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Depredation and angler interactions involving bottlenose dolphins (Tursiops truncatus) in Sarasota Bay, Florida

Jessica R. Powell

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Depredation and Angler Interactions involving Bottlenose Dolphins (*Tursiops truncatus*)

in Sarasota Bay, Florida

by

Jessica R. Powell

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
College of Marine Science
University of South Florida

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Keywords:  behavior, fishing, passive acoustics, auditory evoked potentials (AEP), outreach, habitat, activity budgets, social, red tide

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Dedication

This thesis is dedicated to my family, Joel, Sarah, Kristin, and Amanda Powell. For my father, who never accepts anything less than my best and always pushes me to “not just follow my dreams, but catch them as well.” For my mother, whose caring, supportive words always carry me through. For Kristin, whose strength and ambition never cease to inspire me. And for Amanda, whose spirit I admire most. Thank you.
Note to Reader

The original of the document contains color that is necessary for understanding the data.

The original thesis is on file with the USF library in Tampa, Florida.
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Depredation and Angler Interactions involving Bottlenose Dolphins  
(*Tursiops truncatus*) in Sarasota Bay, Florida

Jessica R. Powell

ABSTRACT

Typical depredation behavior by cetaceans involves stealing or damaging prey items already captured by recreational or commercial fishing gear. Depredation among cetaceans has been reported to be increasing in both severity and frequency globally. This behavior is of particular concern for small stocks of cetaceans since any interaction with fishing gear has the potential to injure or kill animals leading to unsustainable losses. In Florida, depredation became evident in 2006 when the number of bottlenose dolphin (*Tursiops truncatus*) strandings resulting from fishing gear ingestion or entanglement sharply increased. For the resident dolphin community in Sarasota Bay, modeling showed continued mortalities from recreational fishing gear interactions were not sustainable.

The major goals of this study were to 1.) characterize depredation and recreational angler interactions involving dolphins in Sarasota Bay, 2.) reduce dolphin-angler interactions through outreach, 3.) examine a case study to investigate the link between dolphin hearing loss and angler interaction behavior, 4.) test the effectiveness of passive acoustics in monitoring dolphin depredation at a fishing pier.
Findings from this study provided a better understanding of depredation and angler interactions. Results indicated that dolphin-angler interactions in Sarasota Bay are increasing in frequency and are affecting an increasing number of dolphins, specifically adult males. Some dolphins in Sarasota Bay appear to utilize depredation as a foraging method (not just an opportunistic behavior) and were significantly more likely to be within 50 m of an active fishing line. Depredation and angler interaction behavior appear to increase in times of prey depletion (such as during a red tide) and heightened angler fishing activity. Educational outreach using an informational card proved successful in a case study showing about a 30% reduction in dolphin provisioning rates. The case study of F201 offers preliminary evidence that hearing loss is linked to depredation behavior and death for wild dolphins. Also, by detecting echolocation clicks as a proxy for dolphin presence, passive acoustics showed potential as an inexpensive method for monitoring depredation in problematic areas. Conclusions from this study can be utilized by scientists and managers when assessing depredation rates for a cetacean community and implementing an action plan.
Preface

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1. Introduction

Depredation by a predator is the act of stealing or damaging a prey item already captured by some other process (Zollett and Read 2006). Depredation of commercial and recreational fishing gear by cetaceans is a growing problem around the world and has been documented in areas such as Australia, the Pacific Ocean, southern Brazil, the Mediterranean Sea, and the eastern United States (Broadhurst 1998, Secchi and Vaske 1998, Donoghue et al. 2002, Noke and Odell 2002, SPREP 2002, Cox et al. 2003, Lauriano et al. 2004, Brotons et al. 2008, and Sigler et al. 2008). Long-line fisheries depredation by larger odontocetes has recently been recognized as increasing in frequency, geographic extent, and severity (Read 2008). Removal of, or damage to, bait or catch by cetaceans create an economic loss, degrade a recreational experience, and increase the chance of retaliation by the angler (Read 2008). In addition, this behavior increases the animal’s risk of ingesting or becoming entangled in fishing gear which could then result in injury or death (Gorzelany 1998; Wells et al. 1998, 2008).

Any activities that bring dolphins into contact with fishing gear have the potential to seriously injure or kill the animals through entanglement or ingestion (Wells and Scott 1994, Wells et al. 2008). In Sarasota Bay, Florida, ingestion of gear usually leads to mortality through suffocation or starvation as wrapped monofilament line constricts, obstructs, or damages the goosebeak or the esophagus (Wells et al. 2008). Severe constrictive monofilament entanglements (unless wrapped around distal ends of flippers,
flukes, and dorsal fins) are also considered to be fatal without human intervention (Wells
et al. 2008).

For long-term management purposes, it is important to understand the nature of the depredation behavior, such as why animals engage in depredation and if they are targeting specific bait or catch. Depredation has been shown to cause changes to ranging patterns, habitat selection, and natural activity patterns (Chilvers and Corkeron 2001, Reeves et al. 2001, Finn et al. 2008). It can also lead to a decrease in natural foraging predation and a change in prey species (SPREP 2002, Zollett and Read 2006). These changes may disproportionately affect certain sex and age classes. For example, in Western Australia, illegal feeding of dolphins disproportionately involved adult males and subadults (Finn et al. 2008). It is also imperative to examine the frequency of depredation, the proportion of the population that engages in the behavior, and whether or not these frequencies increase with time.

In the state of Florida, there has been a recent increase in bottlenose dolphin (Tursiops truncatus) entanglement and ingestion of fishing gear (NOAA 2006a). In 2005, five dolphins were recovered that had ingested or become entangled in fishing gear. In 2006, thirteen animals that had ingested or were entangled in gear stranded and there were many reports of non-stranded, entangled dolphins from around the state (NOAA 2006a). This trend may be a result of increased depredation rates. Therefore in response to the greater number of deaths, NOAA, working in conjunction with Mote Marine Laboratory, Chicago Zoological Society, Hubbs SeaWorld Research Institute, and anglers and fishing guides, developed and disseminated a list of “Best Fishing Practices for Avoiding Interactions with Wild Dolphins” (NOAA 2006a).
One area hit particularly hard by fishing-related mortalities during 2006 was southwest Florida. In 2006, the Mote Marine Laboratory Stranding Investigations Program retrieved 5 dolphins, four adults and one calf, whose deaths were related to interactions with fishing gear. The fluke of the calf was nearly severed by monofilament line. The four adults were all long-term residents of the Sarasota Bay dolphin community that has been studied since 1970 (Wells 1991, 2003). Of the three adults believed to have died from ingestion of fishing gear, only one animal had a previous history of angler interactions (Wells et al. 2006). The other adult died with a large fishing lure caught in her mouth, but a stingray barb was considered to be the primary cause of death. In comparison, Mote recovered only one entangled dolphin in 2005 and death was from other causes. Of the total Sarasota Bay recovered strandings in 2006, approximately 25% were a result of fishing gear interaction, compared to the average 2.9% rate for dolphin deaths attributed to fishing gear for the years of 2000-2005 (NOAA 2006a).

The deaths in 2006 resulted in a loss of more than 2% of the resident Sarasota dolphin community (Wells et al. 2006). Continued losses at this rate, in addition to those from previously-existing mortality sources, were determined to be unsustainable for the Sarasota Bay dolphin community, through preliminary population modeling using the program Vortex (Wells et al. 2006). In terms of conservation management, small stocks of cetaceans, like the Sarasota Bay bottlenose dolphin population of about 160 dolphins, are especially susceptible to depletion by localized impacts such as effects of depredation and angler interactions (Read 2008, NOAA 2006a).

In addition to the documented mortalities, increasing numbers of interventions or rescues have occurred in recent years along the west coast of Florida, involving dolphins
entangled in fishing gear. In January 2007, a resident 1.5-year-old female dolphin (F201) was rescued and admitted to Mote’s dolphin hospital because of a severe entanglement around its fluke. In summer of 2007, a 42-year-old male dolphin and long time resident of the Sarasota Bay area (FB28) was entangled with monofilament wrapped around the dorsal fin and flukes. With use of a cutting tool, the animal was freed from the majority of the threatening line without further intervention. Also in 2007, a 26-year-old male dolphin (F106) that was frequently seen depredating from a local fishing pier and was the pair of an adult male that died of fishing gear ingestion in 2006, disappeared and is presumed dead, possibly as a result of a fishing related injury.

Depredation is expected to be a persistent and rising problem as humans and cetaceans compete for the same resources (Read 2008). The depredation behavior and dolphin-angler interactions will likely increase due to a combination of factors like the decline of prey populations due to overfishing from commercial (both current and emerging) and recreational fisheries and cultural transmission of the behavior throughout cetacean populations (Myers and Worm 2003, Sutinen and Johnston 2003, Wells 2003, Coleman et al. 2004, Whitehead et al. 2004, Read 2008). The use of long-term data sets, like those available for the Sarasota Bay bottlenose dolphin community, offers a unique opportunity to employ, experiment, and evaluate the value of exploratory methods. Evaluating and comparing the effectiveness of the methodologies used in this study to evaluate and mitigate depredation will set the foundation for future research design and dolphin-angler interaction management.
1.1 Goal of this Thesis

The overall goal of this thesis is to characterize the behavior of dolphins interacting with anglers (referred to as angler interaction dolphins or depredators) and to identify all possible factors that may be associated with the rise in depredation. Chapter one focuses on understanding dolphin depredation in terms of animal behavior. Depredation is evaluated in relation to fishing effort, red tide (*Karenia brevis*) blooms, dolphin activity budgets, dolphin habitat use, dolphin socialization patterns, and angler behaviors. This chapter also examines larger trends in depredation, identifying potential patterns over time, age class, sex, and maternal lineages. Chapter two is a case study of an entangled dolphin (F201) and explores the potential link between hearing impairment and depredation behavior. Chapter three tests the effectiveness of passive acoustics as an inexpensive tool for monitoring dolphin depredation behavior at a fishing pier.

This thesis also compared the usefulness and power of different methodologies in understanding the depredation behavior and its effects on dolphin behavior and biology. Methods included visual and passive acoustic pier surveys, auditory evoked potentials, focal animal behavioral follows, and the use of longitudinal data sets. These results can serve as a base line when examining the potential success of methodologies for studying dolphin-angler interactions in other areas.

Another, very central goal of this project was to reduce the human role (specifically focusing on boaters and anglers) in depredation and other adverse dolphin interactions through public awareness and outreach. By developing and distributing “Dolphin-Friendly Fishing and Viewing Tips” informational cards, the intention was to
reduce depredation by teaching people simple steps that are designed to reduce the association between people and fish that some dolphins have learned to recognize.
2. Behavior: Characterization of Dolphins Engaging in Angler Interactions

2.1 Introduction

The Sarasota Bay bottlenose dolphin community is exposed to a variety of anthropogenic disturbances. Previous studies in the area have focused on the effects of boat presence and noise to changes in dolphin behavior (Nowack et al. 2001, Buckstaff 2004). Another study initiated in 1997 identified and quantified illegal feeding and boat interactions with a commonly begging dolphin (Cunningham-Smith et al. 2006). The longitudinal data set collected in Sarasota Bay provides a rare opportunity to study, in detail, the rise and effect of anthropogenic impacts on a dolphin community.

Anthropogenic, environmental, and behavioral sources likely all supported the rise of dolphin depredation in Sarasota Bay to detrimental levels. The relative contributions of sources to the increase in dolphin interactions with recreational fishing gear were investigated in order to evaluate the problem and identify specific management needs. Understanding the demographics of depredation behavior, such as sex and age classes most commonly involved, was also necessary for the evaluation of the behavior. The frequency of occurrence and when the behavior first entered into the population was
also considered. Furthermore, “Dolphin-Friendly Fishing and Viewing Tips” cards were distributed in an effort to increase public awareness and reduce dolphin depredation.

2.1.1 Anthropogenic Factors of Depredation and Implications

Dolphins have become increasingly exposed to recreational fishing and boaters as the population of resident and visiting humans rises in Florida coastal areas. The Florida population has risen by 135% from 1970 to 2000, with growth skewed towards coastal areas (Florida Charts 2007). Within Sarasota and Manatee Counties, the home range of the Sarasota Bay resident dolphins, the total number of registered boats has quadrupled since 1970 to 44,839 boats in 2005. In addition, marine recreational fishing in the United States increased by 20% from 1996 to 2000 (Sutinen and Johnston 2003). Broadly, the Gulf of Mexico and the Atlantic region have the greatest number of saltwater recreational anglers in the nation (Van Voorhees and Pritchard 2008). More specifically, the state of Florida has the greatest number of resident (64%) and visiting (64%) saltwater recreational anglers (2,002,000) (U.S. Dept. of the Interior et al. 2006).

