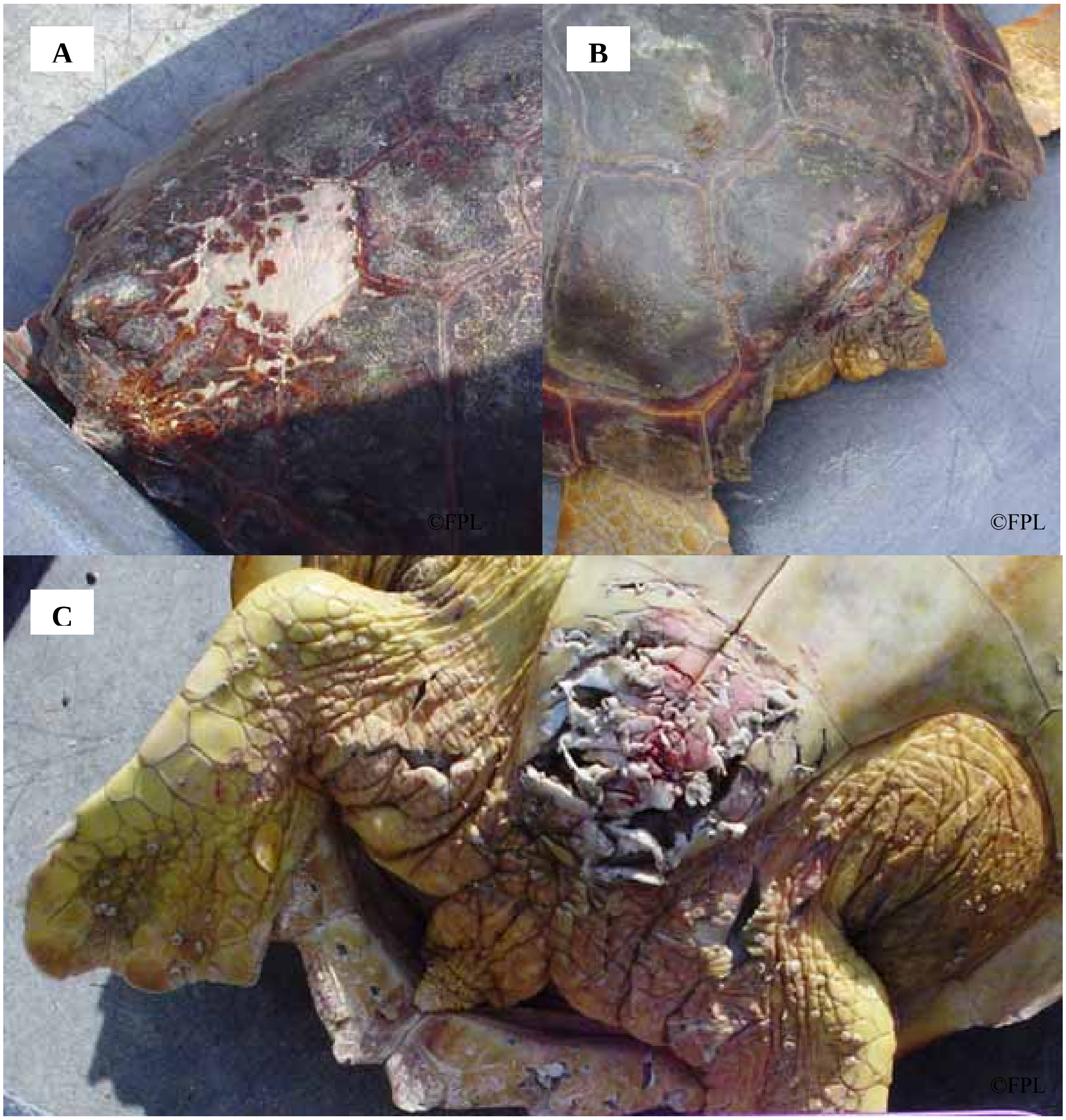


Figure 2-6. Shark-related injuries. A) Rake marks from shark on posterior end of *C. caretta* carapace (numerical region 2ab). B) Crescent-shaped portion of posterior end of carapace removed with slashing wounds from shark on dorsal side of tail (numerical regions 2ab and 8). C) Tooth impressions and slashing wounds from shark on posterior end of plastron and on rear flippers; same *C. caretta* as in photograph A (numerical regions 7ab, 5cd and 6cd).

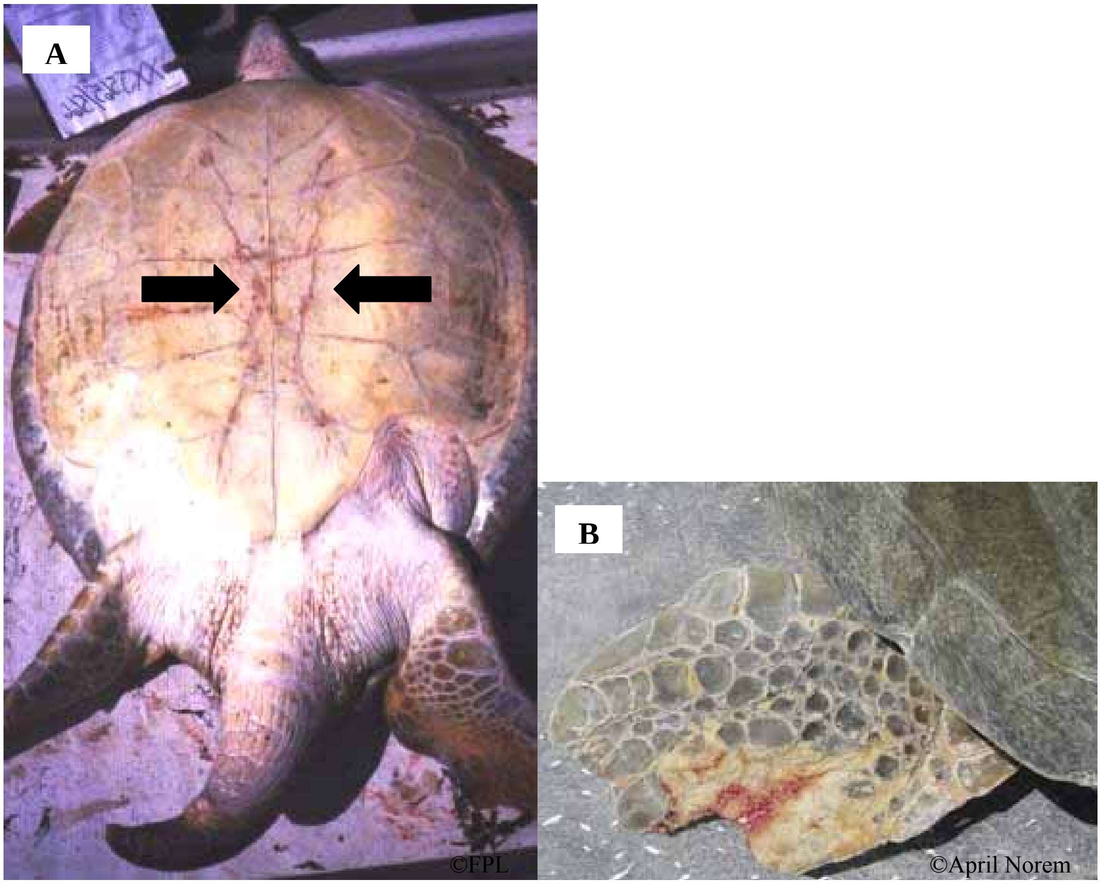


Figure 2-7. Injuries resulting from social interactions among turtles. A) Male *C. mydas* with symmetrical creases on plastron indicative of mating activity (numerical region 7abcd). B) Symmetrical abrasion on rear left flipper on adult male C. mydas (numerical region 5ab).

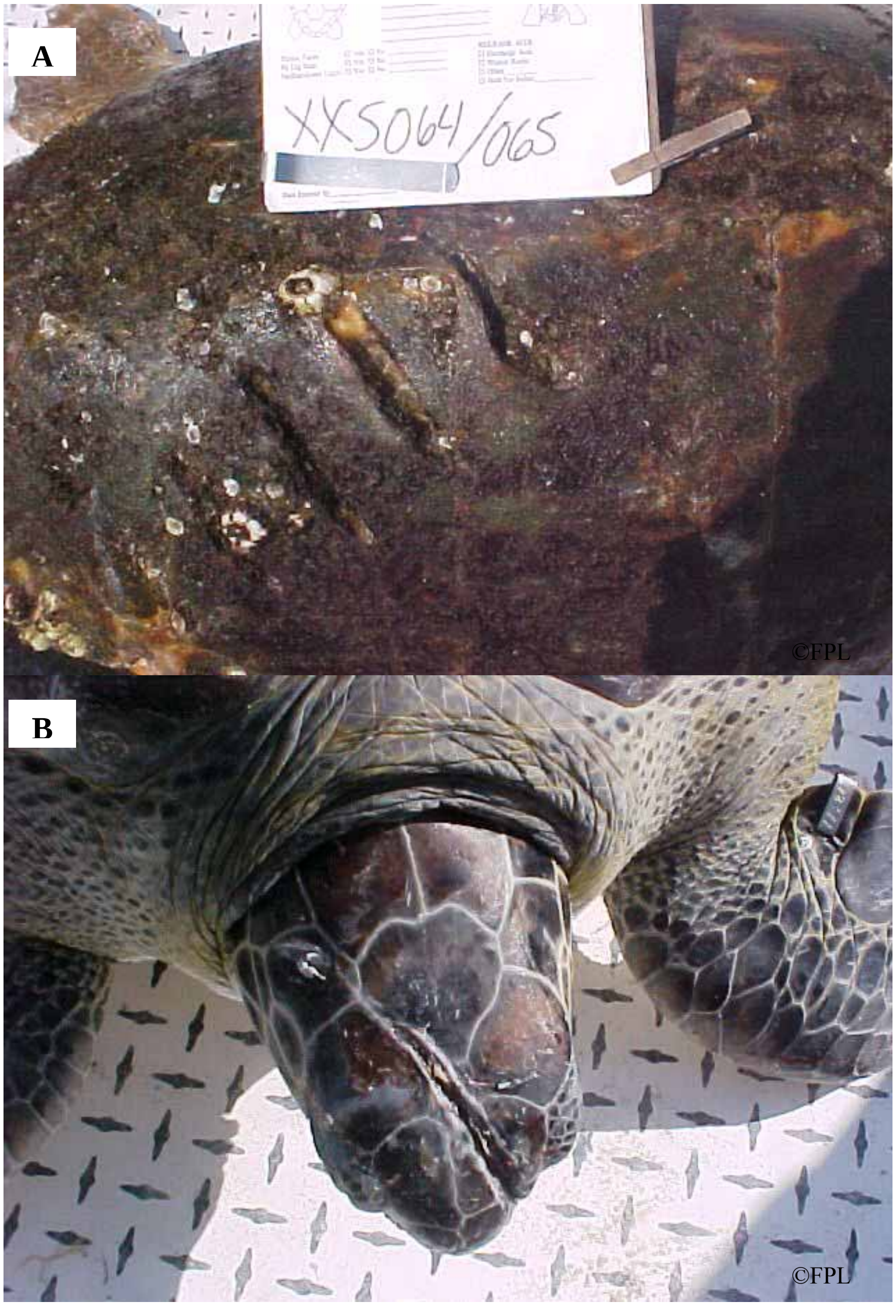


Figure 2-8. Boat propeller injuries. A) Slice wounds in parallel configuration on *C. caretta* carapace (numerical region 2b). B) Dorsal photograph of boat propeller slice through head on juvenile *C. mydas*.

Figure 2-9. Cracked carapace on *C. caretta* (numerical region 2cd).The cause of injury was classified as unknown.

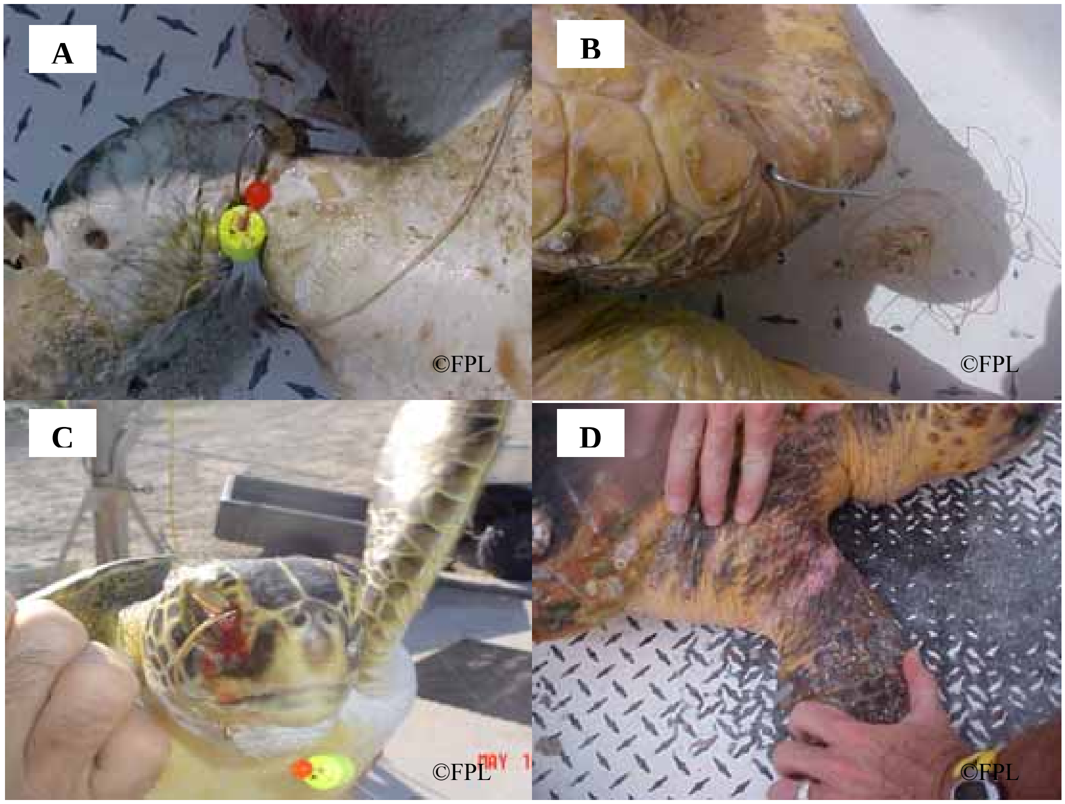


Figure 2-10. Fishing-related injuries. A) Monofilament strangulation of the front right flipper on *C. mydas* (hook and sinker attached, numerical region 4cd). B) Fishing hook with monofilament attached embedded into front right flipper on *C. caretta* (numerical region 4c). C) Fishing hook embedded into the right eye of juvenile *C. mydas* (hook and sinker attached, numerical region 10). D) Strangulation wound on front right flipper of *C. caretta* (numerical region 4cd).