These factors increase the probability for a dolphin to come within the vicinity of an angler or boater. Furthermore, in 2007, more anglers were engaging in catch and release: 58% of recreational caught fish were released alive in 2007 (Van Voorhees and Pritchard 2008). As the number of anglers rise with more anglers releasing injured catch, dolphins may begin to associate boats or fishing piers with easy prey, especially if the animals learn that these can be sources of bait, caught fish on line, or released catch. This
potential problem would be exacerbated through direct feeding of dolphins, as has been documented in the Sarasota Bay area (Cunningham-Smith et al. 2006).

**2.1.2 Environmental Factors of Depredation and Implications**

Natural environmental factors were also examined relative to the increase in depredation events. Red tide, a form of harmful algal bloom (HAB) common to the Gulf of Mexico, involves blooms of a toxic dinoflagellate, *Karenia brevis*, resulting in massive die-offs of fish. *K. brevis* produces a suite of brevetoxins (neurotoxins) which impact many organisms through inhalation and/or trophic transfer (Tester et al. 2000, Flewelling et al. 2005, Fire et al. 2008). Brevetoxins can cause mortalities for marine mammals and studies have shown that prey fish act as vectors for toxin transfer to dolphins during a red tide outbreak (Flewelling et al. 2005, Fire et al. 2008).

A severe red tide, such as occurred in Sarasota Bay and surrounding areas in 2005, can deplete prey fish populations and may force dolphins to search for other means of nourishment, such as angler’s bait or catch. Ongoing studies by the Sarasota Dolphin Research Program have shown that the 2005 bloom not only depleted dolphin prey but also caused a change in composition of the local fish community to more pelagic species, not typically found in the diets of resident dolphins (Barros and Wells 1998, Gannon et al. 2009). These effects of red tide on prey species were correlated with declines in dolphin body condition (Wells et al. 2006) and behavior changes such as increased group size, shifts in habitat use, and increased reports of begging and depredation (Gannon et al. 2009).
2.1.3 Behavioral Factors of Depredation and Implications

*Habitat Selection and Home Range*

When investigating habitat selection and home range, depredating dolphin habitat preference for heavily fished areas must be measured (Reeves *et al.* 2001). Results from previous behavioral fisheries interaction studies (e.g. Chilvers and Corkeron 2001, Cunningham-Smith *et al.* 2006, Finn *et al.* 2008) would suggest that dolphins interacting with anglers may more commonly select for areas with high numbers of passing boaters or a concentration of anglers, such as near fishing piers, and in passes or channels. Depredating dolphins may also have overall, smaller home ranges since dolphin movements depend largely on the location of prey species (Shane *et al.* 1986, Ballance 1992). For example, the encounter rates for begging dolphins in Cockburn Sound, Australia were significantly correlated with the density of recreational boats (Finn *et al.* 2008). In Moreton Bay, Australia, a coastal community of *Tursiops aduncas*, known to feed in association with a trawl fishery, selected for deep, offshore habitat conducive to trawling rather than shallow, coastal areas and had ranges half the size when compared to non-trawler associated dolphins (Chilvers and Corkeron 2001).

*Activity Budgets*

Activity budgets and changes in behavioral states can be valuable tools for assessing conservation impacts to cetacean populations and have been used to assess potential anthropogenic impacts related to boat and swimmer disturbance in multiple studies (Lusseau 2003, 2004, 2006; Constantine *et al.* 2004, Danil *et al.* 2005, Bejder *et al.* 2006, Williams *et al.* 2006). Baseline data collected by Waples (1995) found that in
summer months resident dolphins in Sarasota Bay spent 67% of time traveling, 14% feeding, 13% milling, 5% socializing, and 2% resting. It is particularly important to understand and quantify changes to the natural activity states as a result of angler-interaction behavior.

Social Behavior

The well-established ability of dolphins to learn by observation may increase the frequency of depredation behavior through social transmission (Donoghue et al. 2002, Wells 2003, Whitehead et al. 2004, Cunningham-Smith et al. 2006). In general, dolphin foraging and feeding behaviors in Sarasota Bay are composed of a number of behaviors which demonstrate the behavioral plasticity of these animals (Nowacek 2002, Wells 2003). In particular, an angler-interaction dolphin may have a greater probability of having a depredating mother since bottlenose dolphins teach feeding behaviors to their calves (Nowacek 2002, Wells 2003).

Sarasota Bay bottlenose dolphins live in a fission-fusion society where group compositions and dolphin associates change by minutes, hours or days (Wells et al. 1987). Typical group size for bottlenose dolphins ranges from two to fifteen animals (Shane et al. 1986) and for Sarasota Bay, group size is usually between five to seven animals (Wells et al. 1980, 1987). Sarasota dolphins are typically found in larger groups in open waters with large, patchy prey schools whereas smaller groups or solitary animals are typically found in seagrass beds where prey is more evenly distributed (Wells et al. 1980, 1999; Shane et al. 1986). The idea that group size is influenced by prey availability is further supported by the large group sizes recorded in Sarasota Bay during
a severe harmful algal bloom in 2005 in which only clupeids, a schooling fish, were known to thrive as other prey species were utterly wiped out (Gannon et al. 2009).

Depredation lends itself to a smaller group size or solitary foraging strategy since multiple animals are not needed to cooperatively locate or herd fish. Depredation typically involves a single prey item struggling on a line, a debilitated thrown-back fish, or the hand-feeding of fish to dolphins. All of these scenarios would be optimal for a solitary forager. For example, mother-calf pairs (Tursiops sp.) in Australia did not form as large or as cohesive of groups and calves had fewer associates inside provisioning areas than in non-provisioning areas (Mann and Smuts 1999).

2.2 Methods

2.2.1 Study Area and Population

This study was conducted within an approximately 125 km² area including Sarasota Bay, Florida and surrounding waters (including southern Tampa Bay, Palma Sola Bay, Anna Maria Sound, Venice Inlet and coastal waters) (Figure 2.1). This area is home to a community of about 160 resident bottlenose dolphins that has been closely monitored by the Chicago Zoological Society’s Sarasota Dolphin Research Program (SDRP) for over 38 years (Wells 1991, 2003). Monitoring is conducted through monthly photo-identification surveys and occasional health assessments (Wells 1991, 2003). This community of dolphins was appropriate for study because of the incidence of dolphin-angler interactions and the wealth of data that already exists on family lineages, stranding
records, age, sex, behavioral history, distribution, social associations, and hearing abilities (Wells 1991, 2003; Cook 2006).

### 2.2.2 Behaviors of Interest

Activities measured for this project were defined by the Sarasota Dolphin Research Program (SDRP 2006) and were supplemented with definitions specific to angler interaction behaviors of interest (Tables 2.1, 2.2). Working definitions for additional behavioral categories were developed for the terms patrol, beg, scavenge, attempted depredation, line depredation, and provision (Table 2.2). Definitions of bait and catch were also established. Bait was defined as a fish, invertebrate, or part of either that was attached to an angler’s line and then lowered into the water with the intent of catching fish (e.g. shrimp or pinfish). Catch was defined as a fish that was free swimming in its natural habitat before it was hooked and caught by an angler (catch was not present when the angler initially lowered the line into the water). However, a fish initially defined as catch is not finite. In some instances, an angler may then use the catch as bait. In this case, the fish would now be redefined as bait.

During the course of this study, SDRP members that witnessed a dolphin-angler interaction were asked to record if the dolphin took bait or catch from the line, the size and species of depredated item, the number of fishing lines in the water, and the distance (m) of the dolphin from the angler.
2.2.3 Distance Estimation

Distance estimation was essential for measuring interactions between dolphins and anglers. At the beginning of each day, the field team practiced distance estimation at the Sarasota Sailing Squadron mooring field. Field workers individually estimated the distance of 25 randomly-selected boats or buoys 10 to 300 m away and then compared estimates to a reading from a laser rangefinder. I estimated most distances in the field and stationary distances for boats or anglers were always confirmed with the rangefinder. My mean error for distance range categories was calculated by computing the absolute value of the difference between the actual distance and the estimate (n=2391) (Figure 2.2). Mean error increased with object distance, ranging from 4 m (SD=7.92) for distances between 10-25 m to 29 m (SD=22.52) for distances greater than 201 m.

2.2.4 Pier Observations

Four fishing piers and two jetties within the home range of the Sarasota dolphins were surveyed for dolphin presence, fishing effort, environmental conditions, and dolphin depredation behaviors. In May, June, and July of 2007, Anna Maria City Pier, Rod and Reel Pier, Venice Pier, and the north and south Venice jetties, were monitored on rotation five days a week (weather permitting), usually including both weekend days (Table 2.3, Figure 2.1). Surveys were conducted between 06:30 and 18:30 for an average of 6.5 hours. Efforts in later afternoon hours were less successful due to frequent thunderstorms forcing the suspension or end of surveys. From October 2007 through April 2007, Anna Maria City Pier, Rod and Reel Pier, and Bradenton Beach City pier (added in October 2007) were monitored on rotation four times per month (weather permitting) for seasonal
changes in dolphin depredation and fishing effort. Sustained effort on piers or jetties was based on the ease and quality of data collection, opportunities available (e.g. ability to use a hydrophone), number of residents sighted, and apparent or possible dolphin depredation behavior. A total of 64 pier/jetty surveys were conducted.

The Venice Pier and jetties were dropped from the project due to a lack of observations of dolphin-angler interactions and the difficult circumstances presented to monitor and identify animals. The Venice jetties were adjacent to an inlet, a corridor of heavy boat use, and half of the dolphins identified were not members of the study population, further reducing the value of these sites. Venice Pier is approximately 6 m above the water, making photo-identification very difficult and during surveys, only one dolphin was seen farther than 200 m. Bradenton Beach City Pier was added to the study in October 2007, after it re-opened following three years of closure. The pier was of much interest since dolphins had often been seen feeding in this area and I wanted to document the possible transition of the area into a site of depredation once the pier re-opened.

Surveys of each pier/jetty involved constant monitoring for dolphin presence within a 200 m radius (Figure 2.3). All field workers rotated visual monitoring areas on the half-hour to reduce sightability bias. Standard SDRP sighting data were collected and photo-identification was completed using a Nikon D100 digital camera with a 70-300 mm lens and standardized photo-identification techniques (SDRP 2006, Würsig and Würsig 1977). During surveys, every half hour, data was collected on the number of lines in the water, if bait or lure was in use, the presence or absence of dolphins within 100 m, and environmental conditions (surface water temperature, Beaufort sea state,
cloud cover). Bait or lure had to be visually confirmed by a field worker and was not assumed based on comments from an angler, fishing technique, or presence of a bait bucket.

If the animal stayed within 100 m of the pier for five minutes or more, a focal animal behavioral follow was started. If more than one dolphin was present, I selected an adult or juvenile focal animal ("focal") at random (calves were excluded). Using standardized techniques (Altmann 1974, Mann 1999), I collected instantaneous data every three minutes on the dolphin’s associates, group spread, and number of active fishing lines within 15 m of the animal. The total number and type of depredation events and the focal’s dominant activity (the activity in which the animal engaged in for the majority of observations over the three-minute interval) were documented (Tables 2.1, 2.2). The follow was terminated when the focal dolphin left the 100 m radius around the pier for nine consecutive minutes (three time-points).

When an act of depredation was observed, the depredating dolphin, depredation type, size and species of catch/bait taken, lost fishing gear, number of lines within 15 m, reaction of the angler, the dolphin’s associates, and the behavior of the dolphin following the event was documented. A single depredation event was defined as a single act or multiple consecutive depredation acts by a single dolphin involving the same individual (angler or boater) or set of individuals (e.g. three anglers on a fishing boat). Photos or video of depredation events were obtained whenever possible.

In order to avoid influencing angler behavior during surveys, the field team was restricted from wearing clothing or bringing gear with dolphin images or organization logos. When asked by anglers about the specifics of the study during a survey, team
members provided vague responses, and did not indicate that the focus of the study was dolphin depredation and angler interaction behavior.