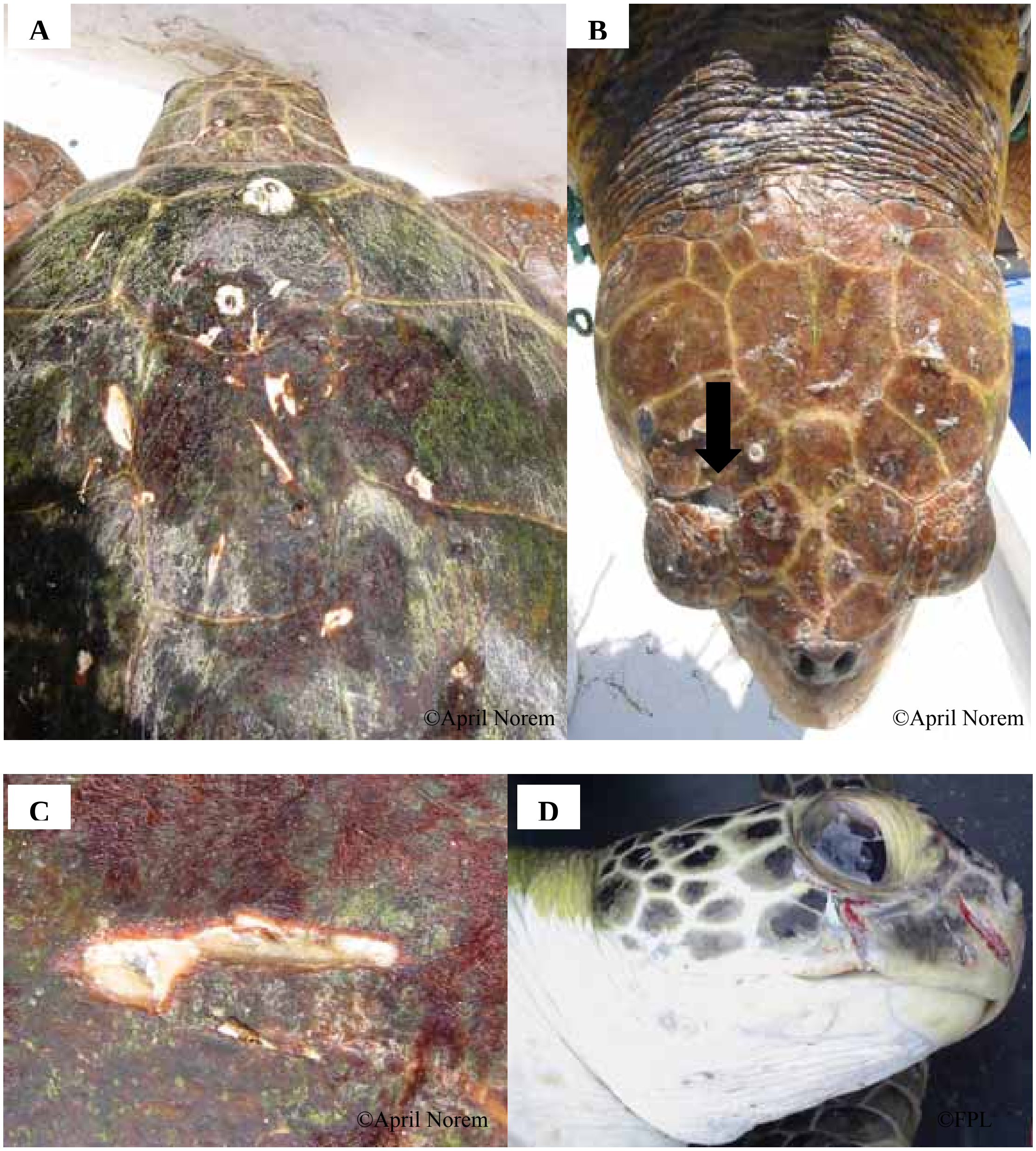


Figure 2-11. Fresh scrape injuries. A) Fresh scrapes on carapace of *C. caretta* (region 2abcd). B) Dorsal view of head on *C. caretta* exhibiting several fresh scrapes, note deep fresh scrape above right eye (numerical regions 1 and 10). C) Close-up view of fresh scrape on carapace. D) Side view of juvenile *C. mydas* head showing fresh scrapes between right eye region and mouth, and below right nare (numerical regions 1 and 11).

Figure 2-12. Oil on the ventral side of *C. caretta* (numerical regions 3abcd, 4abcd, 5abcd, 6abcd, 7abcd, and 8).

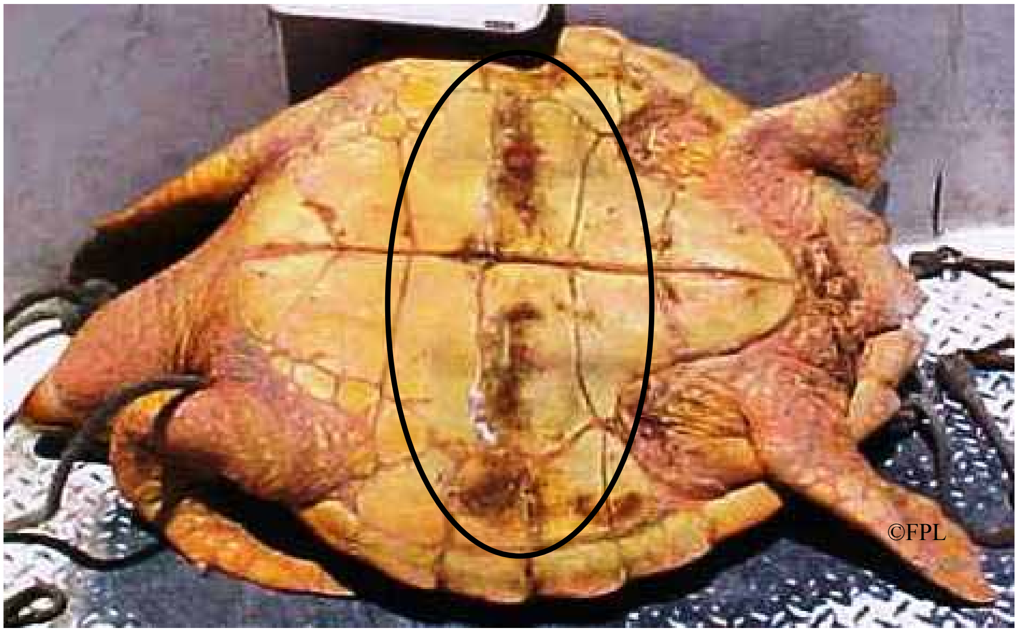


Figure 2-13. Symmetrical non-descriptive injuries on the plastron of *C. caretta* (numerical subregion 7ab). The cause of injury was unknown.

Table 2-1. Categories of injury recency (fresh, partially healed, and healed).

Fresh	Exhibiting no signs of closure or fibrin deposition.
Partially healed	Exhibiting some signs of scute/scale growth around the wound, in addition to fibrin deposition within the wound.
Healed	Exhibiting signs of complete scute/scale growth, resulting in full closure of the wound.

Table 2-2. Shark-related injury criteria. Each criterion may be mutually exclusive.

Criterion number	
(1)	Obvious shark tooth impressions/rakings located on any region of the body.
(2)	Crescent-shaped section removed from carapace or flipper that could only have been caused by a shark.
(3)	Flipper amputations coupled with tooth impressions, punctures, and/or slashing wounds indicative of sharks.

CHAPTER 3
ANTHROPOGENIC AND NON-ANTHROPOGENIC INJURY ANALYSES

Background

Non-anthropogenic Threats to Sea Turtles

Sharks

Several examples exist within the literature of sharks being listed as likely sea turtle predators, but the extent of predation pressure placed on turtles by sharks is relatively unknown. Previous literature reviews have noted six shark species to be likely predators of sea turtles: bull (*Carcharhinus leucas*), hammerhead (*Sphryna sp.),* lemon (*Negaprion brevirostris*), oceanic white tip (*Carcharhinus longimanus*), tiger (*Galeocerdo cuvier*), and white (*Carchardodon carcharias*) (Stancyk 1982). The tiger shark, however, is the only species cited as preying extensively on large cheloniid (hard-shelled) sea turtles (Stancyk 1982; Witzell 1987; Heithaus 2001b; Simpfendorfer et al. 2001).

Significant temporal and spatial habitat overlap exists between sea turtles and sharks (Witzell 1983, 1987; Marquez 1990) and both animals exhibit a series of ontogenetic shifts (i.e., geographical and diet) throughout their lifetimes (Meylan and Meylan 1999; Simpfendorfer et al. 2001). Sea turtle hatchlings leave their natal beaches for an oceanic (open ocean environment exceeding bottom depths of 200 m) existence for a period of years, whereas juvenile, subadult (transitional), and adult cheloniid sea turtles are sympatric with several shark species in their wide utilization of neritic zones (inshore coastal waters not exceeding bottom depths of 200 m) such as lagoons, salt marshes, bays, creeks and river mouths (Ernst et al. 1994). Furthermore, occurrences of sea turtle-shark interactions may vary depending upon factors such as diet and geographical distribution among species, sex and size class of both organisms. This variation is clear if one reviews global examples of shark stomachs containing parts of and/or whole sea turtles. Fergusson et al. (2000) described a 60 cm loggerhead turtle (*Caretta caretta*) removed from the stomach of a female white shark ≤ 550 cm total length TL caught in the Mediterranean Sea. A 295.2 cm TL tiger shark captured in the Eastern Caribbean was reported to contain a partially digested ~30 cm hawksbill turtle (*Eretmochelys imbricata*)(Young 1992). Balazs (1979) reported various turtle parts (e.g., mandible, plastron, and carapace) belonging to a 55-60 cm loggerhead turtle within the stomach of a 400 cm tiger shark caught off of Kure Atoll in the Northwestern Hawaiian Islands. Moreover, behavioral differences between male and female turtles may lead to significant differences in the rates of sea turtle-shark interactions, and subsequent injury rates. Heithaus et al. (2002) concluded that loggerhead turtles (n = 115, mean = 89.7 ± 12.0 SD) exhibit higher rates of shark-related injuries than green turtles (n=133, mean = 90.7 ± 13.2 SD).This same study speculated that male loggerhead turtles may incur higher injury rates of shark-related injuries in comparison to female loggerheads, as well as male and female green turtles, because they engage in behaviors that could be considered higher-risk (Heithaus et al. 2002).

Social interactions

Very little is known about injuries incurred from social interactions among sea turtles. It has largely been presumed that turtles are predominantly solitary animals, with the exception of social grouping during courtship and mating (Carr 1995). However, Dodd (1988) reported aggregations of both juvenile and adult loggerheads. Mating occurrences have been observed with a male typically mounting a female. This may involve some pre- and inter-biting behavior on the flipper and/or neck region (Miller et al. 2003) and the males clasping to the female carapace via enlarged and strongly curved claws (sexually dimorphic trait found only in mature individuals, Kamezaki 2003) during mating (Ernst et al. 1994; Gulko and Eckert 2003; Miller et al. 2003). In addition to injuries between male and female mating pairs, minor to serious injuries may arise from competition among other turtles for space or mating opportunities. For example, loggerhead turtles have been observed exhibiting aggressive behavior towards conspecifics by attempting to or actively biting them when they were too close (Limpus and Limpus 2003).

This study quantified wounds indicative of social interactions among turtles. Examination of wounds resulting from mating interactions may allow researchers to identify wound types and locations indicative of reproductive activity and/or social interactions with other turtles, as well as estimating the timing of such events based on the recency of the wound.

Barnacles

Barnacles have been recorded among the epibionts found on sea turtles, specifically within *C. caretta* (Frick et al. 1998). Barnacles may negatively affect a turtle’s health by inducing tissue damage, which may allow pathogens to enter the body (George 1997).

Anthropogenic Threats to Sea Turtles

Commercial and private boating

The direct and indirect effects of boating activity on sea turtle populations are largely unknown. Air breathing marine organisms such as sea turtles and marine mammals (e.g., manatee *Trichechus sp.*), are at high risk of being struck by boats because they must surface to obtain the oxygen required to survive. In addition, activities such as basking, mating, and resting at the surface make the animals susceptible to boat strikes. Moreover, sick or injured turtles may spend significant amounts of time at the surface and may be incapable of diving properly to avoid approaching boats. The ability of turtles to detect approaching water vessels via auditory and/or visual cues in the wild is unknown due to the difficulty of observing and measuring such interactions. However, some information is available on the auditory capabilities of loggerhead and green turtles. For example, Ridgway et al. (1969) concluded that the auditory function in green turtles is optimal for detecting lower frequencies between 60Hz and 1000 Hz (peaking between 300Hz and 400 Hz). Moein et al. (1999) studied the auditory capabilities in 35 juvenile loggerhead turtles and found that their hearing was also specialized for low frequency sounds with optimal detection between 250 Hz and 750Hz (peaking around 250Hz). An additional study by Lenhardt et al. (1983) found that bone-conducted (bc) sound was a reception mechanism for marine turtles with the carapace and skull functioning as the receiving surfaces.

Despite the specialized capability of marine turtles to hear low frequency sounds, the time available between a turtle detecting an oncoming boat and diving to escape being struck by the hull or propeller may be insufficient even for turtles in healthy condition. This problem may be exacerbated if the turtle is in shallow water and unable to dive deep enough to avoid collision with an oncoming boat motor. Boat propeller strikes may result in lacerations, fractures, paralysis, buoyancy problems, breathing difficulties, and mortality (Walsh 1999).

The level of boat traffic within an area may give some indication of the threat that boating may impose on sea turtles. For example, the Sea Turtle Stranding and Salvage

Network (STSSN) have reported many sea turtle boat propeller injuries off coastal states that have high levels of boat traffic (Ecological Associates 2000). However, it is very difficult to determine how many of these dead stranded turtles died as a result of being hit by a boat, or were struck post-mortem (after they were already dead). The 2004 Florida Boating Statistics indicate that boat registration increased by 0.5% (n=4,682) from 2003-2004, reaching 982,907 vessels registered. This project, however, recognizes that time and place of capture does not necessarily equal time and place of injury.

This project had the rare opportunity to quantify the frequency of boat propeller strikes in live sea turtles (and thus quantifying boat propeller strike survivors) utilizing the nearshore system of SLNPP. Comparing the frequencies of boat propeller injuries among species and size class may provide new information for researchers to use to estimate how many turtles are sustaining such injuries. This may indicate the level of threat that boating activity poses to sea turtles, as well as assessing the health impacts (e.g., paralysis and/or buoyancy problems) of such injuries.

Marine debris

Marine debris can be described as items discarded by humans (purposely or inadvertently) into the marine environment. This includes trash from both land-based and water-based human activities. The Ocean Conservancy's (TOC) 2004 International Coastal Cleanup report stated that over 7 million pounds of debris were removed from the marine environment. An example of the most deleterious types of debris in marine system is derelict fishing gear (nets, fishing line and hooks) from commercial and recreational-based fishing activities. It is not uncommon for marine organisms to be become entangled and drown in fishing line (Milton et al. 2003), nor is it uncommon for marine organisms to either directly or indirectly consume marine debris. It has been estimated that one third to one half of all sea turtles ingest plastic products (Gulko and Eckert 2003). Among the items that have been found in sea turtle digestive tracts are plastic bags, beads, pellets, rope, latex balloons, styrofoam, fish hooks, charcoal, glass, paper and cardboard (Milton et al. 2003). Leatherback sea turtles are known to mistake plastic bags for jellyfish, which are one of their primary food sources (Milton et al. 2003). A study conducted by McCauley and Bjorndal (1999) found that consumption of marine debris by posthatchling loggerhead turtles imposes an indirect and direct lethal effect that may lead to decreased growth rates, an increase in the time the turtles remain in smaller size classes increasing their risks of predation, reduction in energy reserves and reproductive output, and decreases in survivorship.

In this study, only impacts of marine debris that could be observed externally were quantified. This included hook and line entanglement and presence of tar/oil on the turtles. It is unknown how many of the turtles captured at the SLNPP contain marine debris within their digestive tracts.

Oil and tar pollution

In the marine environment, sea turtles are exposed to continuous levels of oil throughout their lives in the form of tarballs and slicks. Such long-term exposure may degrade the turtle’s ability to deal with other natural and anthropogenic stresses (Milton et al. 2003) by damaging organs and increasing drag (Gulko and Eckert 2003). Posthatchling and oceanic staged turtles may be more vulnerable to oil slicks because they spend more time at the waters surface than juvenile, subadult and adult sea turtles (Milton et al. 2003). In a study examining posthatchling loggerhead turtles, Witherington (1994) found that 63% of the turtle sampled (n=103) were found with tar upon stomach or mouth examination.

Oil and tar exposure in this project was recorded by the presence of the substances on the exterior of the turtles. Turtles lacking external cues of oil and tar were not accounted for in this project.

Sea Turtle Life History Traits

Flipper function

The front and rear flippers serve several key functions in a sea turtle's life. Beginning with the initial steps of hatching and exiting the egg chamber, turtles must use their flippers to dig out in a facilitative manner. In order to reduce mortality resulting from predation and/or heat consumption, hatchlings must crawl hastily from the egg chamber to the surf. Malformed flippers can impede this process which may lead to mortality. Turtles use their front flippers to propel themselves forward in the water and their rear flippers in a rudder-like fashion to steer. It is probable that the turtles use their flippers in several modes that are still unknown. However, it is known that the front and rear flippers are important for both males and females during reproductive periods. The second claw of the front and rear flippers are secondary sex characteristics within male sea turtles (Gulko and Eckert 2003; Kamezaki 2003). During copulation, male turtles will use these claws to grasp onto the female (Ernst et al. 1994). It is unknown if males lacking these claws and/or flippers have lower reproductive fitness than those males with claws. More research is needed is this area.

However, the nesting process of adult female turtles has been studied extensively. The females use their front and rear flippers to construct a body pit and their rear flippers to dig an egg chamber (Miller et al. 2003). Generally, turtles missing a rear flipper are unable to dig a proper egg chamber that can hold the clutch of eggs (Miller et al. 2003). Other flipper functions among sea turtles may include defense, cleaning and foraging tools. Loggerhead turtles have been observed to mine for their food by sweeping their front flippers across soft-bottom habitats to expose buried prey items (Preen 1996). Davenport and Clough (1985) suggested that young loggerhead hatchlings may use prominent scales (pseudoclaws) on their front flipper to gain access to food items such as vegetation and holeotherms (e.g., medusae). However, the presence of these scales may vary geographically as well as with age (Davenport and Clough 1985). This same study noted that the young turtles used their rear flippers in a brake-like fashion to stabilize themselves when utilizing their front flippers as foraging tools (Davenport and Clough 1985).