### 2.2.5 Focal Dolphin Selection and Focal Animal Behavioral Follows

Depredating focal dolphin (n=8) selection was based on history of angler interactions (dolphins had interacted with a recreational angler or were entangled on at least two occasions prior to July 2007). A matching set of control dolphins (n=8) never observed interacting with anglers but with similar ages (+/- 5 years), sex and home ranges were selected to match a specific depredating dolphin (Table 2.4, Figure 2.4). In total, 78.9 h and 66.1 h of follow time were completed for depredator and control focal dolphins, respectively.

Focal animal behavioral follows were conducted from a 19-foot center-console outboard boat in summers of 2007 and 2008. Using standardized techniques developed for work with Sarasota Bay dolphins (Altmann 1974, Mann 1999, SDRP 2006), focal dolphins were followed for up to two hours per day and instantaneous data was collected on position, associates, group spread, habitat, and number of active fishing lines within 50 m and fishing boats within 100 m every three minutes. Possible habitats in Sarasota Bay included coastal Gulf waters, open bay, sand, seagrass meadows, mangrove, channel, and pass (SDRP 2006). Activity was not instantaneous, but recorded as the behavior in which the dolphin engaged in for the majority of observations over the three-minute interval (Tables 2.1, 2.2). Position was collected with a Garmin GPS 12, and associates within 200 m were identified using photo-identification (SDRP 2006). Acts of depredation were documented in the same manner as with pier/jetty surveys. After
plotting initial activity and habitat changes for each focal’s first follow, a two hour follow time period was found to be the best option since activity and habitat choices varied widely in duration and the depredation behavior was difficult to capture. In addition, respiration data were recorded continuously throughout the follow: each time the dolphin took a breath, the hour, minute, and seconds were recorded.

2.2.6 Methods of Analyses

Depredation Longevity and Demographics

Data on interactions between dolphins and anglers from observations during 1972 to 2007 were considered when examining rates of occurrence over time. However, only dolphin-angler interaction rates for the years of 2000 to 2007 were used for analyses. This time frame was chosen for several reasons: 1.) it is after the 1995 implementation of a state-wide commercial net fishing ban, 2.) it follows enactment of amendments to the U.S. Marine Mammal Protection Act and court upheld prohibitions making it illegal to feed wild dolphins, 3.) and it includes a period of consistent data collection and field effort in Sarasota Bay. Microsoft Excel 2003 was used to compile and calculate descriptive statistics. Updated data on Sarasota Bay dolphin abundance and residency were provided by Randall Wells (unpublished data).

I calculated yearly and monthly dolphin-angler interaction rates (2000-2007) based on possible and confirmed depredation and related behaviors (patrol, beg, scavenge, and provision) (Table 2.2). All rates were standardized by effort (number of boat-days). Dolphin-angler interaction rates were considered for 2000-2007 under two conditions: 1.) only for incidents that occurred during monthly photo-identification
surveys, and 2.) for all sighting effort (including survey, opportunistic and capture-release sighting effort) in Sarasota Bay. Surveys offer a high level of consistency in that every month the SDRP field team completes 10 daily surveys (weather-permitting) covering the entirety of the survey range twice. Dolphin-angler interaction rates were further analyzed by excluding data on interactions with a long-time, regularly-begging dolphin (BEGR) in order to look at recent changes in depredation behavior among Sarasota dolphins.

In an attempt to relate dolphin-angler interaction rates to variations in the presence of anglers and boats in the study area, several proxies for human activities were considered. The mean dolphin-angler interaction rates from monthly photo-identification surveys and all sighting effort were compared to hotel/motel occupancy rates in Sarasota County for 2000-2007 as well as to boat fuel sales for 2003-2007 from Cannons Marina, located south of Longboat Pass within the home range of Sarasota dolphins. A Spearman rank correlation in StatSoft Statistica 6.1 was used to compare interaction rates and sales.

Based on all archived field notes, all dolphins that were part of the Sarasota Bay dolphin community from 2000 to 2007 were considered for entanglements or angler interaction behavior. Dolphins were classified as either a confirmed depredator (an animal that has clearly engaged in patrolling, begging, scavenging, attempted depredation, line depredation, or provisioning) or a possible depredator (field notes were vague). A percentage of the number of resident dolphins that depredated during the specified year was then calculated. Cumulative values were also calculated in order to determine what percentage of the current dolphins in the population had ever participated in angler-interaction behavior. A dolphin was taken out of the analysis the year after its
death. If a dolphin went missing for at least one year, that dolphin was assumed dead and was only considered in the population as of the date of its last sighting. Data from monthly photo-identification surveys as well as all sighting effort were analyzed.

Based on age-sex class composition of the Sarasota population, expected numbers for male and female, immature and mature confirmed depredators were calculated and compared to the observed number depredators of known age and sex (n=50) using a goodness of fit G-test in PopTools (version 3.0, build 5). Animals that had a coefficient of association (COA) of 0.50 or greater with their mother were considered calves; if less than 0.50, the dolphin was considered a juvenile. Females were not considered adults until they gave birth to their first calf, and males were considered adults at age 13.

Depredation related to Red Tide (Karenia brevis) Blooms

Monthly dolphin-angler interaction rates were compared across K. brevis bloom months, months following K. brevis blooms, and non-bloom months from 2000-2007. A bloom with potential for killing fish was considered to occur when K. brevis cell counts reached greater than or equal to 100,000 cells/L for three consecutive weeks (Spencer Fire, personal communication; Steidinger et al. 1998). If any day was considered part of a K. brevis bloom, the month was counted as a bloom month. A bloom was considered complete on the day when cell counts fell below 100,000 cells/L and cell counts remained below this threshold value for a consecutive three weeks. Daily K. brevis cell counts were provided by Mote Marine Laboratory, courtesy of Gary Kirkpatrick. The three months following a bloom (or less, if a new bloom occurred) were deemed the lag period. The lag period is the time following a red tide when fish stocks are still exposed
to brevetoxins remaining in the environment and environmental recovery is beginning (Fire et al. 2007, 2008; Gannon et al. 2009).

There were six red tide blooms in Sarasota Bay from 2000-2007; September-December 2001, July-September 2002, January-October 2003, January-February 2004, January-December 2005, and August-December 2006. Statistical software SPSS 16.0 (Graduate Student version) for one-way ANOVAs and post-hoc Tukey tests was used to compare bloom periods with respect to monthly dolphin-angler interaction rates.

To further explore differences among red tide periods and make comparisons to the number of anglers on the water, I calculated dolphin-angler interaction rates per unit of fuel sales, by dividing the monthly dolphin-angler interaction rate by the corresponding monthly fuel sale. I then used an ANOVA in SPSS to compare across the three HAB categories.

Habitat selection

For each follow, the number of times each habitat was recorded was tallied (habitat per time-point was counted as 1, unless the habitat was split in which each habitat would then count as 0.5.) Cumulative habitat scores were averaged across the total number of time-points, and further averaged across the total number of follows for an individual. Individual averages were combined to determine the overall mean for control and depredator focal animals.

Habitat means for control and depredator focal animals were then compared statistically using a custom randomization program built in MATLAB (version 7.4). The program randomizes a focal follow habitat or activity matrix 10,000 times in order to estimate the probability of randomly finding differences in habitat or activity means
between depredator and control dolphins. The analysis was run as a one-tailed test using a test statistic calculated as the ratio between depredating and control dolphins.

Proximity to Fishing Lines and Boats

At every three-minute interval during behavioral follows, the number of actively fishing boats within 100 m and active fishing lines within 50 m of the dolphin were recorded. The mean number of boats or lines per three-minute interval of a follow was calculated, then averaged across all follows for the dolphin, and further averaged over depredator and control categories. Comparisons between depredator and control focal dolphins’ proximity to boats or lines were made using Mann-Whitney U tests in Statistica.

Home Range

Home range determination for all focal animals included all sightings from 2004 (the first year with a dolphin-angler interaction, not including begging) to August 2008. I used the Animal Extension Movement Spatial Analyst (version 2.04 beta) in ArcView GIS 3.3 and XToolsPro (version 1.0.1, build 19) in ArcMap (version 9.0) to calculate the areas of the 95% kernel home ranges and 50% core kernels for all focals. The area of overlapping land was clipped and subtracted from the core and range areas. The 95% and 50% kernels of depredator and control focals were then compared using a Student’s t-test in SPSS.
Pier

Data from half-hourly scans were used in a logistic regression in Statistica to determine the effectiveness, if any, of the number lines with bait, number of lines with lures, and total number of lines as predictors for dolphin presence at a fishing pier.

I examined fishing effort effects on dolphin presence for monthly, seasonal and hourly timescales. Using a one-way ANOVA in SPSS, monthly averaged differences in dolphin presence, number of baited lines, number of lines with lures, and total number of lines were examined. Seasonal analyses were performed in a similar manner after categorizing months as rainy (summer/fall) or dry (spring/winter) using a Mann-Whitney U test in Statistica. Rainy season (n=42 surveys) included May through October and dry season (n=22 surveys) included November through April. In addition, using an ANOVA and a post-hoc Tukey test in SPSS, I looked at differences in dolphin presence and total fishing effort as a result of time of day. For purposes of analysis, times were considered in hour blocks (e.g. 6:00-6:59).

Activity Budgets

I created activity budgets for each focal animal and stratified them relative to their classification as depredators or controls. Activities recorded as dominant in a three-minute interval were mill, forage (combination of feed and probable feed behaviors), travel, rest, social, beg, patrol, and provision. Activity data were prepared and analyzed using the same methods as with the habitat data.
For further analysis, non-natural foraging behaviors (begging, provisioning, and patrolling) and natural foraging were collapsed in order to determine if depredators and control focals spend similar amounts of time foraging.

**Depredation**

Depredation data were recorded through concerted efforts by SDRP members during 2007-2008 while conducting monthly photo-identification surveys, research for this study, or various other research initiatives. Detailed notes on depredation taken from SDRP staff and students were analyzed for commonalities in dolphin-angler interaction behaviors. The aspects of depredation considered were the species of fish depredated (or attempted), the most common types of depredation (e.g. scavenging, provisioning, attempted depredation, or line depredation), lost gear, and angler or boater reaction to depredation.

**Social Behavior: Group Size**

For Sarasota Bay, a group is defined as all dolphins associating within 100 m (Wells et al. 1980, 1987). Group size for each focal dolphin was determined using all available sightings between the years of 2000-2007 from the Sarasota Dolphin Research Program database. Group size means were further calculated for depredator focals when engaging in angler interaction behavior versus the overall mean. Mean group size was also calculated for all focals based on data from focal animal behavioral follows from summers of 2007 and 2008. A Student’s t-test was performed on these data sets in SPSS.
Social Behavior: Coefficients of Association

Coefficients of associations (COAs) were calculated for each focal animal from two data sets: focal animal behavioral follows and the Sarasota Dolphin Research Program database. For purposes of the behavioral focal follow analysis, all identifiable dolphins within a 100 m radius of the focal dolphin recorded at the three minute interval were considered an associate (Wells et al. 1987). The total time the associate and focal were recorded together was tallied and then divided by the total minutes spent following the focal in 2007 and 2008. The associates that spent at least 10% of total follow time with the focal were used in a further analysis to determine if depredator focals spent significantly more time with other angler interaction associates than did control focals.

I also calculated top associates for focal animals using the SDRP database. Only sightings from monthly photo-identification surveys from 2004 (first report of dolphin-angler interaction behavior) until May 2008 were included in the analysis. For each focal animal, the half-weight index COA of all possible associates was calculated. Only associates with COAs of at least 0.10 were included in a further analysis to determine if depredator focals spent significantly more time with dolphins that also engaged in angler interaction behavior than did control focals. Microsoft Excel and the SPSS Student’s t-test were used for both COA analyses.

2.2.7 Educational Outreach: Card Design and Distribution

In an effort to raise public awareness for depredation and other adverse human-dolphin interactions, guidelines on “Best Fishing Practices for Avoiding Interactions with Wild Dolphins” developed by NOAA, Mote Marine Laboratory, the Chicago Zoological
Society, Hubbs-Sea World Research Institute and anglers and fishing guides were reproduced into an informational card, “Dolphin-Friendly Fishing and Viewing Tips.” The card is compact and water resistant to allow for card storage in pockets, tackle-boxes, or boat consoles. The first edition of the card featured a close-up of a dolphin face on the cover (Figure 2.5). The second edition of the card was redesigned to include a variety of images on the cover in order to elicit the attention of the broad target audience including, recreational boaters and anglers (both tourists and locals) (Figure 2.6).