Body region susceptibility

Sea turtles spend the majority of their lives in the sea. At various life stages, turtles occupy different regions within the water column (e.g., upper, middle, and lower stratums). Utilizing such a myriad of zones increases the type and causes of injuries that the turtle may incur. As previously mentioned, one objective of this study is to gain insight into whether or not certain regions of the body are more susceptible to injuries. The significance of an injury can vary depending on its location on the body. Some regions of the body serve critical key functions. One way of obtaining this information is to record the location of where the injury was found (i.e., dorsal or ventral). This also suggesting the direction the injury source came from. However, when a region of the body is missing (e.g., a flipper or portion of the carapace) the direction from which the injury was sustained is unknown. Therefore such injuries were classified as dorsal/ventral. If certain regions of the body are more prone to injuries than others, this information may be of use to researchers developing research techniques (e.g., telemetry and flipper tags) and defining locations of the body where the life of the equipment would be optimized.

Methods

Statistical Analysis

Injury analysis: May through December 2000

A Loughin Scherer (LS) permutation chi-square test was used in the statistical program S-Plus version 7 to test for significant differences (associations) in the causes of injury found among species, size class, and sex class (Loughin and Scherer 1998). Injury causes were not counted more than one time per Turtle Id (thus avoiding pseudodoreplication of injury causes when evaluating recaptures during the study period).

Boat propeller and flipper amputation analysis: May 2000 through July 2004

A naïve Chi-square test was used in the statistical program SAS version 9.1 to test for significant differences (associations) in boat propeller and flipper amputations within species, life stage, and sex from May 2000-July 2004. Amputations or boat propeller strikes were not counted more than one time per Turtle Id (thus avoiding pseudodoreplication of injury causes when evaluating recaptures during the study period). Captures involving *D. coriacea*, *E. imbricata*, and *L. kempii* were removed from flipper amputation and boat propeller analyses due to too few captures compared with *C. caretta* and *C. mydas*.

Since sea turtles may be more susceptible to boat propeller strikes and incurring flipper amputations during different life stages, turtles captured between May 2000 and July 2004 were divided into three life stages (i.e., juvenile, transitional, and adult). It is assumed in this project that juvenile turtles would be individuals within smaller size classes in the neritic zone. Adult turtles are assumed to be those turtles that may be moving between neritic foraging habitats and neritic internesting habitats through oceanic corridors.

Turtles below 71 cm SSCL were classified as juveniles, >85 cm SSCL were classified as adults, and turtles 71-84 cm SSCL were classified as transitional turtles (Hirth 1980). The distinction between juvenile and transitional turtle's was based on the high numbers of turtles found within the 60-69 cm SSCL. This may be an indication of life history differences between the 60 and 70 cm SSCL size classes.

Although assessing a turtle's maturity by size is an imprecise method according to Limpus and Limpus (2003), grouping different size/age classes together may be a valuable method when testing for certain types and sources of injury threats within life stages. This is based on the idea that turtles found in the neritic and oceanic habitats may be subjected to different threat levels. In the Atlantic Ocean, juvenile loggerheads leave the oceanic zone around 46-64 cm curved carapace length (CCL) and recruit into the neritic zones (Bjorndal et al. 2000). Green turtles recruit into the neritic zone around 20-35 cm CCL (Bjorndal 1997).

Fortunately, some progress has been made with loggerhead life history patterns, however, several gaps remain within green turtles (Bolten 2003). Adult loggerhead and green turtles may undergo seasonal movements through oceanic migration corridors between neritic foraging habitats and neritic internesting habitats (Bolten 2003). Water depth differences in the neritic (< 200 m) and oceanic zones (>200 m) combined with a turtles location in the water column (i.e., pelagic, epipelagic, or benthic) may alter the threat sources within each life stage. For example, Murphy et al. (2003) noted that large immatures and adults are observed on the outer zones of continental shelves. In theory, these turtles would be at less risk of being struck by recreational boats than smaller size classes found in the shallower inner zones of the continental shelf. Witherington (2003) speculated that older neritic stage juveniles may migrate hundreds of kilometers among foraging areas.

Results

May through December 2000 Captures

A total of 511 turtles (including recaptures) were captured between May and December, 2000. A total of 448 individual turtles (*C. caretta*, *C. mydas*, and *E. imbricata*) comprised the 511 captures (Fig. 3-1). A total of 10.7% (n=48) of the 448 individual turtles captured were classified as recaptures (i.e., previously captured during the time period of May through December 2000) and 24.6% (n=126) of the 511 total captures were classified as recaptures during or prior to the study period of May through December 2000 (Fig. 3-2). The turtles ranged in size from 26.2-106.8 cm SSCL (Table 3-1 and Fig. 3-3). A total of 96.1% (n=491) had a body condition index of good, 2.9% (n=15) were in fair condition, 0.6% (n=3) were dead, and 0.4% (n=2) were in poor condition (Fig. 3-4). The three dead turtles consisted of 2 juvenile *C. mydas* and 1 juvenile *C. caretta*. The death of one *C. mydas* was attributed to plant operations. The turtle was found with its head and front left flipper entangled in the first barrier net. The remaining dead *C. mydas* was found moderately decomposed floating in the canal with its eyes and front left flipper missing. The juvenile *C. caretta* was emaciated (sunken plastron) with no apparent injuries with the exception of a small missing section from its lower jaw.

A total of 14.1% (n=72) of the 511 captures were classified as not injured. Of the 72 turtles classified as not injured, 75% (n=54) were classified as new recruits (35 *C.*

caretta, 18 *C. mydas* and 1 *E. imbricata*), whereas 25% (n=18) were classified as recaptures (during or prior to the year 2000) (9 *C. caretta* and 9 *C. mydas*). A total of 85.9% (n=439) of the 511 captures were classified as injured. Of the 439 turtles classified as injured, 75.4% (n=331) were classified as new recruits (191 *C. caretta*, 131 *C. mydas* and 1 *E. imbricata*), whereas 24.6% (n=108) were classified as recaptures (during or prior to the year 2000) (24 *C. caretta* and 84 *C. mydas*). Injuries were categorized into anthropogenic (i.e., tar, boat propeller strike, and fishing), non-anthropogenic (i.e., shark, social, and barnacle), and unknown. The total number of records for each cause of injury can be found in Fig. 3-5 and Table 3-2. Anthropogenic injuries accounted for injuries on 11 turtles (not including intake-pipe related injuries, which are discussed in chapter 4). A total of 288 turtles were found to have non-descriptive injuries that were classified as unknown. A total of 858 injury records were found on the 511 captures (Table 3-3). Of these, 53.5% (n=459) were dorsal injuries, 19.7% (n=169) were dorsal/ventral, and 26.8% (n=230) were ventral injuries.

The type of injury sustained by a turtle was not independent of species (p=0). However, it is unclear if the type of injury sustained is exclusively species dependent, or if it is a size effect and/or species effect. A limitation in testing for species effect is the considerable differences in the mean size classes captured for each of the species (i.e., loggerhead turtles (n=243, mean = 79.0 ± 13.1 SD) and green turtles (n=203, mean = 46.4 ± 19.7 SD).

Size class analyses indicate that type of injury sustained was not independent of size class. Size class dependency analyses within *C. mydas* included none, intake pipe, unknown and other (i.e., fishing, social, boat, and barnacle) (X^2=55.94, p=0.002). Size class dependency analyses within *C. caretta* included none, intake pipe, shark, unknown, and other (i.e., social, boat, and barnacle) (X^2=47.47, p=0.007). Limitations were placed on analyses when comparing species and size class relationships for each type of injury due to the low occurrences of turtles found with each injury type and within each size class.

Anthropogenic Injuries

Boat propeller strike

Nine turtles were found to have boat propeller strikes. Wound locations are discussed in a subsequent section discussing the results of boat propeller strikes from May 2000 through July 2004.

Tar

A juvenile *E. imbricata* was found to have tar on the anterior portion of its plastron (numerical region 7cd) and on the ventral side of all four of its flippers (numerical regions 3cd, 4cd, 5cd, and 6cd).

Fishing

One known fishing related injury was found on a juvenile *C. mydas* with a deeply embedded fishing hook in its front left flipper (numerical region 2d). Monofilament and sinker were attached to the hook at the time of hook removal. The turtle was observed for 1.5 hours before being released into the adjacent coastal waters.

Non-Anthropogenic Injuries

Shark

A total of 12 *C. caretta* were found with shark-related injuries compared with zero shark-related injuries in *C. mydas* (df=1, X^2=10.3, p=0.0013). Four of the turtles were adult females, and the remaining eight turtles were juveniles of unknown sex. Tooth impressions, crescent-shaped bite marks indicative of sharks, and/or rake marks were found on the flippers and/or carapace and/or plastron on 11 of the 12 turtles determined to have been injured by a shark. The remaining turtle that lacked any of the previously mentioned injuries was missing a large crescent-shaped portion of the carapace (numerical region 2a) that extended into the costal scutes.

Social interactions

Injuries resulting from social interactions among turtles were found only in adult *C. caretta* (n=5) and *C. mydas* (n=4). All turtles were classified in good body condition. Wound types consisted of circular bites found on the dorsal neck region of three *C. caretta* and one *C. mydas*, symmetrical abrasions found on the dorsal side of both rear flippers (regions 5abcd and 6cd) on one adult male *C. mydas*, and similar symmetrical abrasions found on the dorsal side of all four flippers (numerical regions 3b, 4b, 5bd, and 6bd) on one adult male *C. mydas*. One adult female *C. caretta* had symmetrical mating wounds on the ventral side of both front flippers (numerical regions 3d and 4d). Other injury types included two deep symmetrical creases expanding the entire plastron (numerical region 7abcd) on the adult male *C. mydas* discussed above with the symmetrical abrasions on all four flippers. Two of the individuals found with social related injuries were observed fighting in the canal the day of or prior to being captured. Both individuals were adult female *C. caretta*. One female sustained a cut above the left eye from fighting, while the other female sustained a cut on the head and a deep bite wound in the mouth region.

Barnacle

Two juvenile *C. caretta* and two juvenile *C. mydas* were found with superficial to deep depressions on the plastron or carapace (numerical regions 2cd and 7cd) resulting from barnacles of unknown species.

Summary of Injury Locations

A total of 858 injury location records were found on the 511 captures between May through December 2000 (Table 3-4). The carapace region (numerical region 2abcd) accounted for 41.1% (n=353) of all injury location records, whereas the cloaca/tail region (numerical region 8) had the lowest with zero injury records (Table 3-4).

Summary of Missing Regions of the Body

Approximately 6.7 % (n=30) of the 448 individual turtles had flipper amputations (Table 3-5). Of these, 53.3% (8 female: 8 unknown sex) were missing less than half of a flipper, 10.0% (1 female: 2 unknown sex) were missing half of a flipper, 16.7% (3 female: 2 unknown sex) were missing over half of a flipper, and 20% (1 male:1 female: 4 unknown sex) were missing an entire flipper (Table A-1) . Results of the locations of the year 2000 flipper amputations (i.e., half through entire flipper amputations) are discussed in a following section covering flipper amputations equal to or greater than half of one or more flippers May 2000 through July 2004.

Turtles were found with missing “shaped’ sections (crescent-shaped n=39, scalloped n=3, u-shaped marginal n=6, and v-shaped n=34) from their flippers and carapace, which were caused by an unknown injury source.

May 2000 through July 2004 Boat Propeller Strikes and Flipper Amputations

A total of 3,290 turtles (including recaptures) were captured during the 51-month period from May 2000 through July 2004. Of these, 80% (n=2,532) were classified as new captures, while 23% (n=758) were classified as recaptures (i.e., captured >1 at the SLNPP during or prior to the study period). A total of 2,632 individual turtles comprising five species contributed to the 3,290 captures (Table 3-6). Fig. 3-6 contains the size class distribution for each species. *D. coriacea*, *E. imbricata*, and *L. kempii* were removed from flipper amputation and boat propeller analyses due to the relatively small numbers captured compared with *C. caretta* and *C. mydas* (no amputations or boat propeller strikes were found in these individuals).

Flipper amputations (equal to or greater than half)

A total of 3.1% (n=81) of the 2,632 individual turtles were found to have equal to or greater than half of one or more of their flippers missing between May 2000 through July 2004. Body condition indices indicated that 74.1% (n=60) of the 81 turtles had a body condition index of good, 23.4% (n=19) were in fair condition, 1.2% (n=1) was dead, and 1.2% (n=1) was in poor condition. Six turtles with original body condition indexes of good were later recaptured at which time body condition indexes were classified as good. A total of 72.8% (n=59) of the flipper amputations were found in *C. caretta* (52.8-98.8 cm SSCL, mean = 78.3 ± 12.3 SD) of which 62.7% (n=37) were of unknown sex, 30.5% (n=18) were females, and 6.8% (n=4) were males. The remaining 27.2% (n=22) were *C. mydas* (25.9-87.2 cm SSCL, mean = 41.4 ± 15.9 SD), which consisted of 21 turtles of unknown sex, and 1 female. Two of the 81 turtles were missing equal to or greater than half of two of their flippers. One individual was an adult female missing over half (>75% of both rear flippers) (sections 5abcd and 6abcd). The second was a juvenile of unknown sex missing both rear flippers (entire). The injury cause of 88.9% (n=72) of the 81 turtles with amputations was unknown, however, the remaining 1.1% (n=9) were shark-related injuries. Seven of the turtles with shark-related amputations were *C. caretta* (3 juveniles and 4 transitional) and two were juvenile *C. mydas*.

Analysis indicate no significant difference (df=1, X^2=1.03, *p*=0.3107) between the frequency of amputations found between species (*C. caretta* 3.4% of 1761, *C. mydas* 2.6% of 842) (*p*=0.3107). However, a significant difference was found between the overall percentages of amputations found among life stages (df=2, X^2=24.32, *p*<0.0001). A total of 6.0% (n=21) of the 351 adults had amputations, 5.7% (n=21) of the 371 transitional turtles had amputations, and only 2.07% (n=39) of the 1881 juveniles were found with amputations (Table 3-7). Further analysis indicate a significant difference in the frequency of amputations found within the three sex categories (male, female and unknown) (df=2, X^2=12.17, *p*=0.002). A total of 6.1% (n=19) of the 312 females had flipper amputations, 7.7% (n=4) of males had amputations, and 2.6% (n=58) out of 2239 of unknown sex category had amputations (Table 3-7).

Within-species analyses

A significant difference was found between the percentages of amputations found among life stages of *C. caretta* (df=2, X^2=27.4, *p*<0.0001). A total of 6.3% (n=20) of 316 adults, 6.21% (n=21) of 338 transitional, and only 1.63% (n=18) of the 1107 juveniles were found with flipper amputations. However, insufficient sample sizes restricted the ability to confidently compare life stages within *C. mydas* (i.e., 2.7% (n=21) of 744 juvenile *C. mydas* captured with amputations to the 2.86% (n=1) of 35 adults captured with amputations, and 0% (n=0) of the 33 transitional individuals). A significant difference was found among the percentages of amputations in males, females and those of unknown sex within *C. caretta* (df=2, X^2=16.8, *p*=0.0002). A total of 6.2% (n=18) of 292 females were found with amputations within *C. caretta*, 11.4% (n=4) of 35 males, 2.6% (n=37) of 1434 of unknown sex. Again, insufficient sample sizes restricted the ability to confidently compare differences in amputations among sex categories within *C. mydas* [i.e., 2.6% (n=21 of 805 juveniles captured to 5.0% (n=1) of 20 females, and 0% (n=0) out of 17 males].

Location analyses

The majority of amputations were found in *C. caretta* 72.3% (n=60) compared with the 27.7% (n=23) found in *C. mydas*. Overall flipper amputation location analyses (combined species data) indicate no significant statistical differences in the following: 1) anterior versus posterior (front versus rear flippers), 2) anatomical location, or 3) side (left versus right). However, within species analyses indicate a significant difference in the number of amputations found in the front right, front left, rear left, and rear right flipper (numerical region 3, 4, 5, and 6) (X^2 = 11.6, $0.01<p<0.001$) within *C. mydas*. (the rear left and rear right flippers each accounted for ~40% of the amputations within the species). A total of 35% (n=21) of the amputations within *C. caretta* occurred in the front right flipper, however, this was not different statistically from the number of amputations found in the front left (df=1, X^2=1.4, $0.5>p>0.1$). Furthermore, anterior versus posterior (front versus rear flippers) analysis indicate a significant difference within *C. mydas* with 22.7% (n=5) of the 22 amputations located in the front and 77.3% (n=17) in the rear flippers (df=1, X^2=7.4, $0.01> p>0.005$). No significant difference was found in *C. caretta* with 58.3% (n=35) of the 60 amputations found in the front and 41.7% (n=25) located in the rear flippers (df=1, X^2=1.7, $0.5>p>0.1$).

Boat propeller strikes

A total of 1.9% (n=49) individual turtles were found with boat propeller strike injuries between May 2000 through July 2004. Body condition indices indicated that

55.1% (n=27) had a body condition index of good, 36.7% (n=18) were in fair condition, and 8.2% (n=4) were in poor condition. A significant difference was found in the number of boat strikes between species (X^2=7.4, p=0.0064). Eighty-six percent (n=42) of the propeller strikes were found in *C. caretta* (60.0-104.3 cm SSCL, mean = 79.0 ± 12.74 SD) of which 54.8% (n=23) were of unknown sex, 35.7% (n=15) were females, and 9.5% (n=4) were males (Table 3-8). The remaining 14.3% (n=7) were *C. mydas* (28.1-69.1 cm SSCL, mean = 43.4 ± 16.6 SD), which consisted of all juvenile turtles of unknown sex.