Inside the card are message points and tips about how to avoid or address interactions with wild dolphins. The cards offer bold headings as well as explanations in layman’s terms of each dolphin-friendly fishing and viewing tip to help the audience understand how such actions can be helpful. The information is presented in a positive manner to encourage boaters and anglers to “buy in” to the mitigation measures voluntarily. The second edition of the card offers slightly more condensed text with larger font (Figure 2.6).

The first edition of the “Dolphin-Friendly Fishing and Viewing Tips” card (64,800 copies) was printed in January 2008. An additional 51,800 first edition cards were printed in February 2008. Beginning in January 2008, cards were distributed to a variety of facilities with the ability to reach the target audience with the majority of cards going to conservation and education organizations such as aquariums and universities primarily within the state of Florida (Figure 2.7). Other areas of high card distribution included Florida state and local governments as well as fishing, bait and tackle shops, boat rental facilities, and marinas (Figure 2.7).
Local distribution was conducted in January and February of 2008 and a second delivery and restock took place in May 2008. The focus of local card distribution within Sarasota and Manatee counties (counties coastal to the Sarasota Bay dolphin community home waters) included Mote Marine Laboratory & Aquarium, Coast Guard Auxiliary chapters, fishing, bait and tackle shops, boat rental facilities, marinas, fishing piers and jetties, and waterfront restaurants. The second edition of the card was printed in November 2008. The printing supplied 228,950 English cards and 17,300 Spanish version cards. Local distribution of second edition cards was conducted in November and December 2008.

2.3 Results

2.3.1 Depredation History and Demographics

With the exception of two consistently-begging dolphins, MOCH and BEGR, only four dolphin-angler interaction cases were reported from 1972 to 2000.

The dolphin-angler interaction rate (2000-2007) for monthly surveys rose continually since 2003 and for all sighting effort, rates began rising consistently in 2005 (Table 2.5; Figures 2.8, 2.9). The peak of angler interactions in 2001 for all sighting data is explained by a study focused on BEGR regarding begging rates. When the dolphin, BEGR, was excluded from the analyses, rates continually rose from 2003 for both monthly survey and all sighting effort (Table 2.5; Figures 2.8, 2.9). The number of animals involved in confirmed depredation type behaviors has been rising since 2004
Cumulatively, it was estimated that between 13 to 27% of the 2007 population had engaged or possibly engaged in an angler interaction one or more times from 2000 to 2007 (Table 2.6, Figures 2.10, 2.11). The expected ratio of immature and mature males and females were significantly different from expected values ($p=0.003$) with adult males being the most over-represented and adult females being the most under-represented depredator age-sex class (Table 2.7).

Angler interaction rates were greatest in March with smaller peaks in May and November (Figures 2.14). Hotel/motel occupancy was greatest in Sarasota County in March (Figure 2.15). Boat fuel sales rose in February and March and remained high throughout the summer months, and there was a small increase in sales in November (Figure 2.16). However, no significant correlations were found between angler interaction rates and hotel occupancy or boat fuel sales ($p=0.99, p=0.077$, respectively).

### 2.3.2 Depredation related to Red Tide ($K. brevis$) Blooms and Boating Activity

Dolphin-angler interaction rates were significantly different between $K. brevis$ lag months ($0.347$ dolphin-angler interactions/lag month), $K. brevis$ bloom months ($0.089$ dolphin-angler interactions/bloom month), and non-bloom periods ($0.133$ dolphin-angler interactions/non-bloom month) ($p=0.031$) (Figure 2.17). A post-hoc test revealed that dolphin-angler interaction rates for $K. brevis$ bloom and lag periods were significantly different ($p=0.024$). Significant differences were also found between HAB periods and interaction rates with regard boat fuel sales ($x_{bloom}=1.58\times10^{-5}$, $x_{non-bloom}=3.04\times10^{-5}$, $x_{lag}=3.77\times10^{-5}$; $p=0.034$). A post-hoc Tukey test revealed that the greatest differences was between red tide and lag periods ($p=0.052$).
2.3.3 Habitat Selection

Depredating and control animals were not found to spend significantly different amounts of time in different habitats (Fig. 2.18). However, depredation by three focal animals during the 2007-2008 was only seen to occur in three habitats: open bay (around a fishing pier), channel, and pass.

2.3.4 Proximity to Fishing Boats and Lines

Depredator focals were not significantly more likely to be within 100 m of an actively-fishing boat than were controls ($x_{depredator} = 0.05$, $SD=0.01$; $x_{control} = 0.015$, $SD=0.04$; $p=0.32$). However, depredator focals were significantly more likely to be within 50 m of active fishing lines ($x_{depredator} = 0.10$, $SD=0.21$; $x_{control} = 0.01$, $SD=0.03$; $p=0.02$).

2.3.5 Home Range

No statistically significant difference was found between control or depredator focals for 95% kernel home range ($x_{depredator} = 94.02$ km$^2$, $SD=73.28$; $x_{control} = 135.86$ km$^2$, $SD=83.15$; $p=0.304$) or 50% core kernel areas ($x_{depredator} = 14.88$ km$^2$, $SD=13.46$; $x_{control} = 22.33$ km$^2$, $SD=15.92$; $p=0.330$) (Figure 2.4).

2.3.6 Pier

Numbers of lines (bait, lure, or total) were not predictors of dolphin presence. For baited lines and dolphin presence, lines with lures and dolphin presence, and total number
of lines and dolphin presence, logistic regression $R^2$ values were 0.001, 0.004, and 0.001, respectively.

March 2008 had the greatest means for both total fishing and dolphin presence, however, no significant differences between pier survey months were found for any tested conditions, including dolphin presence ($p=0.513$), number of baited lines ($p=0.073$), number of lines with lures ($p=0.262$), and total number of lines ($p=0.136$) (Figure 2.19). Total fishing effort was significantly greater during the rainy season than the dry season ($x_{\text{rainy}}=5.30368$, SD=5.31; $x_{\text{dry}}=5.12999$, SD=5.13; $p=0.02$). However, there was no significant difference between seasons for dolphin presence ($p=0.301$), baited lines ($p=0.44$), or lines with lures ($p=0.20$).

Dolphin presence at piers was found to vary significantly with time of day ($p=0.001$). Specifically, a post hoc test revealed that there were significantly more dolphins at the pier at 16:00 than during 09:00–14:00 (Figure 2.20). Fishing effort also varied significantly with time of day ($p<0.001$) increasing in the early morning and remained elevated through much of the day (Figure 2.20).

### 2.3.7 Activity Budgets

Depredating focals were found to spend significantly more time milling ($p=0.05$) and significantly less time engaging in activities like foraging ($p=0.05$) and traveling ($p=0.02$) (Figure 2.21). When the non-natural and natural foraging strategies were collapsed, there were marginally to significant differences with depredators spending more time milling ($p=0.056$) and less time traveling ($p=0.02$) (Figure 2.22).
Individual activity budgets reveal the differences between depredators and their control counterparts (Figure 2.23). In total, four depredator focal animals (BEGR, F106, F109, and F232) were recorded engaging in angler-interaction behavior as a dominant activity during a follow.

2.3.8 Depredation

During pier surveys and behavioral focal follows, 58 acts of depredation (including attempted depredation, line depredation, provisioning, and scavenging) by a total of four animals were documented. Of these four animals, one was a known animal (BEAN) from the Eckerd College Dolphin Program in St. Petersburg, Florida, and the other three dolphins were focal Sarasota Bay residents (BEGR, F106, F109). Overall, the most common type of depredation was provisioning, followed by scavenging, attempted depredation, and line depredation (Figure 2.24). However, each dolphin appeared to exhibit a different depredation strategy. BEGR depredates solely by provisioning. F109 was only seen scavenging and F106 engaged in all four types of depredation behavior. BEAN depredated mainly by taking or attempting to take fish off fishing lines.

After a dolphin depredated the first fish, in 95% of documented cases the animals continued to engage in a depredation or behaviors like begging or patrolling. At least 11 different species of fish were depredated (or attempted). No particular fish species was favored by dolphins. However, the numbers are high for bait fish and sardines as this is what was commonly used by anglers and thus, fed to dolphins.

The 2007-2008 reports from other SDRP field initiatives showed that of the 12 confirmed depredation events witnessed (not including begging or patrolling), 42% were
scavenging, 25% were provisioning, 17% were attempted depredation, and 17% were line depredation. When added to the total of depredation events collected for this study, provisioning was the most common type of depredation, followed by scavenging, attempted depredation, and line depredation (Figure 2.25).

**Angler or Boater Reaction to Depredation**

Few people engaged in the recommended tips of moving locations or reeling in their line to avoid further interactions with the dolphin following a dolphin depredation event (Figure 2.26). Most people encouraged another interaction by either continuing to feed the dolphin or summoning it closer to the pier or boat (Figure 2.27). Other anglers or boaters engaged in negative behavior towards the dolphin such as taunting or intentionally casting at the animal (Figure 2.26). Nineteen percent of anglers or boaters showed no change in behavior following a dolphin depredation event (Figure 2.26).

**2.3.9 Social Behavior**

**Group Size**

The mean depredator focal follow group size of 2.3 (SD=0.7) was not significantly different from the control focal follow group size of 3.3 (SD=1.4; \(p=0.087\)). From the SDRP database sightings, the mean depredator focal group size (\(x=5.0\), SD=1.2) was significantly less than the control focal group size (\(x=6.5\), SD=1.6; \(p=0.052\)). Group size during angler-interaction behavior (\(x=3.0\), SD=1.1) was significantly less than the overall group mean for the depredator focal (\(x=5.0\), SD=1.2; \(p=0.010\)) (Figure 2.27).
Association Patterns

Confirmed Sarasota depredator dolphins that spent greater than or equal to 10% of follow time with a focal accounted for 5.5% of control focal and 32.1% of depredator focal associates. However, neither control nor depredator focals spent significantly more time with depredator associates than non-depredator associates ($p=0.759$, $p=0.737$, respectively). None of the control focal animals had a depredator as their most common associate, but 25% of depredator focals had a fellow depredator as their most common associate.

From the SDRP database, 20% of control focal and 24.1% of depredator focal top associates (COA $\geq 0.10$) were confirmed depredators. However, neither control nor depredator focal dolphins had significantly greater COAs with depredator associates than with non-depredator associates ($p=0.659$, $p=0.095$, respectively). Twenty-five percent of focal controls’ and 50% of focal depredators’ most common associates were confirmed depredators. Control focals had significantly higher levels of association with their top associate than did depredator focals (control $x=0.198$, depredator $x=0.178$, $p=0.0502$).

2.3.10 Case Studies: Beggar and F106

Beggar

Beggar (BEGR) is a confirmed male resident of the Sarasota Bay dolphin population, first observed as a subadult in 1990. This animal has never been temporarily captured for a health assessment, because he is rarely outside the deep water of the ICW. Beggar was first seen on 10 August 1990 already exhibiting begging behavior.
A typical BEGR begging sequence begins in the slow speed zone with the dolphin surfacing approximately 25 m in front of and perpendicular to the bow of an approaching boat (Figure 2.28). Beggar then parallels the vessel (less than a 1 m in distance) on either the starboard or port stern and rolls with his ventral side facing the boat. Beggar’s heading remains in line with boat (Figure 2.28). If the animal is further enticed either by a boater putting hands over the boat’s gunwale or offering fish, BEGR will spyhop out of the water with his mouth open (Figure 2.28). Beggar further pursues the boat by swimming just centimeters below the propeller, and surfacing on the right or left side of the engine (Figure 2.28).

Beggar has been observed interacting with a boat in 91% of 317 sightings from January 1990 through August 2008. From the 14 hours of behavioral focal follows that were conducted in summers 2007 and 2008, BEGR spent nearly 69% of time begging from watercraft. This dolphin has never been seen outside of approximately a 6.8 km extent of the ICW in which 2.2 km are slow speed for vessels (Cunningham-Smith et al. 2006). BEGR depredates purely through provisioning and has also been suspected of teaching other dolphins how to beg (Cunningham-Smith et al. 2006). In at least one instance, the calf of a begging female associated with BEGR died with numerous indications of human interactions (Cunningham-Smith et al. 2006).

Beggar is a well-known “attraction” and bait to feed the dolphin has been blatantly sold to boaters from a nearby marina. In 2006, NMFS sent a number of businesses in this area a letter and education packet reminding them of the MMPA, specifically concerning the illegality of feeding wild dolphins (Stacey Horstman, NMFS, personal communication). Included in the letter were responsible viewing guidelines for
businesses such as avoiding advertisements that depict people feeding or touching a wild dolphin (NOAA 2006b).