A significant difference was found between the overall percentages of boat propeller strikes among life stages (df =2, X^2=25.7, p<0.0001). A total of 4.6% (n=16) of the 351 adults, 3.5% (n=13) of the 371 transitional, and only 1.06% (n=20) of the 1881 juveniles were found with boat propeller strikes. Further analysis indicate a significant difference in the frequency of amputations found within the three sex categories (i.e., male, female and unknown) (df=2, X^2=27.5, p<0.0001). Of the 312 females, 4.8% (n=15) had boat propeller strikes, 7.7% (n=4) of the 52 males, and 1.3% (n=30) of the 2239 of unknown sex had boat propeller strikes.

Within-species analyses

A significant difference was found between the percentages of boat propeller strikes among life stages of *C. caretta* (df=2, X^2 =19.8, p<0.0001). Within *C. caretta*, 5.1% (n=16) of 316 adults, 3.8% (n=13) of 338 transitional, and only 1.2% (n=13) of the 1107 juveniles were found with boat propeller strikes. However, insufficient sample sizes restricted the ability to confidently compare life stages within *C. mydas* [i.e., 0.9% (n=7) of 744 juvenile *C. mydas* captured with propeller strikes compared to 0% (n=0) of the 35 adults and 33 transitional individuals]. A significant difference was found between the percentages of boat propeller strikes among sex classes of *C. caretta* (df=2, X^2=25.6, p<0.

.0001). A total of 5.1% (n=15) of 292 females, 11.4% (n=4) of 35 males, and 1.6% (n=23) of 1434 of unknown sex were found with boat propeller strikes. Again, insufficient sample sizes restricted the ability to confidently compare differences in boat propeller strikes within sex of *C. mydas* [i.e., 0.9% (n=7) of 805 juveniles captured to 0% (n=0) out of 20 females and 17 males].

Location analyses

A total of 57 boat slice records were compiled from the 49 turtles with boat propeller strikes. Of the 57 slice records, 83% (n=48) were found on the carapace, 10.3% (n=6) on the head, 3.4% (n=2) on the plastron, 1.7% (n=1) on the neck, and 1.7% (n=1) on the rear left flipper. Injury condition consisted of the following: 46.5% (n=27) healed, 32.3% (n=19) partially healed, 5.2% (n=3) fresh, and 15.5% (n=9) were unknown. Subregional analysis indicates a significant difference between the location of propeller strikes on the anterior and posterior regions of the carapace (subregion 2cd and 2ab, respectively) (Table 3-9). A total of 48.8% (n=20) *C. caretta* were found with propeller strikes within the anterior region of the carapace (subregion 2cd) compared to 100% (n=7) of the *C. mydas* (df=1, X^2=6.4, *p*=0.0116). Further analyses within *C. caretta* indicated no significant differences among life stages and the location of injury. A total of 85.37% (n=35) *C. caretta* were found with propeller strikes within the posterior region of the carapace (subregion 2ab) compared to 42.9% (n=3) of the *C. mydas* (df=1, X^2=6.5, *p*=0.0105). The sample size for *C. mydas* was too small to analyze statistical differences among life stages for both the posterior and anterior regions of the carapace. Closer examination of frequency of propeller strikes within subregions of the carapace (i.e., A, B, C, or D) indicate that *C. caretta* are injured significantly more within subregion A than

C. mydas, 70.7% (n=29) of 41 *C. caretta* compared with 28.6% (n=2) of 7 *C. mydas* (df=1, X^2=4.6, *p*=0.0311).

Conclusion

The injury assessment data presented in this project is based on turtles entrained within the SLNPP intake pipes. Therefore, observed injuries are recorded from turtles that have survived injuries or have not been previously injured. This project provides information for five species of live sea turtles utilizing the nearshore waters of the Atlantic Ocean.

In general, it is was difficult to ascertain species, size class, or sex association within injury types and causes due to significant differences in the predominant size classes for each of the species. The turtles captured at the SLNPP were predominantly small juvenile green turtles, and large juvenile and adult loggerhead turtles (Fig. 3-2 and Table 3-1). The majority of loggerhead turtles captured at the SLNPP were within the upper size classes (>60 cm SSCL), whereas the majority of the green turtles were within the smaller size classes <60 cm SSCL) (Fig.3-2). The overall body condition of the turtles was good (96.1%, n=491, Fig. 3-4).

Details for each injury cause (i.e., barnacle, tar, fishing, social, boat propeller strike, and shark) recorded during May through December, 2000 can be found in Table B-1 (i.e., anatomical and numerical location, view, type, depth, and recency of the injury). Injury types that were not found in this project or were found in low frequencies, could be interpreted to mean that the intensity of the injury source is zero, or the injury source leads to 100% mortality (Schoener 1979). However, without knowing both the injury and survival frequencies, the ecological and biological pressure placed on a species by an injury source is unknown (Schoener 1979). Injuries related to tar, fishing, and barnacles were all found in low frequencies (Table 3-2). Unfortunately, it is not known if the data accurately represents the pressure of each source (i.e., tar, fishing, and barnacles) on the sea turtles utilizing the nearshore waters of the SLNPP, or if there are other explanations for such findings. For example, fishing related injury sources may be placing medium to high impacts on sea turtles, however, such injuries (e.g., punctures, deep cuts, and strangulation wounds) may not be possible to identify if the injury source (e.g., fishing line or hooks) are no longer present. Future injury data should be compiled and analyzed at the SLNPP and elsewhere, in order to understand the injury impacts such sources may be having on sea turtle populations.

Shark-related injuries were found only within loggerhead turtles >67 cm SSCL (n=12), which supports previous findings by Heithaus et al. (2002), which concluded that loggerheads are found with higher rates of shark-inflicted injuries than green turtles (*p*=0.0013). Alternatively, the data from this study could suggest that loggerheads are able to survive shark-related attacks whereas green turtles do not survive shark attacks. Heithaus et al. (2002) concluded that male loggerhead turtles may incur higher rates of shark-inflicted injuries than female loggerhead turtles, male green turtles, and female green turtles due to their possible engagement in higher risk activities. This study was unable to support or refute such findings due to insufficient sample sizes of ‘known’ sex-class (i.e., only 4 females and 8 individuals of known sex ere found with shark-related injuries). However, some biological importance may exist in that no male turtles (loggerhead or green turtles) were among the 12 turtles determined to have shark-related injuries.

Furthermore, it was difficult to assess size class associations due to the significant differences in the mean size class of captured loggerhead (*n*= 243, mean = 79.0 ± 13.1 SD) and green turtles (n=203, mean = 46.3 ± 19.6 SD) (Table 3-1). No turtles smaller than 67 cm SSCL were captured with shark-related injuries, which may indicate that turtles in smaller size classes are unable to survive shark-inflicted injuries and/or they are small enough to be consumed whole by a shark as stated by Heithaus et al. (2002). The latter scenario leaves zero probability of survival.

One significant difference that may influence the injury data presented in this study and that by Heithaus et al. (2002) is the differences in capture methodologies. In this study, turtles are entrained into the intake pipes within the nearshore system (see Chapter 2 for details), whereas Heithaus et al. used the 'rodeo' technique. This method involves spotting turtles in the water from a boat, and a person jumping off the bow of the boat to capture the turtle.

Injuries relating to social interaction were found in five adult loggerhead turtles and 4 adult green turtles. One very interesting injury type was the symmetrical creases found on the plastron of an adult male green turtle (no such wounds were found in male loggerhead turtles in this study). To the author's knowledge, no such injury has been previously reported in the literature. The creases may be the result of the plastron bending to fit closely against the female's carapace, which may ease his ability to properly clasp onto the marginals with the claws located on his front and rear flippers (Ernst et al. 1994), which may lengthen the duration of copulation by increasing the hydrodynamics of the mating pair. In other words, if the male is secured tightly to the female, there is less chance of them becoming separated during the copulatory process. Symmetrical wounds found on the dorsal side of the front and rear flippers of two male green turtles were also of interest. It is unknown if these wounds result from the pre-copulatory process between the male and female, or if the wounds are the result of aggressive biting from other males before or during the copulatory process between the male and female mating pair.

The percentage of turtles (3.1%) sustaining flipper amputations compared to the total number of individual turtles captured (n=2,632) at the SLNPP was relatively low. This may indicate that turtles that sustain flipper amputations have lower survival probabilities. A turtle missing a flipper may be less likely to escape predation, forage properly, as well as successfully complete reproductive processes. The turtles that were captured at the plant with flipper amputations consist mostly of transitional and adult turtles. This follows the logic that as a function of time, a higher number of non-lethal, permanent injuries would be found in the larger size/age classes.

In this study, no statistically significant differences were found in the number of amputations recorded for each of the species (loggerhead and green turtles). Within loggerhead turtles, a higher proportion of amputations were found in the front flippers (58.3%) than in the rear flippers (41.7%) (Fig. 3-7). This was statistically non-significant, however, there may be some biological significance in this finding. It may be suggested that in projects only applying a single tag to a turtle that the tag not be placed in the front right flipper based on the higher rates amputation rates associated with this limb in loggerhead turtles. Furthermore, the injury data from the time period of May through December 2000 indicate that the neck region may be a more advantageous region of the body for PIT tag placement compared with the front right flipper. A total of 18 injury records (2.1%) were found in the neck region compared with 41 injury records (4.8%) in the front right flipper (Table 3-4). Placement of PIT tags in the neck region may increase tag retention rates and the ability to identify individual turtles in subsequent captures, which could be especially important in research programs where placement of a single PIT tag (and no external tags) is standard.

Conversely, the rear flippers in green turtles (77.7%) accounted significantly for the majority of the amputations found within the species (Fig. 3-8). Such differences in the location of the amputation between species incite several questions. Are the differences a result of behavioral factors between loggerhead and green turtles such as a ‘fight’ or ‘flight’ response? Perhaps green turtles have evolved a flight response (e.g., quick speed and maneuverability) to predators. For example, if a predatory shark approached a green turtle, the turtle would swim rapidly away from the predator, and thus leaving the posterior end of the body (e.g., the rear flippers) exposed to injury. If loggerhead turtles have evolved a more fight behavior response, this may be one explanation for the higher amputation rates in the anterior body region of the species. Loggerheads, unlike green turtles, are not known for speed and agility. Instead, these turtles are better known for their large head size compared with the rest of their bodies, powerful crushing jaws and reduced speed compared with other turtle species. Loggerhead turtles may have a higher likelihood of survival if they fend-off predators by using their powerful jaws to inflict injury upon their predator. Both species have been observed to avoid being grasped by predators by maneuvering their carapace or plastron within a vertical plane towards predators (Marquez 1990; Heithaus et al. 2002).

Abiotic threats such as fishing line may impact one species compared to another based on their flipper functions. Loggerhead turtles have been reported to use their front flippers when ‘mining’ for food (Preen 1996). No such behavior has been noted in green turtles. This behavior may subject them to increased threats (e.g., fishing line, hooks, and contaminants) that have settled into the benthic zone over time. Clearly, more data should be collected in order to answer such questions.

It is evident that sea turtles may lose one or more of their flippers in their lifetime. The question that remains is how the partial to complete loss of a flipper is impacting their ability to function (e.g., propelling and steering through the water, foraging, predator avoidance, and reproductive fitness). For example, are males that are missing flippers less fit than males with no flipper loss when competing for females on the mating grounds (i.e., reduced fitness)? Is a male with a front or rear flipper amputation able to properly grasp onto a female during copulation, especially if there are several males attacking him (e.g., biting at his flippers) during the process? The long-term reproductive effects of flipper loss in adult females are better understood. Females that are missing the scooper portion of their rear flippers are unable to dig a proper egg chamber (Miller et al. 2003), which reduces her reproductive ability. Unfortunately, unlike other injuries that may subside with time, the loss of a flipper is a permanent injury that affects the sea turtle for the remainder of its life. Understanding how many turtles are undergoing the plight of flipper loss, as well as identifying the causes of such injuries may help reduce the number of turtles that sustain such injuries in the future.

The boat propeller injury data from this project prompts several questions. The data suggests that loggerhead turtles are hit more frequently by boat propellers than green turtles. The results could also be interpreted that greens are hit more frequently than loggerheads, but do not survive the strikes. Further leading to questions related to the locations of the boat propeller strikes on the body. The data suggests a trend that loggerheads are hit more frequently in the posterior ends of their carapace compared to greens in the anterior ends (specifically subregion 2a, refer to Fig. 2-3). It could be suggested that injuries located in one end versus the other could be linked to higher or lower survival rates associated with certain regions of the body. However, if rate of survival is not responsible for the differences in the frequency of strikes found between the posterior and anterior end, it could attributed to behavioral differences between the two species (just as it could be for the differences in the frequency of flipper amputations and other injury sources and types).

As previously stated, green turtles are generally referred to as being faster than loggerhead turtle (i.e., greater escape ability). If a loggerhead turtle and a green turtle were positioned at the waters surface equal distance from an oncoming boat, it is reasonable to suggest that the green turtle would respond faster than the loggerhead turtle. This is assuming that each turtle would respond the same way such as diving vertically down into the water. Due to the lack direct observations between boats and sea turtles, the detection time and behavior response(s) of turtles is largely unknown. One or both species may initially move parallel to the surface for a period of time before diving, which may be one explanation as to why green turtles may be hit more frequently in the anterior portions of their body (e.g., time at the waters surface attempting to ‘out swim’ the boat). Further, loggerhead turtles may have a longer response time (i.e., decreased escape ability) compared to green turtles, and thus may be why they are hit more frequently in the posterior end of the carapace.

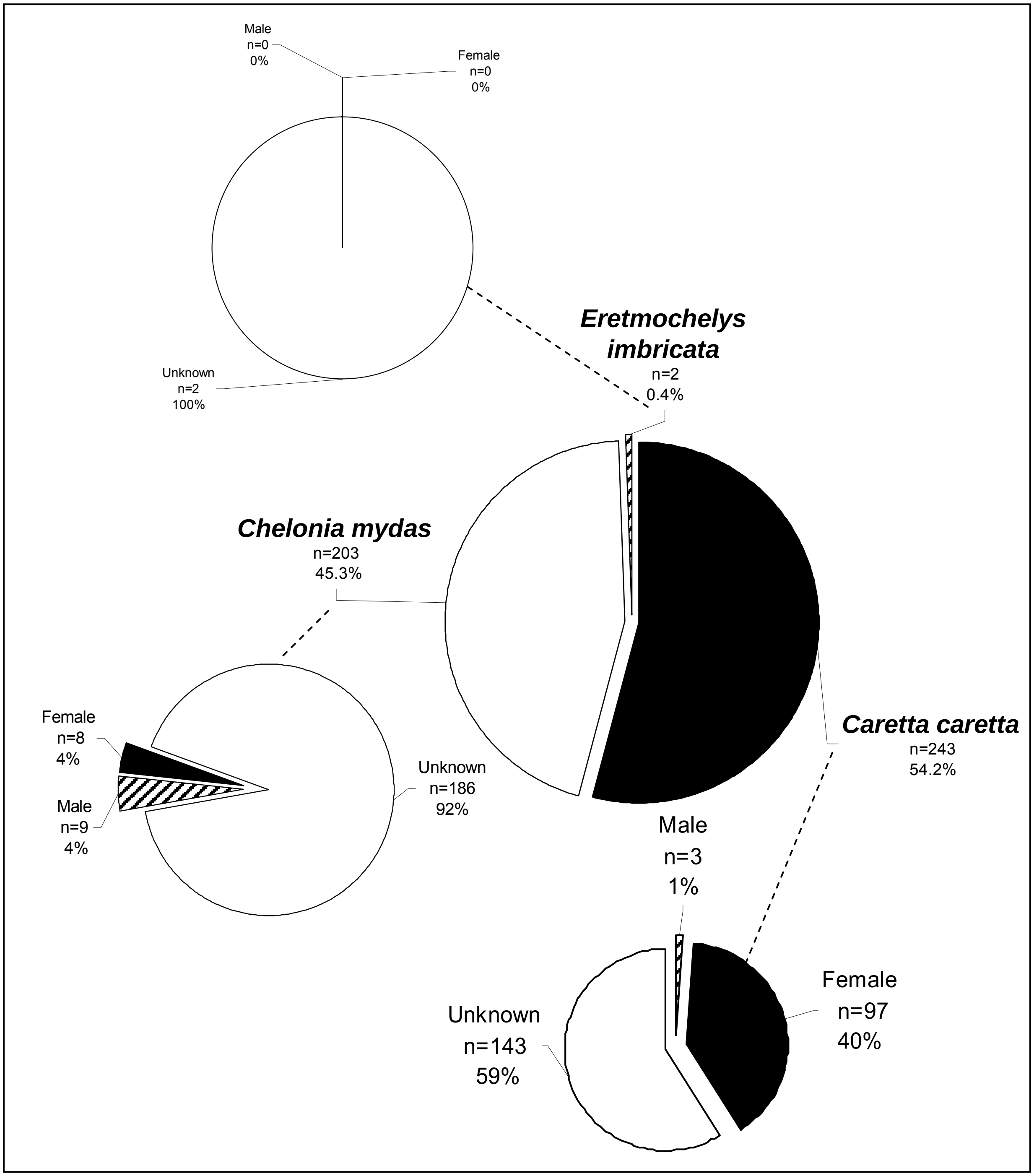


Figure 3-1. Species (*Caretta caretta*, *Chelonia mydas*, and *Eretmochelys imbricata*) and sex composition (male, female and unknown sex category) of the individual turtles (n=448) captured May through December 2000 at the SLNPP.

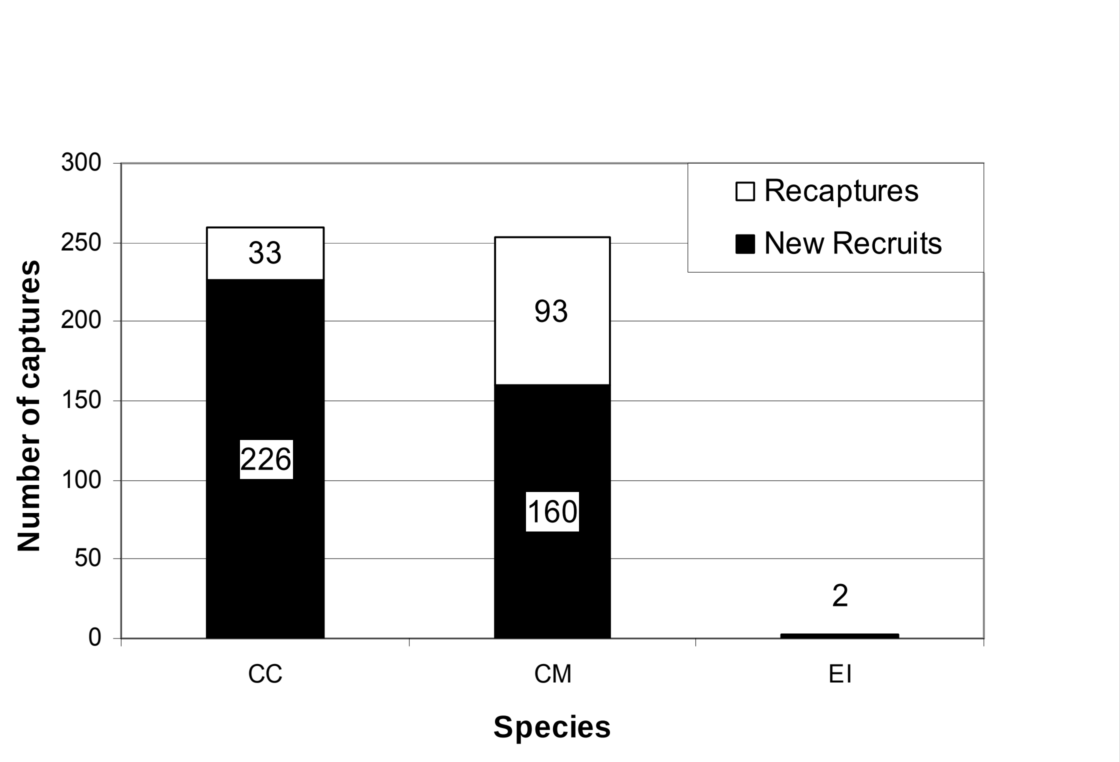


Figure 3-2. Total number of recaptures and new recruits for *Caretta caretta* (CC*)*, *Chelonia mydas* (CM), and *Eretmochelys imbricata* (EI) May through December 2000.

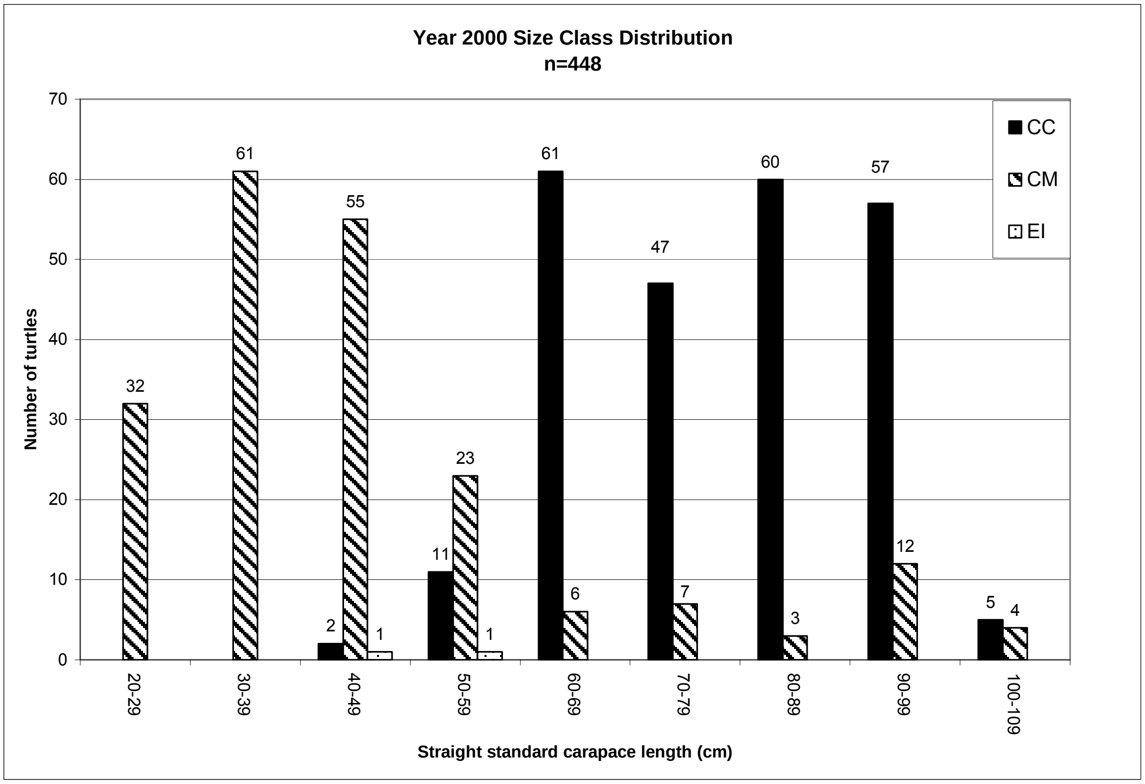


Figure 3-3. Size class distribution of *Caretta caretta* (n=243), *Chelonia mydas* (n=203) and *Eretmochelys imbricata* (n=2) captured May through December 2000 at the SLNPP.

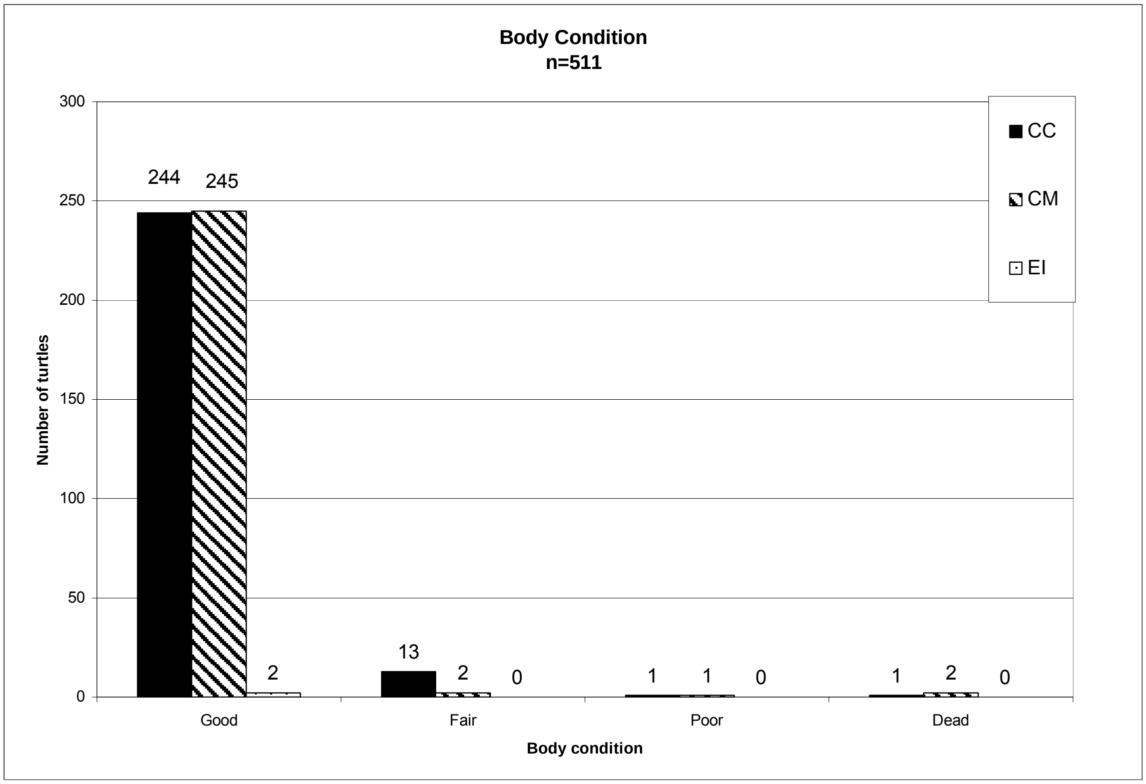


Figure 3-4. Proportion of turtles (n=511, captures and recaptures) found within each body condition (good, fair, poor, and dead) captured May through December 2000 at the SLNPP.

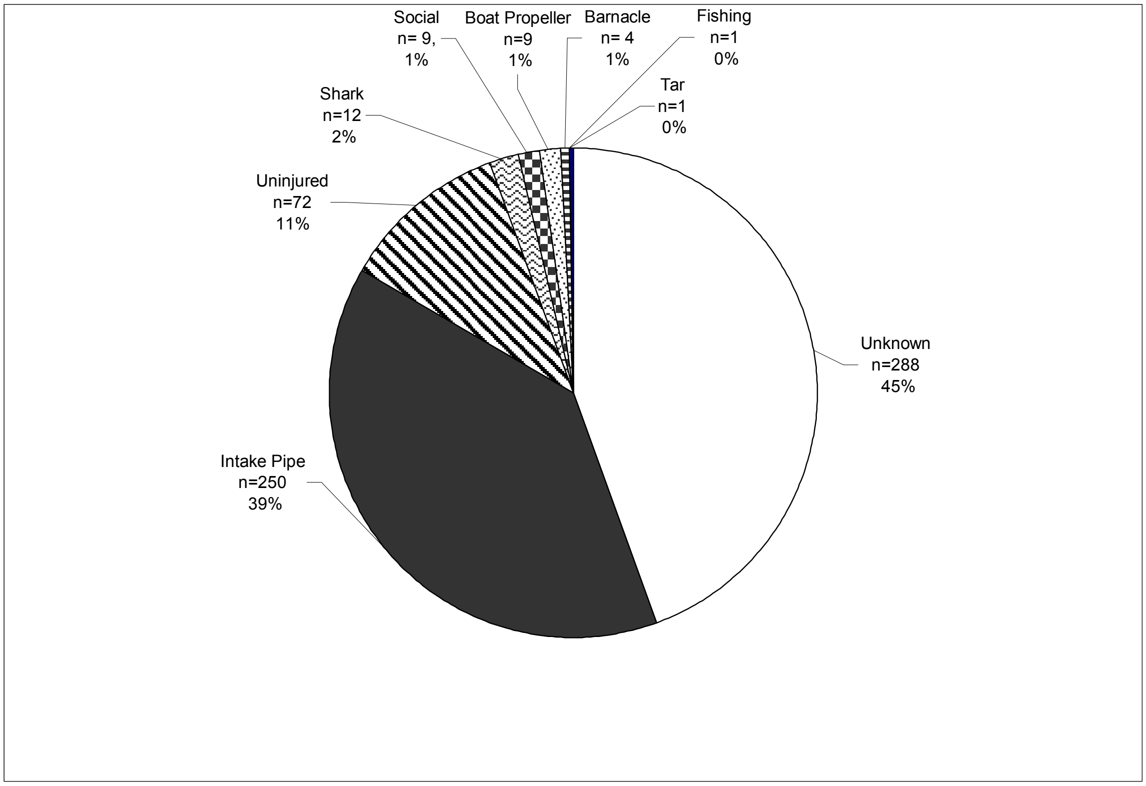


Figure 3-5. Proportion of injury causes found on the 511 turtles captured May through December 2000. Individuals may have multiple injury causes.

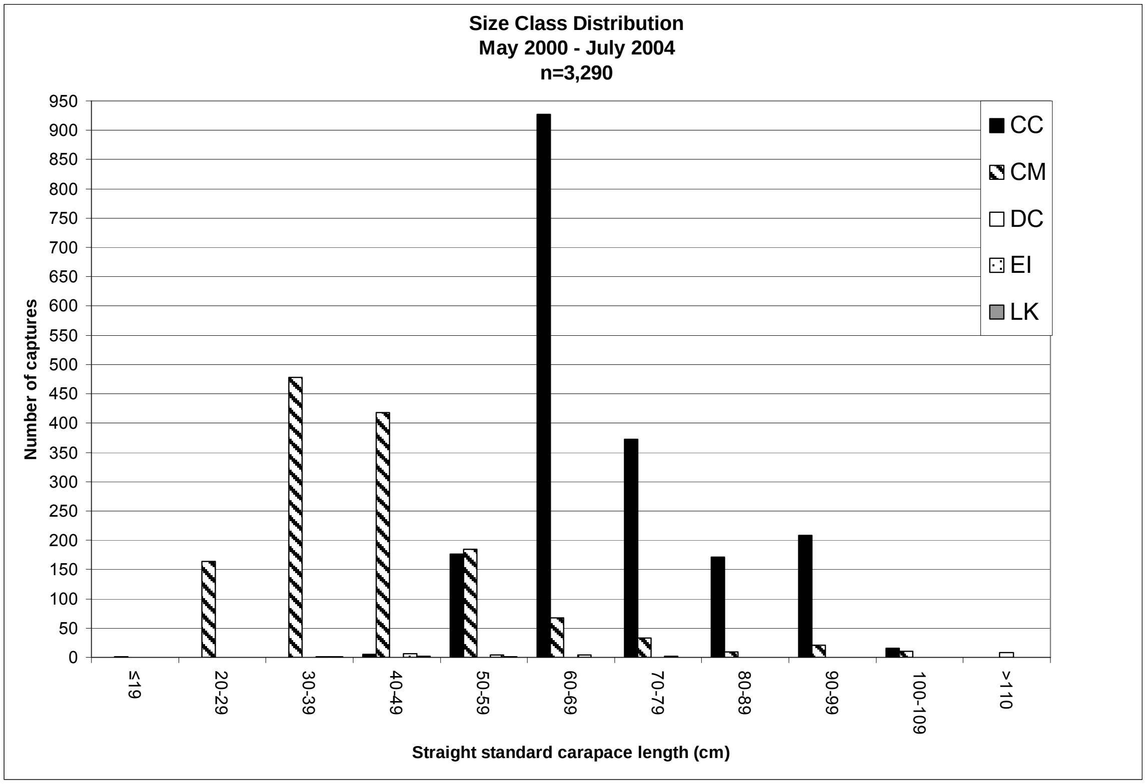


Figure 3-6. Size class distribution of *Caretta caretta* (n=1875), *Chelonia mydas* (n=1386), *Dermochelys coriacea* (n=8), *Eretmochelys imbricata* (n=17), and *Lepidochelys kempii* (n=4) captured May 2000 through July 2004 at the SLNPP (includes recaptures).