A study initiated in 1997 compared pre and post educational efforts, and showed little success in reducing BEGR-human interactions in the absence of marked vessels dedicated to reducing interactions (Cunningham-Smith et al. 2006). The 1997 Beggar study did not distribute educational information to the numerous businesses around the area, but instead focused on educational efforts within the waterway through direct interactions with boaters and increased signage (Cunningham-Smith et al. 2006). By distributing “Dolphin-Friendly Fishing and Viewing Tips” cards to local businesses and organizations frequented by boaters and anglers, the expectation was that a broader audience could be reached and education would become effective before boaters or anglers were approached by BEGR (Figures 2.5, 2.6).

Cards were distributed throughout the Sarasota Dolphin home range, however only businesses from south of the Sarasota Bay Ringling Bridge to the Englewood area were included in this analysis. This enabled me to look at more fine-scale effects of educational efforts through card distribution. The area just south of the Sarasota Bay Ringling Bridge was included in a special effort to incorporate a large yacht marina, Marina Jacks. Vessels with greater than a 5 foot draft docked at this marina only have two options for reaching the Gulf of Mexico: travel 21 km north to reach Longboat Pass or 25 km south (through BEGR’s range) to pass through Venice Inlet. Between January 2008 and May 2008, 4,680 cards were distributed to 28 different businesses or organizations within this area, including Marina Jacks. Major points of distribution included bait and tackle shops, boat-rental agencies, and waterfront restaurants.
The months of May-August 2007 were chosen as pre-card distribution months and for post-card distribution, the months of May-August 2008 were selected. The same four summer months were selected for pre and post distribution comparison in order to control for ecological effects of prey availability and seasonal effects of tourist seasons in the area. Although distribution began in January 2008, the decision was made to not to analyze for educational effects until May 2008 in order to allow time for card dissemination from their initial distribution point to the public.

During the selected pre and post time frames, the number of sightings, the total length of time across sightings, and if BEGR was begging and provisioned were recorded. A provisioning rate was calculated by dividing the total number of provisioning events by the total observation hours. In May-August 2007, BEGR was sighted 14 times (276 min of observation), was observed begging in all sightings, and was provisioned seven times by five different boaters. For 2007, Beggar’s provisioning rate was 1.522 provisioning events per hour. In May-August 2008, BEGR was sighted 16 times (696 min of observation). Beggar was again observed begging in all sightings and provisioned on 12 incidents by seven different boaters. For 2008, Beggar’s provisioning rate was 1.034 provisioning events per hour, a 32% decrease from 2007.

More specific data were also collected during summer 2007 and 2008 focal follows. In 2007 and 2008, 240 min and 600 min, respectively, of behavioral data were collected. Beggar was seen begging 67% of the time in 2007 and 69% of the time in 2008. The dolphin was also recorded provisioning 1% of the time in 2007 and 4% of the time in 2008. In 2007, during each follow, BEGR was provisioned three times by two separate boats; a provisioning rate of 1.5 provisioning events/hour. In 2008, BEGR was
provisioned three times in the first follow, twice in the second follow, once in the third and fourth follow, and four times by two boats in the fifth follow. The provisioning rate declined by 27% in 2008 to 1.1 provisioning events/hour.

The “Dolphin-Friendly Fishing and Viewing Tips” cards were well received and were readily accessible to boaters and anglers at numerous locations within the immediate area. It seems from preliminary analyses showing an approximately 30% decline in human interactions with Beggar that the cards may have had an important educational impact and were successful in reducing dolphin-angler interactions in this particular case study.

F106

F106, calf of F191, was a male resident of the Sarasota Bay dolphin community seen 773 times since his birth in 1981. F106 met male pair bond criteria with FB06 since 2005 (Owen et. al 2002). Pair bonds are a common strategy among male bottlenose dolphins in Sarasota Bay (Owen et. al 2002; Wells 1991, 2003). FB06 stranded on 12 June 2006 with fishing hooks, line, and a lure in his mouth and throat (Wells et al. 2008). The circle hook and lure in the dolphin’s throat were considered to be the cause of death (Wells et al. 2008). FB06 was only seen engaging in an angler interaction on 19 May 2006 when FB06 was noted as “stalking a fishing boat.” FB06, a Sarasota Bay resident born in 1984 to FB71, was seen a total of 568 times before his death.

F106 was first recorded engaging in an angler interaction about two months following FB06’s death. On 24 July 2006, F106 was reported as being taunted by anglers at Anna Maria City Pier who were dipping fish hooked on their lines in and out of the
water. Since that date, F106 has been recorded as engaging or possibly engaging in angler interaction behavior in 33 sightings. Specifically, during pier surveys and focal follows of 2007, F106 engaged in 35 acts of depredation (including scavenging, attempted depredation, line depredation, and most commonly, provisioning) at Anna Maria City Pier. F106 was never observed to entangle in or ingest fishing gear.

From visual and acoustic pier observations, it became obvious that F106 was using the pier as a foraging ground. Data from a continuously recording HTI-96 hydrophone installed underneath the pier showed that F106 echolocated during at least four depredation acts. Also, on 19 May 2007, F106 spent 5.58 continuous hours within 200 m of Anna Maria City Pier, engaged in at least five depredation acts, and spent 89.9% of this time milling or patrolling. On this day, F106 spent at least 2.85 hours within 15 m of at least one fishing line. Four other groups of dolphins traveled by the pier during the day and F106 never joined or socialized with any of the passing dolphins.

A typical behavioral pattern involved F106 repeatedly circling the pier, about 10-20 m from the edge. Before completing a full circuit around the pier, F106 would swim down and along the boardwalk where cast fishermen often fished. If F106 was being provisioned or successfully scavenged in an area, the dolphin would spend time tightly circling within 10-20 m of the depredated area.

F106 was last observed on 27 August 2007 patrolling Anna Maria City Pier. At this time, the dolphin was not seen to be entangled or to have lost a significant amount of weight, which can be indicative of fishing-gear obstructing feeding (Wells et al. 2008). However, due to the sighting frequency of F106 (seen on average of about 29 times per year), and the increasing frequency of F106’s involvement in angler interaction behavior,
I expect that F106 died due to either ingestion or entanglement of fishing gear. Because male pairs often work together cooperatively for foraging purposes (Owen et al. 2002; Wells 1991, 2003), I assume that F106 engaged in similar depredation type foraging strategies as FB06, therefore increasing the probability that F106 met a similar outcome to FB06’s. Moreover, in Sarasota Bay, ingestion of fishing gear, in all 12 documented cases was found to be fatal, and severe constrictive entanglements around the flipper or fluke insertions can cautiously be considered to lead to mortality (Wells et al. 2008).

2.4 Discussion

Overall, the most concerning result from this project was the recent and continuing increase in depredation behavior in the Sarasota Bay dolphin community. Dolphin-angler interactions rose both in frequency and in number of dolphins. The 10-year projection for the number of dolphin-recreational angler interactions in Sarasota Bay (based on the angler-interaction rate from 2003-2007 monthly photo-identification surveys) indicates that if unchecked by 2017, 84% of sightings will involve depredation or a related behavior. Furthermore based on the average rise in the number of resident dolphins depredating from 2004-2007, the conservative estimate suggests that in 2017, 29% of animals in the Sarasota Bay population will be seen engaging in angler-interaction behavior.
Behavioral transmission of angler interaction behaviors

Dolphins sometimes cooperatively forage with associates that share similar feeding strategies (Nowacek 1999, Mann and Sargeant 2003), so associates could serve as vectors for transfer of the depredation behavior (Whitehead et al. 2004). Behavioral transmission of long-line depredation has been hypothesized for a number of species in the South Pacific including populations of killer whales (*Orcinus orca*) and sperm whales (*Physeter macrocephalus*) (Donoghue et al. 2002). One major avenue for behavioral transmission and social learning that has been well established in the Sarasota Bay bottlenose dolphin community is between mothers and calves (Nowacek 2002, Wells 2003). Therefore, if depredation is a foraging strategy of the female, then it is conceivable that this behavior would be passed down to offspring especially as the calf learns to forage (Nowacek 2002, Wells 2003). For example, calves in Shark Bay, Australia hunted with foraging techniques exclusive to their mother’s repertoire including begging from boats (Mann and Sargeant 2003).

Anecdotally, maternal transmission of angler-interaction behaviors has been documented in three separate lineages in Sarasota Bay. The best example of maternal transmission of depredation involves the FB79 maternal lineage. FB79, a depredator and focal animal, was the first dolphin to ever be documented as patrolling a recreational fishing boat and has been seen on four separate occasions engaging in this behavior. FB79’s daughter, F109, has also been documented patrolling fishing boats and scavenging on anglers’ thrown-back fish. Furthermore, F109’s two-year-old female calf (1091) was confirmed scavenging a released fish when patrolling a fishing boat in a local pass with her mother in February 2008. The depredation event by 1091 marked the third
generation of depredators from the FB79 lineage. Another juvenile male focal animal, F232, that has been confirmed engaging in angler interaction behavior on multiple occasions was the calf of confirmed female depredator, FB75. FB75 died in 2006 from a lure lodged in her throat. Cunningham-Smith et al. (2006) reported on the case of 4-yr-old male BRD2 who was observed begging within the home range of BEGR several weeks before he died. His mother, BRDO, who frequented BEGR’s range, was observed begging on occasion, including when she was 11 months pregnant with BRD2.

The 3.5-year-old female (“Ginger”), daughter of control focal F127, stranded in December 2008 and was brought to Mote Marine Laboratory’s Dolphin and Whale Hospital for rehabilitation. Neither focal F127 nor calf “Ginger” had ever been observed engaging in angler interaction behavior. During her time in rehabilitation, “Ginger” refused to eat dead or struggling fish and would only eat live, swimming pinfish, mullet, ladyfish, and other local prey. This is further evidence that “Ginger” was not acclimated to dead or incapacitated prey and did not learn depredation as a foraging strategy from her mother, F127. Overall, the combination of evidence for the transmission of depredation through maternal lineages is strongly supported by anecdotal observations.

Because adult males were found to engage in depredation at a disproportionally high rate, this age-sex group may be another source for teaching the depredation behavior or more likely to incorporate the behavior into their foraging repertoire once learned. Most depredation behaviors appear to be favor solitary foragers, therefore making this non-natural foraging strategy ideal for unpaired males (Owen et al. 2002). In fact, all focal adult males seen depredating during 2007-2008 (BEGR, C354, FB78, F106) were
unpaired at the time. Also, in Western Australia, males were the most common group conditioned to human interactions, especially feeding (Finn et al. 2008).

However, results from this study do not strongly support the idea that depredator dolphins associate significantly more often with other angler interaction animals. Results from COAs and statistical analyses found no significant differences between control and depredator focals’ association patterns with other known angler interaction dolphins. Yet, because the nature of depredation foraging lends itself to a solitary strategy, it may be difficult to document transmission or social learning of the behavior. For example, overall group size was significantly smaller for depredator focals when compared to controls and group size was significantly reduced when focals were depredating. It is possible that learning of angler interaction behavior takes place on only a few occasions prior to execution of the behavior by the animal. A social network analysis during a dolphin’s different life stages would prove useful in understanding and pinpointing the transmission of angler interaction behaviors among the Sarasota Bay dolphin community.

_Dolphin depredation as a result of prey resource depletion and increased anglers_

Results indicate that the greatest rates of dolphin-angler interactions occur when there is prey depletion and increased numbers of anglers on the water. Other areas experiencing similar issues regard the depredation problem as a consequence of direct competition for resources between anglers and dolphins (Peddemors 2001, Read 2008). The greatest rates of dolphin-angler interactions in Sarasota Bay were in March, which corresponds with the height of the tourist and seasonal resident period in the Sarasota county area. Boat fuel sales data from Cannons Marina show a substantial increase in
sales between February and March. Although the overall yearly rates of hotel/motel and boat fuel did not correlate with yearly dolphin-angler interaction rates, it may be possible that in this particular month when depredation rates, hotel/motel occupancy, and boat fuel sales all rise, there is an increase in the number of boaters and anglers on Sarasota waters therefore increasing the probability of a dolphin-angler interaction.

March is also part of Sarasota’s winter season when dolphins spend more time foraging in passes and coastal Gulf habitats than in seagrass meadows (Wells 1991, 2003). Prey in Gulf waters are not evenly dispersed, making fish potentially more difficult to locate possibly forcing dolphins to spend more time searching for prey (Wells et al. 1980, Wells 1991, 2003). Passes, corridors to Gulf waters, concentrate anglers to the ideal fishing conditions; the combination of deep water and a strong current. Anecdotal reports from local anglers suggest that March is a time when fish is difficult to find and catch, but March 2008 was found to have the greatest mean fishing effort and dolphin presence at surveyed fishing piers. The combination of these factors increases the probability for dolphin-angler interactions.

The need for energy due to lack of prey and diminished energy stores can also explain the significant peak in angler interactions and angler-interactions per unit fuel sales following a red tide bloom. During a bloom, dolphin prey can be severely depleted as the result of fish kills from brevetoxin (Gannon et al. 2009). Furthermore, dolphins’ poor body condition from lack of prey may be exacerbated from the toxic effects of brevetoxin (Bossart et al. 1998, Bossart 2006, Wells et al. 2006, Fire et al. 2008). As a result, this study suggests that dolphins may turn to anglers and boaters as a potential source of food. Significantly greater rates of dolphin-angler interactions take place
during the lag months following a *K. brevis* bloom. During a lag period, anglers are expected to begin to return to the water for recreation; no longer avoiding aerosolized brevetoxins that cause respiratory irritation (Kirkpatrick *et al.* 2004). Although anglers are again fishing in the bay and coastal waters, fish populations are still low and will take some months to recover (Gannon *et al.* 2009). Therefore, it is reasonable to assume that dolphins might depredate bait or catch to sustain them during this period of environmental recovery. A continuation of this study conducted during a *K. brevis* bloom and the following three month lag period would be useful in determining fine-scale depredation effects as a direct result of red tide.

*Depredation as part of the foraging repertoire*

If depredation behaviors are based exclusively on prey resource availability, then it would expected that once resources returned to sustainable levels, dolphins would no longer engage in angler interaction behavior and again forage naturally. However, data from this study show that this is not necessarily the case. Conservative estimates show that dolphin-angler interactions have been on the rise since 2003. Year 2007 was the highest on record for dolphin-angler interactions despite the lack of a major red tide bloom. Thus prey depletion may trigger spikes in the behavior, but is not the single factor explaining dolphin depredation.

Activity budgets compared between control and depredator focal dolphins showed that control animals spent significantly more time foraging naturally while depredator dolphins allotted more time to other activities such as milling and depredation behaviors. A previous study in Sarasota Bay by Waples (1995) showed summer dolphin activity
budgets and control dolphins had the same order of activities (traveling, milling, foraging, socializing, and resting) and similar values for behaviors. When Waples’ (1995) data are compared to depredator focal dolphins, the order of activities varies due to the inclusion of angler interaction behaviors and the differences between activity budget categories were much greater. These data allow for strong conclusions about the behavior of depredating dolphins since these dolphin were found to differ not only from control counterparts but also from a larger study dedicated to understanding the natural activity patterns of bottlenose dolphins in Sarasota Bay. Depredating focal dolphins are modifying their daily activities to incorporate depredation behaviors. Natural activities such as natural foraging and traveling are occurring at a lower frequency while other behaviors such as milling and depredation are occurring at a much greater rate.

Depredator and control focal activity budgets were still marginally to significantly different in traveling and milling activity when non-natural, depredation foraging strategies were collapsed together into a single foraging category. This is evidence that depredation for some dolphins has become part of the foraging behavior repertoire. Depredator animals have rescheduled their natural activity budgets to adjust for angler interaction behaviors, now investing more time into behaviors that are energetically conducive to foraging via depredation. However, depredation behaviors are not necessarily energetically less costly than natural foraging behaviors. If depredation was in fact a low cost foraging strategy, more dolphins would be expected to frequent fishing piers on days and times when more anglers were present. However, statistical analysis showed that none of the measures including the total number of anglers, number of baited lines, and number of lines with lures were significant predictors of dolphin presence.
This is further supported by F106 echolocating during depredation acts. Echolocation is a potentially costly sensory activity, in terms of both energetics and ecology, and it is thought that dolphins use echolocation sparingly (Nowacek 1999, Gannon et al. 2005).

The effects of depredation behavior on habitat and home range

Although initial analysis proved that depredators did not spend significantly more or less time in different habitats or have smaller home ranges and core areas, I think it is necessary to consider more habitat features before concluding that dolphin habitat selection or home range in not affected by the incorporation of depredation. From this study, depredation by focal animals was only witnessed in three habitats: channel, pass, and open bay (around a fishing pier). A measure of distance to various habitats from focal follow waypoints would allow me to determine habitat selection for focals (Allen et al. 2001). For instance, I would expect that depredator focals are more likely to be in habitats near passes, channels, and fishing piers and incorporate them into their home range since there would be ample opportunities to depredate. Smaller scale habitat selection is already supported by the results that depredator focals were significantly more likely to be within 50 m of an active fishing line than were control focals.

A further habitat analysis is especially necessary for management purposes since varying habitat usage due to depredation could potentially hold increased predation and mortality consequences outside possible injury or death caused by recreational fishing gear (Wells et al. 2008). Natural dolphin foraging behavior in Shark Bay, Australia shows that dolphins foraged less than expected in habitat with the greatest levels of prey resources, but with increased risk of tiger shark encounters (Heithaus and Dill 2002). On
the west coast of Florida, sharks are more common in deeper habitats such as passes, an area which also concentrates anglers, than in shallow waters such as seagrass meadows (Wells et al. 1980). If dolphins are spending more time in passes or just nearby seeking depredation foraging opportunities, probabilities for shark attacks may increase for these dolphins having further negative impacts on the Sarasota dolphin community. A complement to this analysis would to determine and compare survivability rates for depredating and control animals.

Public awareness and education: the key to reducing dolphin depredation

Educating the local and visiting public, specifically anglers and boaters, is a valuable means of reducing depredation. These data have shown that provisioning and scavenging combined were the most common forms of depredation accounting for 79% of all depredation within the Sarasota Bay study area. These two behaviors could be mostly extinguished in the Sarasota dolphin community if the human component involved in these forms of depredation was controlled. Yet, the majority of angler and boater reactions to dolphin depredation events were not ideal, with 73% of reactions either showing no change in behavior or encouragement of the dolphin to continue interacting.

One mechanism of change for human behavior is education and outreach. The “Dolphin-Friendly Fishing and Viewing Tips” cards have been designed to target both anglers and boaters. The first five tips listed on the card are necessary for extinguishing the majority of depredation types, specifically the most common provisioning and scavenging, in the dolphin population. These five tips include federal laws and
guidelines like never feed wild dolphins, reuse or share leftover bait, reel in your line if
dolphins appear, change locations if dolphins show interest in bait or catch, and release
catch quietly away from dolphins. If anglers and boaters heeded this information, all
types of depredation behaviors would decline since awareness of how to appropriately
react to dolphin-angler interaction would be heightened.

Making depredation difficult or less of an opportunity for dolphins would reduce
depredation and stop the increasing trend of the number of animals in the population
depredating, as the behavior would no longer be reinforced with a fish reward. The fewer
animals in the population utilizing depredation as a foraging strategy or given the
opportunity to learn the behavior, the lesser the chance that depredation will continue to
spread through the population via behavioral transmission.

Education and outreach have the ability to reach a large portion of the target
audience in a very positive manner. By saturating target sites frequented by visiting and
local anglers and boaters of all experience levels, the probability of the target audience
becoming aware and informed about the issue of dolphin depredation prior to an
encounter greatly increases. Overall, the “Dolphin-Friendly Fishing and Viewing Tips”
cards have been well-received by the vast majority of businesses and organizations and
there has been an overwhelming response in requests for more cards. The apparent
decline in interactions with Beggar since card distribution in his home range is quite
encouraging, and worthy of continued monitoring.
Table 2.1 Working definitions of activity categories as defined for the Sarasota Bay dolphin community. Definitions taken from SDRP Manual for Field Research and Laboratory Activities (2006).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill</td>
<td>Non-directional movement, and often occurs in conjunction of other activities.</td>
</tr>
<tr>
<td>Feed</td>
<td>Recorded whenever a dolphin is observed with a fish in its mouth.</td>
</tr>
<tr>
<td>Probable Feed</td>
<td>Recorded when there are indications of feeding, but the feeding cannot be confirmed (e.g., active milling by a dolphin with frigate birds diving on it).</td>
</tr>
<tr>
<td>Travel</td>
<td>Directed movement, including zig-zag movement.</td>
</tr>
<tr>
<td>Play</td>
<td>Involves interactions with objects other than dolphins (e.g., throwing a stingray repeatedly)</td>
</tr>
<tr>
<td>Rest</td>
<td>Involves slow, quiescent activity in the absence of other identifiable activities.</td>
</tr>
<tr>
<td>Leap, Tailslap, Chuff</td>
<td>Includes individual aerial or acrobatic behaviors of any kind.</td>
</tr>
<tr>
<td>Social</td>
<td>Includes all active interactions with other dolphins, including contact, chasing/following, sexual interactions, etc.</td>
</tr>
<tr>
<td>With Boat</td>
<td>Includes all cases where the dolphins are interacting with a boat, including bow riding, stern wake riding, making figure-eights ahead of the boat, etc. This could be considered a sub-category of play, but it should be recorded separately in addition to play.</td>
</tr>
<tr>
<td>Other</td>
<td>A catch-all category to accommodate the dolphins’ behavioral flexibility. The behavior should be described in the comments section of the sighting data sheet.</td>
</tr>
</tbody>
</table>
Table 2.2 Depredation and related working definitions created to quantify dolphin behavior when interacting with anglers, fishing vessels, or fishing piers.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patrol</td>
<td>Dolphin is traveling in repeated directions along fishing lines, fishing boats or pier edge or when a dolphin continues to mill after multiple surfacings near fishing boats, fishing lines, or pier. Dolphin must be within at least 15 m of boats, lines or pier.</td>
</tr>
<tr>
<td>Beg</td>
<td>Dolphin is behaving in way to elicit food from a person such as bringing head out of the water and/or opening mouth at surface.</td>
</tr>
<tr>
<td>Scavenge</td>
<td>When a dolphin is observed feeding on an angler’s bait or catch that was thrown back into the water (not on an angler’s line). The intent of the angler was not to feed the dolphin but rather to throw back unwanted bait or catch.</td>
</tr>
<tr>
<td>Line</td>
<td>When a dolphin successfully takes and feeds on the bait or catch from an angler’s line. Even if the dolphin only takes part of the fish from the angler’s line, this is still considered a successful depredation event.</td>
</tr>
<tr>
<td>Depredation</td>
<td></td>
</tr>
<tr>
<td>Attempted</td>
<td>When dolphin attempts to take bait or catch off an angler’s line but is unsuccessful or aborts the behavior before taking bait or catch (e.g., dolphin chases line with catch but line is removed from the water before dolphin takes catch). This category is also used when it is not possible to determine the success of the depredation attempt.</td>
</tr>
<tr>
<td>Provision</td>
<td>Dolphin intentionally being fed bait, catch, or other items by individual(s). Person(s) may be directly dropping item in dolphin’s mouth or throwing item at dolphin.</td>
</tr>
</tbody>
</table>
Table 2.3  Location information on the six piers and jetties within the home range of the Sarasota dolphin community. Also included is the duration of effort and total hours of survey monitoring for each pier or jetty.

<table>
<thead>
<tr>
<th>Pier</th>
<th>Latitude, Longitude</th>
<th>Location Description</th>
<th>Duration of effort</th>
<th>Total hours of effort (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anna Maria Historic City Pier</td>
<td>27.5345, -82.7305</td>
<td>North end of Anna Maria Island inside Tampa Bay</td>
<td>May-July 2007; October 2007-April 2008</td>
<td>169.75</td>
</tr>
<tr>
<td>Rod and Reel Pier</td>
<td>27.5383, -82.7393</td>
<td>North end of Anna Maria Island at the mouth of Tampa Bay</td>
<td>May-June 2007; October 2007-April 2008</td>
<td>109.78</td>
</tr>
<tr>
<td>Bradenton Beach City Pier</td>
<td>27.4668, -82.6939</td>
<td>South east side of Anna Maria Island just south of the Cortez bridge</td>
<td>October 2007-April 2008</td>
<td>50.51</td>
</tr>
<tr>
<td>Venice Pier</td>
<td>27.0725, -82.4529</td>
<td>In the Gulf of Mexico south of Venice inlet</td>
<td>July 2007</td>
<td>8.19</td>
</tr>
<tr>
<td>North Venice Jetty</td>
<td>27.1129, -82.4697</td>
<td>Rock jetty bordering the North edge of Venice inlet</td>
<td>May-June 2007</td>
<td>18.57</td>
</tr>
<tr>
<td>South Venice Jetty</td>
<td>27.0725, -82.4529</td>
<td>Rock jetty bordering the South edge of Venice inlet</td>
<td>May-June 2007</td>
<td>18.08</td>
</tr>
</tbody>
</table>
Table 2.4 Depredator and control focal dolphins selected for behavioral follows in summers of 2007 and 2008. Depredator dolphins had been observed engaging in angler interaction behavior or were entangled in monofilament on more than one occasion. Paired control animals have never been observed interacting with anglers and were also chosen for being the same sex, and having a similar age (+/-5 years) and range to the focal depredator. Mothers with ‘*’ engaged in angler interactions behavior. (BEGR’s birth year is a minimum based on date for first observation).