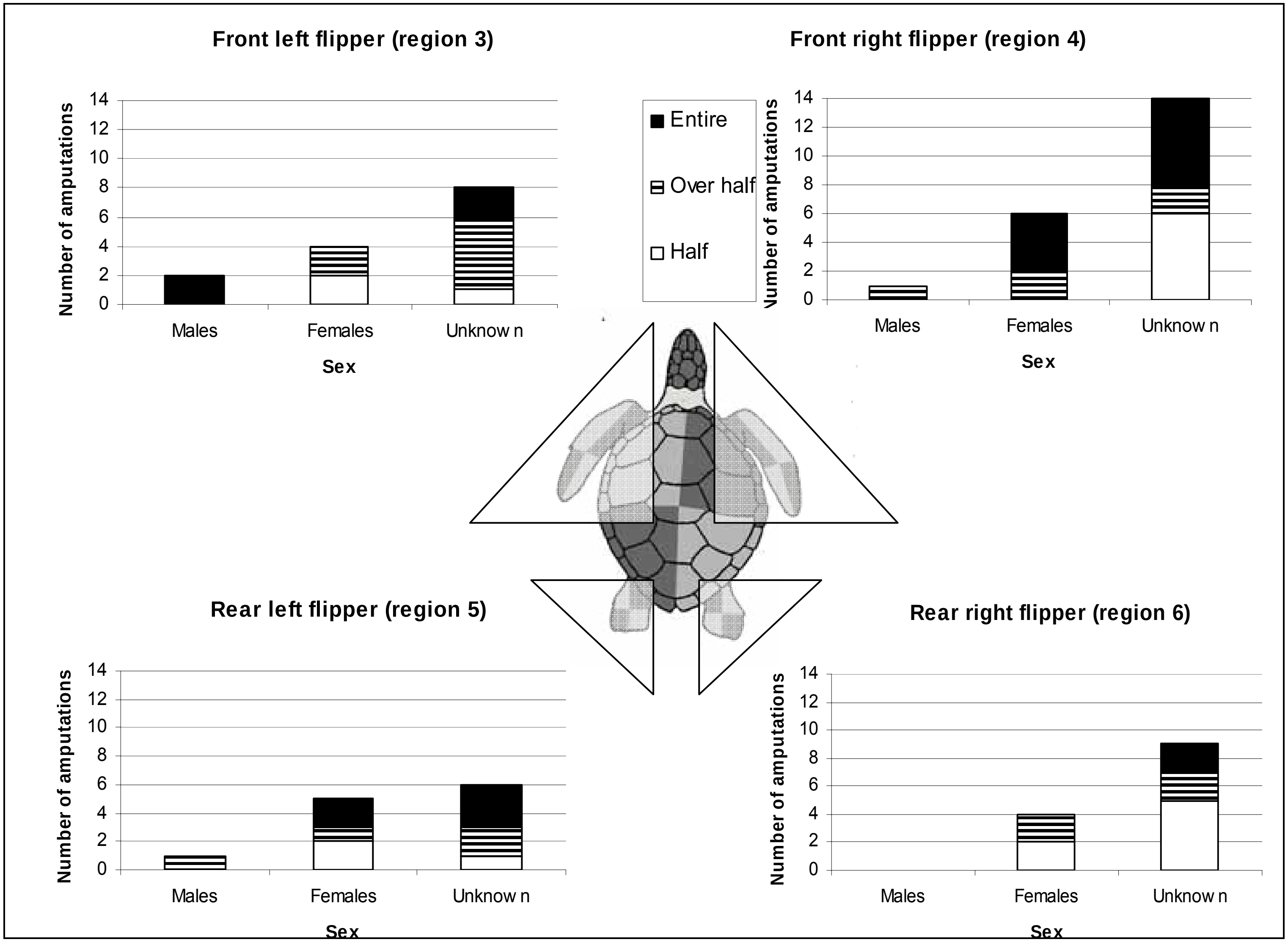


Figure 3-7. Frequency of flipper amputations divided by numerical regions (3, 4, 5, and 6) within *Caretta caretta* (males, females and unknown sex categories).

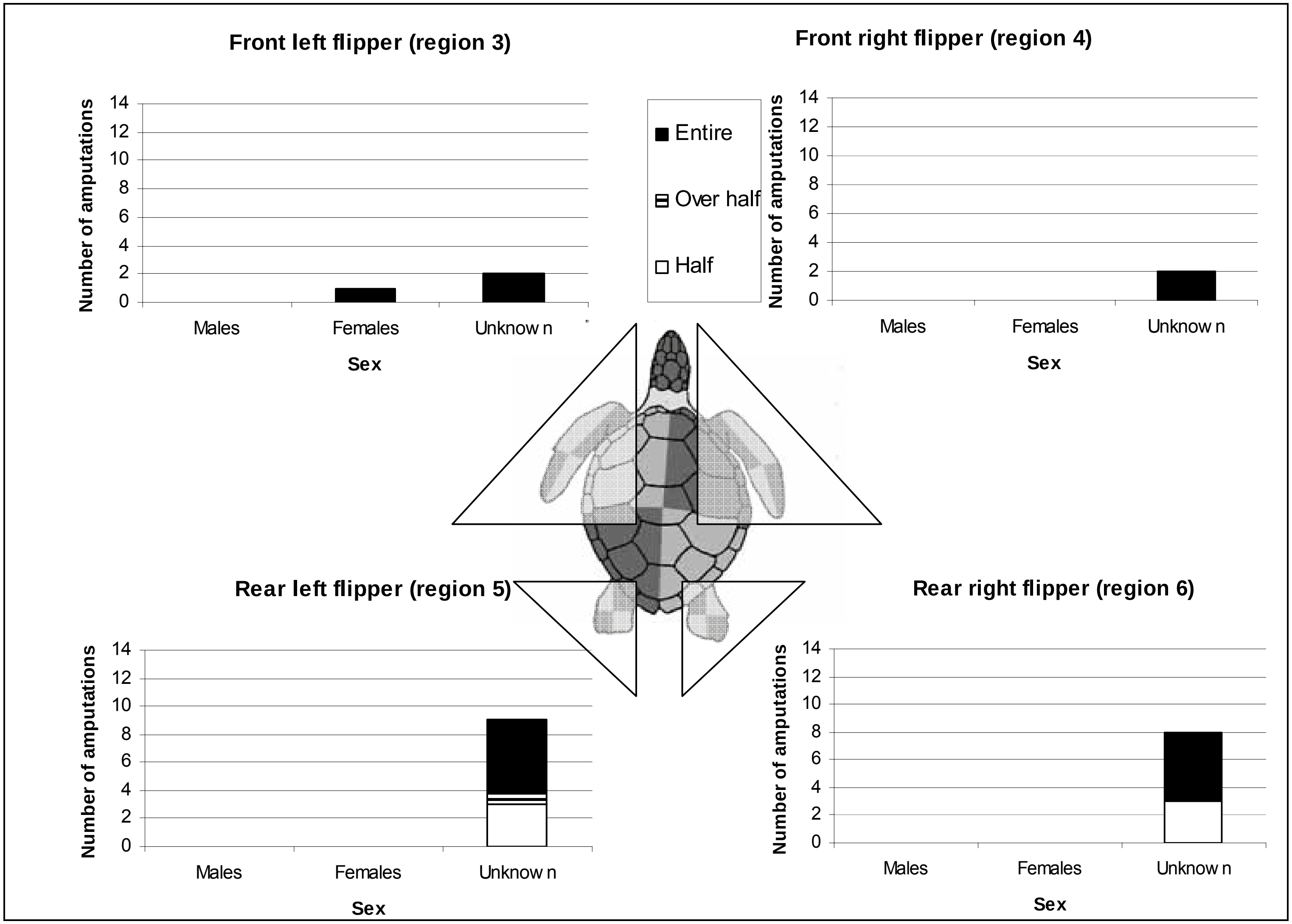


Figure 3-8. Frequency of flipper amputations divided by numerical regions (3, 4, 5, and 6) within *Chelonia mydas* (males, females and unknown sex categories).

Table 3-1. Species, size range, mean ± standard deviation of the 448 individual turtles captured May through December 2000 at the SLNPP.

Species	Size range Straight standard carapace length (cm)	$\bar{x} \pm SD$
Caretta caretta (*n*=243)	47.4-103.1	79.0 ± 13.1
Chelonia mydas (*n*=203)	26.2-106.8	46.3 ± 19.6
Lepidochelys kempii (*n*=2)	48.0-50.6	49.3 ± 1.8

Table 3-2. Overview of all injury causes found within each species May through December 2000.

Injury Cause	*Caretta caretta*	*Chelonia mydas*	*Eretmochelys imbricata*	*Total*
Tar	0	0	1	1
Boat Propeller Strike	7	2	0	9
Fishing	0	1	0	1
Shark	12	0	0	12
Social	5	4	0	9
Barnacle	2	2	0	4
Unknown	116	172	0	288

Table 3-3. Injury type records (n=858) found on the 511 turtles captured May through December 2000.

Injury Type	Number of Injury Type Records	Percentage of Records
Abrasion	6	0.7%
Amputation	31	3.6%
Bite	29	3.4%
Broken	1	0.1%
Crack	3	0.3%
Crease	1	0.1%
Cut	19	2.2%
Depression	19	2.2%
Discoloration	17	2.0%
Hole	2	0.2%
Missing	40	4.7%
Missing (crescent-shaped)	41	4.8%
Missing (marginal)	7	0.8%
Missing (scalloped)	3	0.3%
Missing (u-shaped notch marginal)	6	0.7%
Missing (v-shaped)	34	4.0%
Other	30	3.5%
Puncture	2	0.2%
Raised	2	0.2%
Rake marks	1	0.1%
Scrape	555	64.7%
Slice	9	1.0%
Total	858	100.0%

Table 3-4. Injury location records (anatomical region) with and without intake pipe related injuries found on the 511 turtles captured May through December 2000.

Injury Location	Number of Injury Location Records (with intake pipe related injuries)	Percentage of Records	Number of Injury Location Records (without intake pipe related injuries)	Percentage of Records
Head	112	13.1%	16	3.2%
Carapace	353	41.1%	154	30.7%
Front Left Flipper	48	5.6%	43	8.6%
Front Right Flipper	41	4.8%	40	8.0%
Rear Left Flipper	43	5.0%	43	8.6%
Rear Right Flipper	40	4.6%	37	7.4%
Plastron	190	22.1%	144	28.7%
Cloaca/Tail	0	0.0%	0	0.0%
Left Eye	5	0.6%	2	0.4%
Right Eye	3	0.3%	2	0.4%
Mouth (Jaws/Esophagus)	5	0.6%	5	1.0%
Neck	18	2.1%	15	3.0%
Total	858	100.0%	501	100.0%

Table 3-5. Flipper amputation results May through December 2000 (less than half, half, over half, and entire) within species (*Caretta caretta*, *Chelonia mydas*, and *Eretmochelys imbricata*) and sex class (male, female and unknown sex).

Species	Degree of Flipper Loss #of Males - # of Females - #of Unknown Sex/Total				
	Less than half	Half	Over half	Entire	Total
Caretta caretta	0-8-2 10	0-1-1 2	0-3-2 5	1-1-1 3	1-13-6 20
Chelonia mydas	0-0-7 7	0-0-1 1	0-0-0 0	0-0-3 3	0-0-11 11
Eretmochelys imbricata	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0
Total	0-8-9 17	0-1-2 3	0-3-2 5	1-1-4 6	1-13-17 31

Table 3-6. Species, size range, mean ± standard deviation of 3,290 turtles captured at the SLNPP from May 2000 through July 2004.

Species	Size range Straight standard carapace length (cm)	$\bar{X} \pm SD$
Caretta caretta (*n*=1,875)	47.4-104.3	71.0 ± 11.4
Chelonia mydas (*n*=1,386)	18.7-108.3	43.0 ± 14.3
Dermochelys coriacea (*n*=8)	122.9-152.7	136.4 ± 11.3
Eretmochelys imbricata (*n*=17)	35.9-78.3	54.5 ± 11.4
Lepidochelys kempii (*n*=4)	38.2-61.4	51.4 ± 9.7

Table 3-7. Percentage of turtles found with amputations within each life stage (adult, transitional, and juvenile) and sex category (male, female, and unknown).

Life Stage	Amputation	Sex Category	Amputation
Adult (n=351)	6%	Male (n=52)	7.7%
Transitional (n=371)	5.7%	Female (n=312)	6.1%
Juvenile (n=1881)	2.1%	Unknown (n=2239)	2.6%

Table 3-8. Percentage of turtles found with boat propeller strikes within each sex category (male, female and unknown).

Species	Sex Category		
	Male	Female	Unknown
Caretta caretta (n=42)	9.5%	35.7%	54.8%
Chelonia mydas (n=7)	0%	0%	100%

Table 3-9. Percentage of turtles of each species found with boat propeller strikes within the anterior and posterior subregion of the carapace.

Species	Anterior subregion 2cd	Posterior subregion 2ab
Caretta caretta (n=42)	48.8%	85.4%
Chelonia mydas (n=7)	100%	42.9%

CHAPTER 4
INTAKE PIPE RELATED INJURIES

Background

Since opening in 1976, the SLNPP has significantly reduced potential impacts on the turtles inadvertently entrained into the facility by maintaining a vigilant sea turtle monitoring program (Quantum Resources 2005). However, observations over the past several years have shown that turtles are sustaining fresh scrapes and cuts while traveling through the intake structures at the plant (Quantum Resources 2005). In addition, there is rising concern that the frequency and location of the fresh injuries may be negatively impacting the turtles. Such impacts, whether they are short or long-term, are not well-understood. Unfortunately, in 2003 a turtle died from injuries sustained while traveling through the pipes, an example that suggests a growing problem (Quantum Resources 2004).

The fresh scrapes found on the turtles were assumed to occur as a consequence of encountering biofouling (e.g., epibionts such as barnacles) within the intake pipes, which have not been cleaned since the early 1980’s (M. Bresette, Quantum Resources, pers. comm. 2005). The accumulation of such objects (abiotic and biotic) increases water velocity as well as providing additional substrate for epibionts to colonize, thereby increasing the number of objects the turtles may encounter while traveling through the pipes. One assumption in this study is that turtles traveling at a rate of 4-7 ft/second are unable to actively avoid obstacles within the intake pipes, which may lead to the minor /severe physical trauma referred to as fresh scrapes. In general, fresh scrapes are open wounds that may allow pathogens to enter the body that could lead to infections. At the SLNPP, turtles that are captured and sick or injured are treated, and when necessary are held for observation before being released (Quantum Resources 2005). Turtles requiring further medical evaluation/treatment are sent to an approved rehabilitation facility after contact with the Florida Fish and Wildlife Conservation Commission (FFWCC) (Quantum Resources 2005).

Methods

Study Period and Objectives

Fresh scrapes were evaluated at the SLNPP for a total of 18 months [3-month time periods (May through July) spanning across six years (2000 through 2005)]. The time period of May through July was selected because it provided the longest continuous block of time within each of the years without the data being compromised by natural and/or anthropogenic factors. Two primary factors that narrowed the time-frame in this study were 1) The disturbance of normal plant operation during late summer/fall of 2004 resulting from the hurricanes that impacted the southeastern United States, and 2) Modifications in the sea turtle research staff the SLNPP before May 2000. The core sea turtle research staff (those employed year-round) at the SLNPP has remained stable from May 2000 through July 2005 with the exception of one new hire during 2005. The new hire was considered ‘in-training’ and was largely overseen by senior research members.

The data utilized represent consistent 3-month time blocks during the summer months across six years (2000 through 2005). Therefore the results provided in this study may not accurately reflect intake pipe related fresh scrapes for the fall and winter months of 2000 through 2005. Potentially important differences may exist between the sampling periods (May through July) in this study and the excluded months. For example, the mean size classes captured at the SLNPP vary among seasons. The mean size for turtles captured May through July 2000 to 2005 was 66.8 cm SSCL, but the mean size for turtles captured August through April 2000 to 2005 was 55.5 cm SSCL (M. Bresette, Quantum Resources, pers. comm. 2005). On average, higher percentages of juvenile green turtles are captured during the winter than in the summer (Quantum Resources 2005). If smaller turtles are less severely impacted by fresh scrapes, the overall percentage of turtles being impacted by fresh scrapes during the winter months may potentially be less than what is found in this study that examines only the summer months May through July. Again, this study did not utilize all captures for each year because of the aforementioned natural and anthropogenic factors. Another important temporal factor that may alter fresh scrape impacts is the potential fluctuation in water temperature among seasons. This may affect the level of biofouling within the intake pipes as lower water temperatures may not be optimal for growth of certain epibionts such as barnacles.

Fresh scrape frequency and severity was evaluated for May through July 2000, 2002, and 2004. The severity of the intake pipe related scrapes was determined by the location of each fresh scrape on the body [refer to methods and Sea Turtle Injury Identification System (STIIS) in Chapter 2] and degree of scale/scute and flesh removal (i.e., superficial or deep). Furthermore, fresh scrape frequency was evaluated May through July 2001, 2003, and 2005. It is unknown if species characteristics (e.g., speed, alertness, maneuverability) may significantly influence travel time or ability to avoid obstacles while traveling through the intake pipes. It is possible that differences in fresh scrape frequency between species may actually be due to size class differences.

Project objectives:

OBJECTIVE 1. Determine whether any trend exists in the frequency of fresh scrape occurrence May through July 2000 to 2005.

OBJECTIVE 2. Identify and quantify fresh scrape locations within each of the primary body regions (May through July 2000, 2002, and 2004).

OBJECTIVE 3. Compare presence/absence of fresh scrapes among species and size classes (May through July 2000 to 2005).

Statistical Analyses

A standard normal z-test was used to determine if fresh scrape frequency increased from May 2000 through July 2005. A naïve chi-square statistical test in statistical program SAS version 9.1 was used to test for significant differences in the number of turtles found with fresh scrapes among years, species, and size classes.