<table>
<thead>
<tr>
<th>Focal type</th>
<th>Focal dolphins</th>
<th>Sex</th>
<th>Birth year</th>
<th>Mother</th>
<th>Summer 2007 follow time (min)</th>
<th>Summer 2008 follow time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depredator</td>
<td>BEGR M</td>
<td></td>
<td>&lt;1990</td>
<td>Unknown</td>
<td>240</td>
<td>600</td>
</tr>
<tr>
<td>Control</td>
<td>F110 M</td>
<td></td>
<td>1984</td>
<td>Unknown</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Depredator</td>
<td>C354 M</td>
<td></td>
<td>1992</td>
<td>FB35</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Control</td>
<td>C834 M</td>
<td></td>
<td>1992</td>
<td>FB83</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Depredator</td>
<td>FB78 M</td>
<td></td>
<td>1972</td>
<td>Unknown</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Control</td>
<td>FB36 M</td>
<td></td>
<td>1972</td>
<td>Unknown</td>
<td>120</td>
<td>246</td>
</tr>
<tr>
<td>Depredator</td>
<td>FB79 F</td>
<td></td>
<td>1979</td>
<td>Unknown</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Control</td>
<td>FB65 F</td>
<td></td>
<td>1983</td>
<td>FB67</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Depredator</td>
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<td>1981</td>
<td>F191</td>
<td>240</td>
<td>X</td>
</tr>
<tr>
<td>Control</td>
<td>FB10 M</td>
<td></td>
<td>1981</td>
<td>FB63*</td>
<td>120</td>
<td>X</td>
</tr>
<tr>
<td>Depredator</td>
<td>F109 F</td>
<td></td>
<td>1995</td>
<td>FB79*</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Control</td>
<td>F127 F</td>
<td></td>
<td>1995</td>
<td>FB13</td>
<td>240</td>
<td>360</td>
</tr>
<tr>
<td>Depredator</td>
<td>F222 M</td>
<td></td>
<td>1998</td>
<td>Unknown</td>
<td>234</td>
<td>240</td>
</tr>
<tr>
<td>Control</td>
<td>F196 M</td>
<td></td>
<td>1998</td>
<td>F101</td>
<td>114</td>
<td>363</td>
</tr>
<tr>
<td>Depredator</td>
<td>F232 M</td>
<td></td>
<td>2002</td>
<td>FB75*</td>
<td>240</td>
<td>363</td>
</tr>
<tr>
<td>Control</td>
<td>F224 M</td>
<td></td>
<td>2002</td>
<td>FB27</td>
<td>240</td>
<td>360</td>
</tr>
</tbody>
</table>
Table 2.5  Dolphin-angler interaction rates (including all behaviors such as patrol, beg, scavenge, attempted depredation, line depredation, and provision) in Sarasota Bay, Florida for 2000-2007. Rates were modeled from two different data sets: monthly photo-identification surveys and all sighting effort. Interaction rates were also analyzed including and excluding the male BEGR, a well-known beggar. Interaction rates were calculated by dividing the number of interactions by the number of boat-days for a given year.

### Monthly Photo-identification Estimates

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of boat-days</th>
<th>No. of interactions</th>
<th>Interaction rate</th>
<th>No. of interactions (BEGR excluded)</th>
<th>Interaction rate (BEGR excluded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>95</td>
<td>7</td>
<td>0.074</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2001</td>
<td>92</td>
<td>4</td>
<td>0.043</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2002</td>
<td>107</td>
<td>12</td>
<td>0.112</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2003</td>
<td>103</td>
<td>11</td>
<td>0.107</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2004</td>
<td>102</td>
<td>13</td>
<td>0.127</td>
<td>1</td>
<td>0.010</td>
</tr>
<tr>
<td>2005</td>
<td>98</td>
<td>16</td>
<td>0.163</td>
<td>3</td>
<td>0.031</td>
</tr>
<tr>
<td>2006</td>
<td>107</td>
<td>22</td>
<td>0.206</td>
<td>10</td>
<td>0.093</td>
</tr>
<tr>
<td>2007</td>
<td>117</td>
<td>37</td>
<td>0.316</td>
<td>21</td>
<td>0.179</td>
</tr>
</tbody>
</table>

### All Sighting Effort

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of boat-days</th>
<th>No. of interactions</th>
<th>Interaction rate</th>
<th>No. of interactions (BEGR excluded)</th>
<th>Interaction rate (BEGR excluded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>357</td>
<td>7</td>
<td>0.020</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2001</td>
<td>377</td>
<td>43</td>
<td>0.114</td>
<td>1</td>
<td>0.003</td>
</tr>
<tr>
<td>2002</td>
<td>250</td>
<td>15</td>
<td>0.060</td>
<td>1</td>
<td>0.004</td>
</tr>
<tr>
<td>2003</td>
<td>262</td>
<td>11</td>
<td>0.042</td>
<td>0</td>
<td>0.000</td>
</tr>
<tr>
<td>2004</td>
<td>188</td>
<td>14</td>
<td>0.074</td>
<td>1</td>
<td>0.005</td>
</tr>
<tr>
<td>2005</td>
<td>234</td>
<td>16</td>
<td>0.068</td>
<td>3</td>
<td>0.013</td>
</tr>
<tr>
<td>2006</td>
<td>231</td>
<td>38</td>
<td>0.165</td>
<td>16</td>
<td>0.069</td>
</tr>
<tr>
<td>2007</td>
<td>375</td>
<td>92</td>
<td>0.245</td>
<td>67</td>
<td>0.179</td>
</tr>
</tbody>
</table>
Table 2.6 Depredator dolphins in Sarasota Bay and their percent of the total population from 2000-2007 calculated from monthly photo-identification surveys and all sighting efforts. Estimates for the number of depredators to date include cumulative totals for known depredators in the population from past years until the present year.

### Monthly Photo-identification Surveys

<table>
<thead>
<tr>
<th>Year</th>
<th>Sarasota dolphin population</th>
<th>Depredators (confirmed)</th>
<th>Depredators (confirmed): % of pop.</th>
<th>Depredators (confirmed + possible): % of pop.</th>
<th>Depredators to date (confirmed): % of pop.</th>
<th>Depredators to date (confirmed + possible): % of pop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>175</td>
<td>3</td>
<td>1.71%</td>
<td>3</td>
<td>1.71%</td>
<td>3</td>
</tr>
<tr>
<td>2001</td>
<td>177</td>
<td>1</td>
<td>0.57%</td>
<td>1</td>
<td>0.57%</td>
<td>2</td>
</tr>
<tr>
<td>2002</td>
<td>178</td>
<td>1</td>
<td>0.56%</td>
<td>1</td>
<td>0.56%</td>
<td>2</td>
</tr>
<tr>
<td>2003</td>
<td>174</td>
<td>1</td>
<td>0.58%</td>
<td>1</td>
<td>0.58%</td>
<td>2</td>
</tr>
<tr>
<td>2004</td>
<td>175</td>
<td>1</td>
<td>0.57%</td>
<td>8</td>
<td>4.57%</td>
<td>2</td>
</tr>
<tr>
<td>2005</td>
<td>171</td>
<td>5</td>
<td>2.92%</td>
<td>5</td>
<td>2.92%</td>
<td>5</td>
</tr>
<tr>
<td>2006</td>
<td>170</td>
<td>11</td>
<td>6.47%</td>
<td>20</td>
<td>11.77%</td>
<td>12</td>
</tr>
<tr>
<td>2007</td>
<td>166</td>
<td>16</td>
<td>9.64%</td>
<td>22</td>
<td>13.25%</td>
<td>21</td>
</tr>
</tbody>
</table>

### All Sighting Effort

<table>
<thead>
<tr>
<th>Year</th>
<th>Sarasota dolphin population</th>
<th>Depredators (confirmed)</th>
<th>Depredators (confirmed): % of pop.</th>
<th>Depredators (confirmed + possible): % of pop.</th>
<th>Depredators to date (confirmed): % of pop.</th>
<th>Depredators to date (confirmed + possible): % of pop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>175</td>
<td>3</td>
<td>1.71%</td>
<td>3</td>
<td>1.71%</td>
<td>5</td>
</tr>
<tr>
<td>2001</td>
<td>177</td>
<td>4</td>
<td>2.26%</td>
<td>4</td>
<td>2.26%</td>
<td>6</td>
</tr>
<tr>
<td>2002</td>
<td>178</td>
<td>1</td>
<td>0.56%</td>
<td>3</td>
<td>1.69%</td>
<td>5</td>
</tr>
<tr>
<td>2003</td>
<td>174</td>
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<td>1.72%</td>
<td>3</td>
<td>1.72%</td>
<td>5</td>
</tr>
<tr>
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<td>1</td>
<td>0.57%</td>
<td>9</td>
<td>5.14%</td>
<td>4</td>
</tr>
<tr>
<td>2005</td>
<td>171</td>
<td>5</td>
<td>2.92%</td>
<td>5</td>
<td>2.92%</td>
<td>7</td>
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<tr>
<td>2006</td>
<td>170</td>
<td>17</td>
<td>10.00%</td>
<td>26</td>
<td>15.29%</td>
<td>20</td>
</tr>
<tr>
<td>2007</td>
<td>166</td>
<td>18</td>
<td>10.84%</td>
<td>29</td>
<td>17.47%</td>
<td>24</td>
</tr>
</tbody>
</table>
Table 2.7  Age class and sex distribution of documented confirmed depredating dolphins in Sarasota Bay (2000-2007). Percentages are based on the total number of depredating animals. The age of the animal at the time of the first angler interaction incident was used for the analysis.

<table>
<thead>
<tr>
<th>Age Class</th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
<th>Unknown</th>
<th>Percent Total</th>
<th>Percent Male</th>
<th>Percent Female</th>
<th>Percent Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calves</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6.98</td>
<td>2.33</td>
<td>2.33</td>
<td>2.33</td>
</tr>
<tr>
<td>Juveniles</td>
<td>14</td>
<td>8</td>
<td>5</td>
<td>1</td>
<td>32.56</td>
<td>18.60</td>
<td>11.63</td>
<td>2.33</td>
</tr>
<tr>
<td>Adults</td>
<td>18</td>
<td>14</td>
<td>4</td>
<td>0</td>
<td>41.86</td>
<td>32.56</td>
<td>9.30</td>
<td>0.00</td>
</tr>
<tr>
<td>Unknown</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>18.60</td>
<td>9.30</td>
<td>6.98</td>
<td>2.33</td>
</tr>
<tr>
<td>Totals</td>
<td>43</td>
<td>27</td>
<td>13</td>
<td>3</td>
<td>62.79</td>
<td>30.23</td>
<td>6.98</td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.1 Area surveyed monthly for Sarasota dolphin community members. Sarasota Bay and surrounding waters are located on the central west coast of Florida. Piers monitored are marked with red stars.
Figure 2.2  Mean error for estimating distance (n=2389) for the primary investigator (J.R. Powell). The line graph shows the average error of investigator estimates for actual distances included in the distance bin.
Figure 2.3 Aerial view of Anna Maria City Pier from 2008 Google satellite maps. The red outline encompasses the 200 m radius of area that was visually monitored during pier surveys. The black diamonds represent areas on the pier where the three field workers would monitor from. The radius and the field worker observation positions are similar for all pier and jetty survey sites.
Figure 2.4  The 95% kernel home range (stripes) and 50% kernel core area (dots) for focal dolphins from January 2004 through August 2008. Focal depredators are plotted on the left and focal controls on the right.
Figure 2.4 (Continued).
Figure 2.4 (Continued).
Figure 2.5 The first edition of the “Dolphin-Friendly Fishing & Viewing Tips” educational card. This version includes a single image on the front cover and more detailed text than the second version.
Dolphin-Friendly Fishing & Viewing Tips

Dolphins Need Your Help. Serious and even fatal dolphin injuries from interactions with recreational fishing gear and boats are on the rise. You can prevent injuries to dolphins and other sea life — and have a better day on the water — by following a few tips designed to protect marine animals. These “Best Practices” were developed by marine scientists and wildlife managers working with boaters, anglers, and fishing guides.