Results

May through July 2000 to 2005

Figures 4-1 and Fig. 4-2 provide the total number of turtles captured within each species (*C. caretta*, *C. mydas*, *D. coriacea*, and *E. imbricata*) and size class during May through July 2000 to 2005. Fresh scrape frequency increased significantly from May 2000 through July 2005 (df=1, z=-9.89, p<.001) (Fig. 4-3). Comparisons of fresh scrape occurrence between species (*C. caretta* and *C. mydas*) indicate a significant difference during 2002, 2003, and 2004 (p<.0001). However, no significant differences were found between species for the years 2001(n=131, χ^2=.7553, p=.3848) and 2005 (n=413, χ^2=2.14, p=.1432, n=413). It was of further interest to test for differences among size classes while ignoring species. All years showed a significant difference in the percentage of fresh scrapes found among size classes (p<.0001), except 2001 (χ^2=10.8, p<.0962) (Table 4-1, Fig. 4-4). In addition, fresh scrapes have steadily increased within smaller size classes with each consecutive year. For example, fresh scrape occurrence within the <40 cm SSCL size class increased from 27.8% (n=36) in 2000 to 58.3% (n=36) in 2005 (Table 4-1).

Overall, the number of turtles exhibiting fresh scrapes has significantly increased from May 2000 to July 2005. However, it can not be determined definitively if the increase is a function of species, size or both, due to the large variation among size classes between the two species (i.e., predominantly small juvenile green turtles compared to large juvenile/adult loggerhead turtles).

Fresh scrape body region analysis (May through July 2000, 2002, and 2004)

Fresh scrape severity was examined for the time period of May through July 2000, 2002, and 2004. During this period 95.6% (610 out of 638) of all fresh scrapes recorded were superficial (Table 4-2). For all years, fresh scrapes occurred predominantly within the carapace and anterior regions of the body (Fig. 4-5). A total of 94% (600 out of 638 fresh scrape records) of fresh scrapes during 2000, 2002, and 2004 occurred on the carapace, head, and plastron regions. Fresh scrape records within the eye region increased by 81.2%, from a combined total of three during 2000 and 2002, to 16 in 2004. In addition, three records were found in the mouth region in 2004 compared to zero during 2000 and 2002.

Subregional carapace analyses showed that 95.3% (n=107), 90.5% (n=116), and 94.4% (n=144) of the scrapes found on the carapace were found in the anterior subregion 2c and/or 2d in 2000, 2002, and 2004, respectively. Subregional plastron analyses showed that 81.8% (n=22), 80.0% (n=20), and 78.8% (n=33) were found in the anterior subregion 7c and/or 7d in 2000, 2002, and 2004, respectively.

Conclusion

The number of turtles found to have fresh scrapes has significantly increased ($p<.001$) from 51% in 2000 to 86% in 2005 (Fig. 4-3). The data indicate that as of July 2005, fresh scrapes are found on >50% of all captures within each of the 10-cm size classes at the SLNPP (Fig. 4-4 and Table 4-1). Furthermore, a general increase was found in fresh scrape frequency within smaller size classes (<80 cm SSCL) with each year, which implies that the occurrence of fresh scrapes is not limited to only larger turtles (adults). These findings may infer that the biofouling within the intake pipe has steadily accumulated with each year. It can be further postulated that as of July 2005, the accumulation has reduced the diameter of the intake pipe (at one or more sections) to the degree where only turtles less than 40 cm SSCL have a 40% probability of being entrained and not sustaining fresh scrapes compared to turtles greater than 40 cm SSCL that have less than a 11.5% probability of entrainment and not sustaining fresh scrapes.

A significant contribution of this study is the exhaustive detail and insight it has provided into the location of each fresh scrape on turtles captured at the SLNPP during May through July from 2000, 2002, and 2004 (Fig. 4-5). Fresh scrape location was quantified and statistically evaluated within the major body regions. This fine-scale examination was necessary in order to fully and accurately understand where fresh scrapes were occurring on the body, and to further test for significant increases within body regions (particularly within vital organs such as the eyes). Among the findings in this study were significant increases of fresh scrapes within the eye and overall head region. For example, fresh scrape records within the eyes increased by 81.2% from three records in 2000 and 2002 to 16 records in 2004.

Future research should include data from the winter/fall months during years when the data was not compromised due to natural or anthropogenic factors. While this study may not give a complete picture of the potential impacts of fresh scrapes during the winter/fall months at the SLNPP, the data utilized represent a systematic comparison across six years of sampling within identical 3-month time blocks (May through July). Further, the analyses included sufficient capture data within each size class in order to complete valid statistical comparisons, which allows for introspect into fresh scrape impacts in juveniles among smaller size classes.

The results from this study support some of the concerns previously expressed by the core sea turtle research staff at the SLNPP about cleaning of the intake pipes in order to reduce entrainment impacts on the sea turtles captured at the facility. Plans are currently underway that include cleaning the intake pipes, as well as placing grates around the intake structures that would potentially exclude 25% of the turtles captured (the adults) at the SLNPP (M. Bresette, Quantum Resources, pers. comm. 2005).

The findings and information provided in this study may benefit those (both sea turtles and humans) beyond the southeastern United States. For example, the data now available as a result of this study may provide much-needed information to nuclear electric generating facilities across the globe where potential sea turtle interactions may now exist, or in the future. The majority of sea turtles are highly migratory, and as marine systems are modified via natural and anthropogenic factors, sea turtles may undergo small/large scale behavioral shifts that may involve utilization of previously uninhabited areas. Monitoring and continuous re-evaluation of capture methodologies and protocols at such facilities may reduce and ultimately eliminate such negative impacts on sea turtle populations.

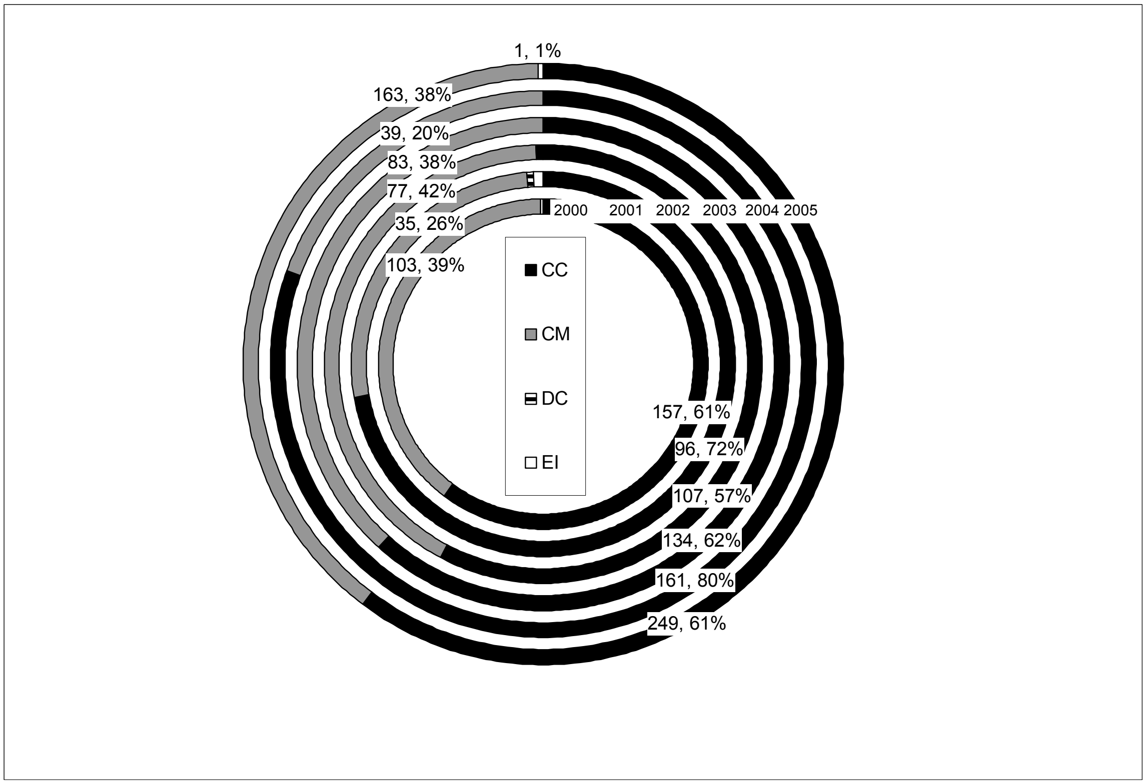


Figure 4-1. Percentage of each species *Caretta caretta* (CC), *Chelonia mydas* (CM), *Dermochelys coriacea* (DC), and *Eretmochelys imbricata* (EI) captured May through July 2000 to 2005.

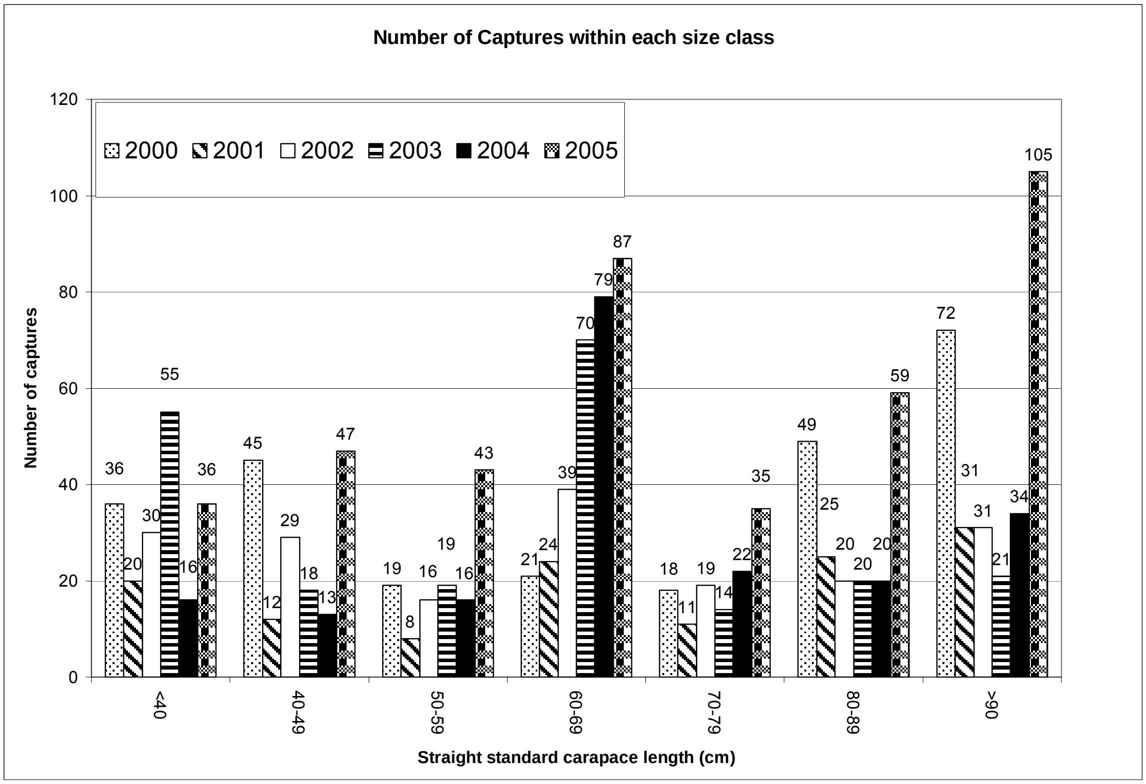


Figure 4-2. Size class distribution for each year May through July 2000 to 2005.

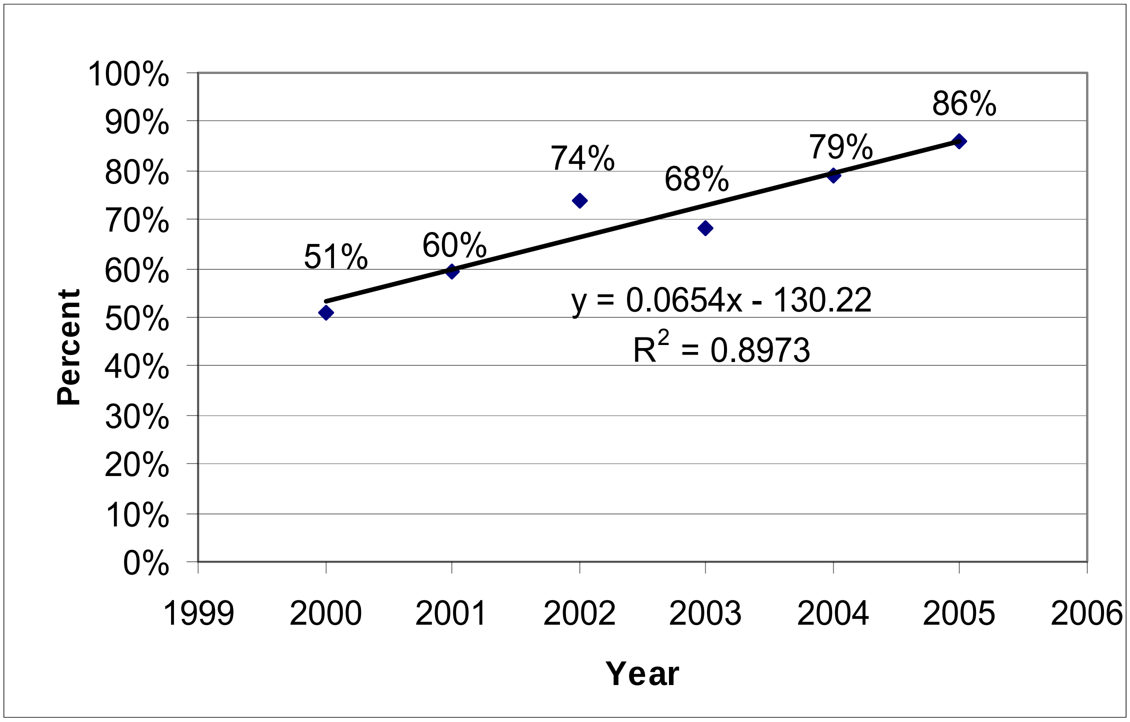


Figure 4-3. Proportion of turtles found with fresh scrapes May through July, 2000 to 2005.

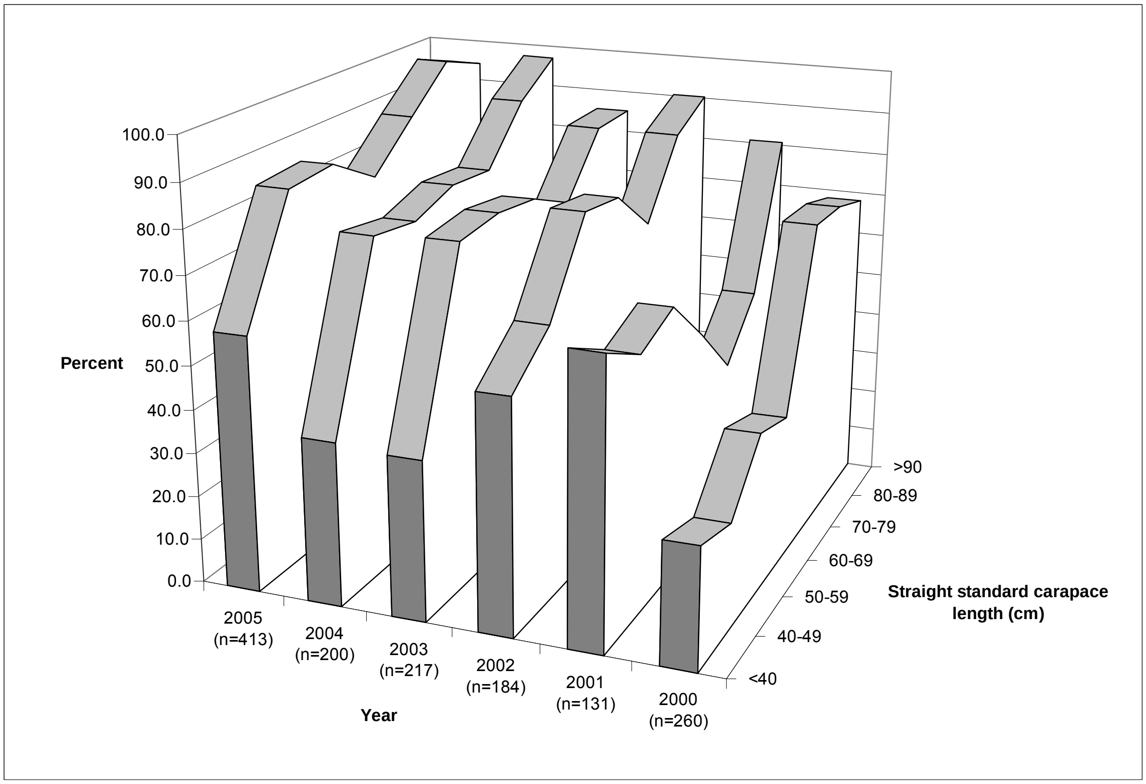


Figure 4-4. Fresh scrape occurrence within size class May through July, 2000 to 2005.

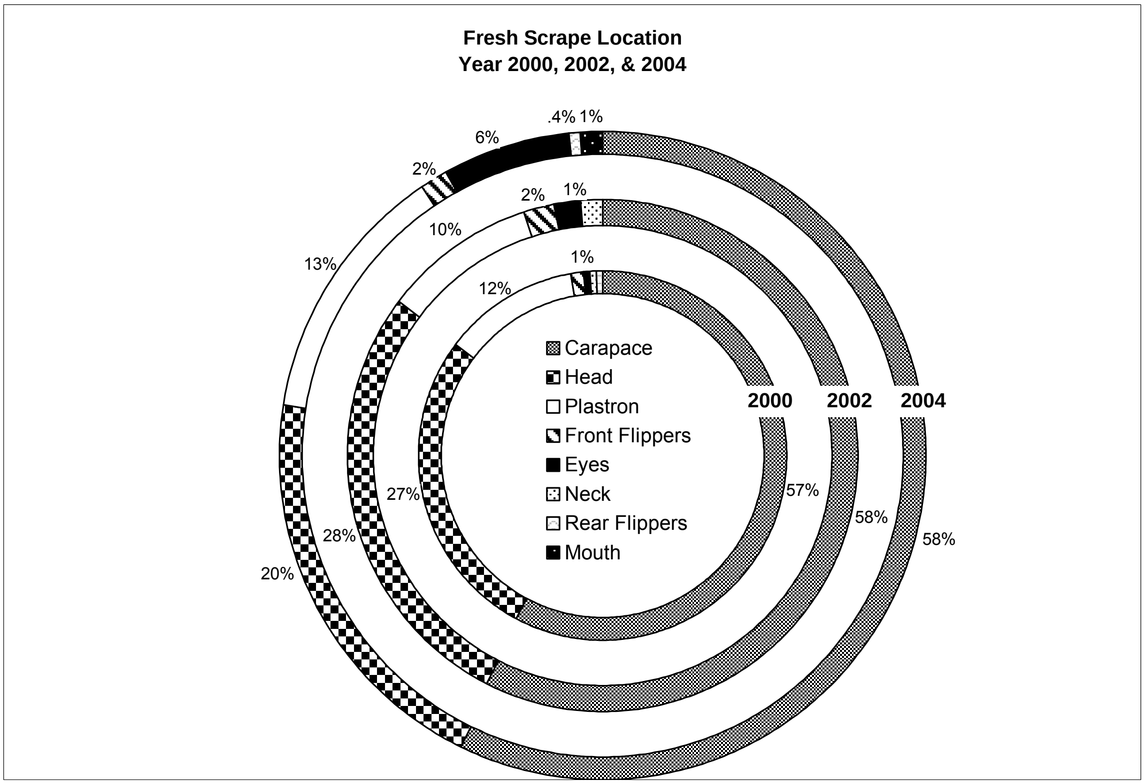


Figure 4-5. Proportion of fresh scrapes found within each body region May through July 2000 (n=185 records), 2002 (n=201 records), and 2004 (n=252 records).

Table 4-1. Percentage of each size class within each year (May through July, 2000 to 2005) found with fresh scrapes. Number in parenthesis represents the total number of turtles captured in each size class per year.

Year	**Size class** **Straight standard carapace length (cm)**						
	<40	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**>90**
2000	27.7%	24.4%	36.8%	33.3%	72.2%	71.4%	68.1%
(260)	(36)	(45)	(19)	(21)	(18)	(49)	(72)
2001	65.0%	58.3%	62.5%	50.0%	36.4%	48.0%	80.7%
(131)	(20)	(12)	(8)	(24)	(11)	(25)	(31)
2002	53.3%	62.1%	81.3%	79.5%	68.4%	85.0%	90.3%
(184)	(30)	(29)	(16)	(39)	(19)	(20)	(31)
2003	36.6%	77.8%	79.0%	77.1%	71.4%	85.0%	85.2
(217)	(55)	(18)	(19)	(70)	(14)	(20)	(21)
2004	37.5%	76.9%	75.0%	78.5%	77.3%	90.0%	97.1
(200)	(16)	(13)	(16)	(79)	(22)	(20)	(34)
2005	58.3%	85.1%	86.0%	78.4%	88.6%	98.3%	94.3%
(413)	(36)	(47)	(43)	(87)	(35)	(59)	(105)

Table 4-2. Percentage of fresh scrapes within each severity class (superficial and deep) May through July, 2000, 2002, and 2004. Number in parenthesis represents the total number of fresh scrape records turtles captured within each size class per year.

Year (Number of fresh scrape records)	Fresh scrape severity	
	Superficial	Deep
2000 (n=185)	99%	1%
2002 (n=201)	97%	3%
2004 (n=252)	92%	8%

CHAPTER 5
SUMMARY AND CONSERVATION SIGNIFICANCE

Foremost, this project provides details of injury related to anthropogenic and natural sources found within sea turtles utilizing the neritic zone of the southeastern United States. Conservation of sea turtle species demands the identification of both lethal and non-lethal threats across the various species, life stages, and sex classes. The short and long-term impacts of non-lethal injuries on sea turtles are poorly understood. The percentage of turtles surviving to adulthood is often of extreme interest when assessing sea turtle populations. Although the survival to reproductive age is essential to the long-term health of sea turtle populations, the reproductive fitness of the surviving animals is as equally important. Does it matter if a turtle survives to adulthood if it cannot reproduce due to a physical handicap resulting from a prior injury event?

In this study, a systematic Sea Turtle Injury Identification System (STIIS) was created and applied to assess several thousand sea turtles captured at the St. Lucie Nuclear Power Plant (SLNPP). The STIIS can be applied globally across research and stranding projects assessing both live and dead sea turtles. Prior to this project, no known method existed that allowed for such detailed injury identification, documentation, and statistical analyses. Using this system, details of each injury (type, cause, condition, depth, location etc.) can be formatted into a database where it can easily be quantified and analyzed.

The STIIS has allowed for consistent injury assessment of the sea turtles captured at the SLNPP, which has in turn allowed for a better understanding of the overall injury condition of the turtles utilizing the nearshore system. The STIIS has provided an essential framework from which to work while attempting to identify not only injury types and sources, but exhaustive detail describing the location of each injury on the body. Such close examination has revealed surprising results. For example, although it had been noted that the frequency of fresh scrapes was increasing on the turtles at the SLNPP, the location of the fresh scrapes had not been quantified, nor was it known that with each passing year higher frequencies of turtles within smaller size classes were being affected. Furthermore, the injury location analysis indicate that it may be more advantageous for researchers to place passive integrated transponder tags (PIT) in the neck region due to the lower number of injury records found between the neck and flippers, thereby possibly increasing tag retention rates and the ability to identify individual turtles in subsequent captures. This could be especially important in research programs where placement of a single PIT tag (and no external tags) is standard.

It is highly recommended that sea turtle researchers implement the use of the STIIS as part of their research programs. The application of the STIIS particularly within long-term nest monitoring and tagging programs, as well as data from long-term open water mark recapture studies is significantly important to the future success of systematic sea turtle injury identification. Collection of such data would allow valuable insight into the types, sources, and locations of injuries within each species, and additionally within size classes (life stages) and sex class. This process would allow for a much deeper understanding of the impacts of each injury source. Such crucial information is currently missing from life history models, and could be limiting the ability of such models to predict accurate survival rates. Unfortunately, most models include no information regarding the non-lethal effects that natural and anthropogenic threats have on sea turtle populations. The collection of systematic injury data would provide the information necessary to improve population models and address various research questions. For example, do certain types of injuries resulting from anthropogenic and natural injury sources reduce a turtle's ability to forage properly, escape future predation, and reproduce? Injuries such as loss of eyesight, flipper amputations, and severe carapace damage could have severe effects on the reproductive success of sea turtles, and thereby diminish recruitment to current populations. Rear flipper loss in adult female turtles is one injury type that has been shown to reduce a turtle's ability to properly dig an egg chamber (Miller et al. 2003). Are adult male turtles reproductively impaired by flipper loss? Are juvenile turtles more or less likely to survive to adulthood if they are missing an eye or a flipper?

One of the objectives successfully addressed in this project was to begin quantifying the number of turtles with injuries that could diminish their ability to function ecologically and biologically in the wild. The work culminated in the STIIS (detailed injury records) can be combined with direct field observations to possibly further our understanding of how certain types and causes of injuries may be affecting the long-term survival of sea turtles.

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APPENDIX A
FLIPPER AMPUTATIONS MAY THROUGH DECEMBER 2000

Table A-1. All flipper amputations (less than half, half, over half, and entire) within species (*Caretta caretta* and *Chelonia mydas*), size class, and sex class (male, female and unknown sex) May through December 2000 at the SLNPP.

		Straight standard carapace length (cm) # of Male- # of Female- # of Unknown Sex / Total									
Species	% Missing	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	Total
Caretta caretta	Less than half	- -	- -	0-0-0 0	0-0-0 0	0-0-1 1	0-0-1 1	0-3-0 3	0-5-0 5	0-0-0 0	0-8-2 10
	Half	- -	- -	0-0-0 0	0-0-0 0	0-0-0 0	0-0-1 1	0-1-0 1	0-0-0 0	0-0-0 0	0-1-1 2
	Over half	- -	- -	0-0-0 0	0-0-0 0	0-0-0 0	0-0-1 1	0-0-1 1	0-3-0 3	0-0-0 0	0-3-2 5
	Entire	- -	- -	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-1-1 2	1-0-0 1	0-0-0 0	1-1-1 3
Chelonia mydas	Less than half	0-0-2 2	0-0-2 2	0-0-1 1	0-0-2 2	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-7 7
	Half	0-0-1 1	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-1 1
	Over half	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0
	Entire	0-0-1 1	0-0-1 1	0-0-1 1	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-0 0	0-0-3 3
Total		0-0-4 4	0-0-3 3	0-0-2 2	0-0-2 2	0-0-1 1	0-0-3 3	0-5-2 7	1-8-0 9	0-0-0 0	1-13-17 31

APPENDIX B
SUMMARY OF INJURY RESULTS MAY THROUGH DECEMBER 2000

Table B-1. Summary of injury results for known causes (barnacle, tar, fishing, social, boat propeller strike, and shark) May through December 2000 at the SLNPP.

Species	Id	Date	SSCL cm	Anatomical	Numerical	View	Type	Depth	Recency	Cause
CC	XXP 105	11/27	51	carapace	2cd	dorsal	depression	deep	fresh	barnacle
CC	XXJ 542	06/06	74	plastron	7cd	ventral	depression	superficial	healed	barnacle
CM	XX M74 2	09/28	32	plastron	7d	ventral	depression	deep	healed	barnacle
CM	XXJ 048	05/17	40	carapace	2c	dorsal	depression	superficial	healed	barnacle
EI	XXJ 881	08/21	48	plastron	7cd	ventral	discoloration	superficial	fresh	tar
EI	XXJ 881	08/21	48	front left flipper	3cd	ventral	discoloration	superficial	fresh	tar
EI	XXJ 881	08/21	48	front right flipper	4cd	ventral	discoloration	superficial	fresh	tar
EI	XXJ 881	08/21	48	rear left flipper	5cd	ventral	discoloration	superficial	fresh	tar
EI	XXJ 881	08/21	48	rear right flipper	6cd	ventral	discoloration	superficial	fresh	tar
CM	XXJ 451	05/24	40	front left flipper	2d	dorsal	puncture	deep	fresh	fishing
CC	XXJ 637	06/25	87	left eye	9	.	cut	superficial	fresh	social
CC	XXJ 530	06/26	88	head	1	dorsal	cut	superficial	fresh	social
CC	XXJ 530	06/26	88	mouth	11	.	bite	deep	fresh	social
CC	XXJ 459	05/26	96	neck	12	dorsal	bite	superficial	healed	social
CC	XXJ 746	07/13	99	neck	12	dorsal	bite	superficial	partial	social
CC	XXJ 797	07/29	103	neck	12	dorsal	bite	superficial	partial	social
CM	XXJ 719	07/07	86	rear left flipper	5abcd	dorsal	abrasion	superficial	partial	social
CM	XXJ 719	07/07	86	rear right flipper	6cd	dorsal	abrasion	superficial	partial	social
CM	XXJ 628	06/24	97	front left flipper	3d	ventral	other	superficial	healed	social
CM	XXJ 628	06/24	97	front right flipper	4d	ventral	other	superficial	healed	social
CM	XXJ 565	06/12	97	front left flipper	3b	dorsal	abrasion	superficial	partial	social
CM	XXJ 565	06/12	97	front right flipper	4b	dorsal	abrasion	superficial	partial	social
CM	XXJ 565	06/12	97	rear left flipper	5bd	dorsal	abrasion	superficial	partial	social

Table B-1. Continued

Species	Id	Date	SSCL cm	Anatomical	Numerical	View	Type	Depth	Recency	Cause
CM	XXJ565	06/12	97	rear right flipper	6bd	dorsal	abrasion	superficial	partial	social
CM	XXJ565	06/12	97	plastron	7abcd	ventral	crease	superficial	partial	social
CM	XXJ615	06/22	99	neck	12	dorsal	bite	superficial	partial	social
CC	XXJ562	06/10	60	carapace	2ab	dorsal	slice	deep	healed	boat
CC	XXD449	08/29	68	carapace	2abcd	dorsal	slice	deep	healed	boat
CC	XXM761	10/06	70	carapace	2acd	dorsal	slice	deep	healed	boat
CC	X1	07/16	70	carapace	2ac	dorsal	slice	deep	partial	boat
CC	XXJ821	08/01	76	carapace	2ab	dorsal/ ventral	slice	deep	healed	boat
CC	XXJ742	07/12	83	carapace	2ab	dorsal/ ventral	slice	deep	partial	boat
CC	XXJ567	06/12	83	carapace	2ab	dorsal	slice	deep	healed	boat
CM	XXP169	12/27	31	carapace	2abd	dorsal	slice	deep	partial	boat
CM	X5	11/08	60	carapace	2abc	dorsal	slice	deep	partial	boat
CC	XXJ705	07/05	67	carapace	2bd	dorsal	bite	deep	partial	shark
CC	XXJ705	07/05	67	plastron	7a	ventral	bite	deep	partial	shark
CC	XXJ734	07/10	68	plastron	7ac	ventral	bite	superficial	healed	shark
CC	XXJ717	07/07	69	front right flipper	4cd	dorsal/ ventral	bite	superficial	healed	shark
CC	XXJ717	07/07	69	carapace	2ab	dorsal	bite	superficial	healed	shark
CC	XXJ717	07/07	69	plastron	7abd	ventral	bite	superficial	healed	shark
CC	XXJ717	07/07	69	rear right flipper	6cd	ventral	bite	superficial	healed	shark
CC	XXJ717	07/07	69	rear left flipper	5cd	ventral	bite	superficial	healed	shark
CC	XXJ668	06/29	70	carapace	2bd	dorsal	rake marks	superficial	healed	shark
CC	XXJ668	06/29	70	plastron	7ac	ventral	bite	superficial	healed	shark
CC	XXJ546	06/06	71	carapace	2bd	dorsal	bite	deep	partial	shark
CC	XXJ546	06/06	71	carapace	2b	dorsal/ ventral	missing (crescent-shaped)	.	partial	shark
CC	XXJ546	06/06	71	rear right flipper	6ab (half)	dorsal/ ventral	amputation	.	partial	shark
CC	XXJ546	06/06	71	plastron	7ac	ventral	bite	deep	partial	shark
CC	XXM744	09/28	71	carapace	2a	dorsal/ ventral	missing (crescent-shaped)	.	healed	shark
CC	XXJ421	05/21	74	plastron	7abcd	ventral	bite	.	healed	shark
CC	XXJ421	05/21	74	rear left flipper	5d	ventral	bite	.	healed	shark

Table B-1. Continued

Species	Id	Date	SSCL cm	Anatomical	Numerical	View	Type	Depth	Recency	Cause
CC	XXJ 577	06/17	78	front right flipper	4a	dorsal/ ventral	bite	deep	partial	shark
CC	XXJ 763	07/17	88	front left flipper	3b	dorsal/ ventral	bite	deep	partial	shark
CC	XX M76 8	10/07	89	front left flipper	3c	dorsal/ ventral	bite	deep	healed	shark
CC	XXJ 401	05/08	95	front left flipper	3a	dorsal/ ventral	bite	deep	partial	shark
CC	XXJ 401	05/08	95	front right flipper	4abcd	dorsal/ ventral	bite	deep	partial	shark
CC	XXJ 401	05/08	95	plastron	7d	ventral	bite	deep	partial	shark
CC	XXJ 457	05/26	97	front left flipper	3cd	ventral	bite	deep	healed	shark
CC	XXJ 457	05/26	97	plastron	7b	ventral	bite	superficial	healed	shark

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BIOGRAPHICAL SKETCH

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