1) Never feed wild dolphins
   • It’s harmful and illegal
     - Feeding attracts dolphins by luring them dangerously close to fishing gear and boat propellers.
     - Feeding is illegal under the federal Marine Mammal Protection Act.

2) Reuse or share leftover bait
   • Freeze leftover bait for later or give it to your fishing buddies.
   • Dumping leftover bait may attract dolphins to fishing areas to beg or steal bait and catch.

3) Reef in the line if dolphins appear
   • Reef in and wait for the dolphins to pass to avoid losing your bait or catch and prevent potential harm to dolphins.
   • Never cast toward dolphins.

4) Change locations if dolphins show interest in bait or catch
   • Move away from dolphins to avoid unintentionally hooking one and prevent damage to gear or catch.

5) Release catch quietly away from dolphins when and where it is possible to do so without violating any state or federal fishing regulations
   • Feeding or attempting to feed a marine mammal in the wild is prohibited.

6) Check gear and terminal tackle
   • Inspect your gear often to avoid unwanted line breaks — even small amounts of gear in the water can be harmful to wildlife if entangled or ingested.

7) Use circle and corroboree hooks
   • Circle hooks may reduce injuries to fish, dolphins, and sea turtles.
   • Corroboree hooks (any hook other than stainless steel) eventually dissolve.

8) Stay at least 50 yards away
   • Stay a safe distance from wild dolphins to avoid causing potential harm.
   • Maintaining a safe distance helps keep dolphins wild.

9) Prevent wildlife entanglements
   • Recycle fishing line
     • Place broken or unused fishing line in a Monofilament Fishing Line Recycling Bin.
   • If recycling bins are available, place broken or unused fishing line that has been cut into pieces in a lidded trash can.

10) Stash your trash
    • Stashing is illegal and can be harmful to wildlife.
    • Collect any trash you’ve left behind and place it in a lidded trash can.

To report feeding or harassment of wild dolphins, call the NOAA Fisheries Southeast Enforcement Division at 1-800-163-1864.

To report an injured or entangled dolphin, or other wildlife, call the Florida Fish and Wildlife Conservation Commission at 1-888-406-FWCC (3922).

For more information on fishing line recycling bin locations, please visit: www.fishingline.org

For more information on dolphins and interactions with anglers, please visit: www.mote.org or www.answeddolphin.org

Figure 2.6 The second edition of the “Dolphin-Friendly Fishing & Viewing Tips” educational card. This version includes multiple images on the front cover as well as more condensed text. This version was also translated into Spanish.
Figure 2.7 “Dolphin-Friendly Fishing and Viewing Tips” card distribution from January to October 2008.
Figure 2.8  Dolphin-angler interaction rates for the Sarasota Bay dolphin community from 2000-2007 based on monthly photo-identification survey data. Interaction rates were analyzed including and excluding the male BEGR, a well-known beggar since 1990. Interaction rates were calculated by dividing the number of angler interactions by the number of boat-days for a given year.
Figure 2.9  Dolphin-angler interaction rates for the Sarasota Bay dolphin community from 2000-2007 based on all sighting effort. Interaction rates were analyzed including and excluding the male BEGR, a well-known beggar. Interaction rates were calculated by dividing the number of dolphin-angler interactions by the number of boat-days for a given year.
Figure 2.10 Data collected from monthly photo-identification surveys showing the percent of dolphins in the Sarasota Bay population engaging in angler interaction behavior from 2000-2007. Data sets plotted include confirmed incidents and confirmed plus possible incidents.
Figure 2.11  Data collected from all sighting effort showing the percent of animals in the Sarasota Bay population engaging in angler interaction behavior from 2000-2007. Data sets plotted include confirmed incidents and confirmed plus possible incidents.
Figure 2.12  Data collected from monthly photo-identification surveys showing the cumulative percentage of dolphins in the Sarasota Bay population from 2000 through the specified year that have been observed engaging in angler interaction behavior. Data sets plotted include confirmed incidents and confirmed plus possible incidents.
Figure 2.13  Data collected from all sighting effort showing the cumulative percentage of dolphins in the Sarasota Bay population from 2000 through the specified year that have been observed engaging in angler interaction behavior. Data sets plotted include confirmed incidents and confirmed plus possible incidents.
Figure 2.14 Monthly angler interaction rates for the Sarasota Bay dolphin community from 2000-2007 based on monthly photo-identification surveys (“Avg surveys”) and all sighting effort (“Avg all effort”). Interaction rates were calculated by dividing the number of dolphin-angler interactions by the number of boat-days for a given month and then plotting the average for all months across all years.
Figure 2.15 Comparison of dolphin-angler interaction rates (based on monthly photo-identification surveys and all sighting effort) and average monthly Sarasota County hotel/motel occupancy rates from 2000-2007.
Figure 2.16 Comparison of angler interaction rates (based on monthly photo-identification surveys and all sighting effort) and boat fuel sales from Cannons Marina 2003-2007.
Figure 2.17 Average of dolphin-angler interaction rates in Sarasota Bay, Florida over three environmental periods based on Florida red tides (non-bloom, *K. brevis* bloom, and lag time following a bloom) from 2000-2007. Differences between HAB periods were significant ($p=0.031$).
Figure 2.18  Habitat use by focal dolphins during focal animal behavioral follows from
summer 2007 and 2008.  (n=16:  8 control focals, 8 depredator focals)
Figure 2.19 The mean presence of dolphins and the mean number of fishing lines (rigged with either bait or lures) by month during pier surveys from May-July 2007, and October 2007-April 2008.
Figure 2.20  The mean presence of dolphins and mean number of fishing lines (rigged with either bait or lures) by hour during pier surveys from May-July 2007, and October 2007-April 2008. Times were binned into one hour increments.
Figure 2.21  Overall mean activity budgets for control (n=8) and depredator (n=8) focal dolphins. Data compiled from summer 2007 and 2008 focal animal behavioral follows. Depredator focals spent significantly less time foraging ($p=0.053$) and traveling ($p=0.02$) and more time engaging in milling behavior ($p=0.054$).
Figure 2.22 Overall mean activity budgets for control (n=8) and depredator (n=8) focal dolphins. Forage is a combined category including natural and non-natural foraging strategies (feed, probable feed, beg, patrol, and provision). Data compiled from summer 2007 and 2008 focal animal behavioral follows. When the forage category is compiled, depredator focals still spent significantly less time traveling ($p=0.015$) and more time engaging in milling behavior ($p=0.0557$).
Figure 2.23  Individual mean activity budgets for control (left) and depredator (right) focal dolphins. Activity budgets are paired by depredator and their corresponding control counterpart. Data compiled from summer 2007 and 2008 focal animal behavioral follows.
Figure 2.23 (Continued).
Figure 2.23  (Continued).
Figure 2.24 Comparison of 58 depredation events documented during pier surveys and focal animal behavioral follows (2007-2008). Events are organized by depredation type.
Figure 2.25  Comparison of 70 total depredation events documented during pier surveys, focal animal behavioral follows, monthly population and photo-identification surveys, and various other research initiatives (2007-2008). Events are organized by depredation type.
Figure 2.26  Angler and boater reactions following a dolphin depredation event documented over 58 incidents during pier surveys and focal animal behavioral follows (2007-2008).
Figure 2.27 Overall depredator focal dolphin group size compared to mean group size when focal was depredating or engaging in depredation related behavior. Data analyzed from the Sarasota Dolphin Research Program 2000-2007.
Figure 2.28 Sequence of photos (in order from top to bottom) illustrating the order of behaviors that BEGR engages in when begging from boaters. The top photo illustrates the animal surfacing perpendicular to the vessel to first elicit attention. Secondly, the animal parallels the vessel, rolling to one side. Beggar then spyhops out of the water in the classic begging pose if fed or taunted. Finally, the animal pursues the boat within a few cm of the propeller. Photos are from different incidents in summer 2008 but were chosen for best illustrating the described behavior.
3. F201 Case Study: Exploring the Potential Link between Hearing Impairment and Depredation

3.1 Introduction

Optimal foraging theory predicts that animals will forage in a way to maximize energetic benefits so to increase their fitness (Emlen 1966, MacArthur and Pianka 1966). Exemplifying this theory is the depredation behavior in which a predator steals or damages a prey item already captured by some other process (Zollett and Read 2006). For hearing-impaired dolphins which are potentially less successful at natural foraging, depredation of injured fish struggling on a hook or released by anglers may yield more calories per energy expended than foraging for live fish.

Hearing in odontocetes is considered one of their most valuable senses. Bottlenose dolphins (*Tursiops truncatus*) rely upon the auditory sense for communication with conspecifics and navigation. Hearing is essential for both passive and active foraging strategies of dolphins (Jones and Sayigh 2002, Gannon *et al.* 2005, Nowacek 2005). Studies suggest that dolphins search for soniferous prey items by listening passively (Barros and Wells 1998, Gannon *et al.* 2005). Utilizing hearing abilities to
listen for prey may offer an energy efficient mechanism for the initial detection of prey as well as the determination of prey number, size, and location (Gannon et al. 2005).

Dolphins actively use echolocation for foraging, especially in the pursuit and capture phases of the hunt (Au 1993, Gannon et al. 2005). In Sarasota Bay, Florida, dolphin echolocation is more often associated with foraging behaviors than with non-foraging behaviors (Jones and Sayigh 2002, Nowacek 2005). Furthermore, echolocation is produced more often by solitary foragers in sand and seagrass-edge habitats (Nowacek 2005). Peak frequencies for dolphin echolocation clicks are typically between 100 kHz to 130 kHz (Au 1993, 2004), within range of the dolphin’s hearing sensitivities (Houser and Finneran 2006a, 2006b; Johnson 1967, Cook 2006, Finneran and Houser 2006). High frequency hearing impairment would affect the dolphin’s ability to use echolocation optimally (Au 1993, 2004; Nowacek 2005) while low frequency hearing impairment would limit prey detection by passive listening (Gannon et al. 2005) possibly forcing an animal to utilize alternative strategies, such as depredation.

Depredation of commercial and recreational fishing gear by cetaceans is a growing problem around the world (Broadhurst 1998, Secchi and Vaske 1998, Noke and Odell 2002, Somoa 2002, Cox et al. 2003, Lauriano et al. 2004, Brotons et al. 2008, and Sigler et al. 2008). Long-line fisheries depredation by larger odontocetes has recently been recognized as increasing in frequency, geographic extent, and severity (Read 2008). Depredation behaviors which bring dolphins near or in contact with fishing gear have the potential to seriously injure or kill the animals through entanglement or ingestion (Gorzelany 1998, Wells and Scott 1994; Wells et al. 1998, 2008). In the state of Florida, specifically the Sarasota Bay area located on the central west coast, bottlenose dolphin
(Tursiops truncatus) death’s from entanglement and ingestion of recreational fishing gear are increasing (NOAA 2006a). Of the total Sarasota Bay recovered strandings in 2006, approximately 25% were a result of fishing gear interaction, compared to the average 2.9% rate for dolphin deaths attributed to fishing gear for the years of 2000-2005 (NOAA 2006a).

Sarasota Bay, Florida and surrounding waters (an area of approximately 125 km²) are home to a community of about 160 resident bottlenose dolphins that have been closely monitored by the Chicago Zoological Society’s Sarasota Dolphin Research Program for over 38 years (Wells 1991, 2003) (Figure 2.1). Monitoring is conducted through monthly photo-identification surveys, occasional health assessments, and other research initiatives (Wells 1991, 2003). These studies have provided a wealth of data that exists on family lineages, stranding records, age, sex, behavioral history, distribution, social associations, and hearing abilities (Wells 1991, 2003; Cook 2006). These long-term, multi-faceted data sets allow for detailed examination of topics, such as depredation, and their relationship to typically unknown factors, like hearing abilities.

For management purposes, understanding contributing factors to depredation is essential as this behavior is expected to be a persistent and rising problem as humans and cetaceans compete for the same resources (Read 2008). Depredation has not been explored in conjunction with hearing impairment or loss and has the potential to explain a dolphin’s shift away from natural foraging behaviors.

In this study, the case of the entangled dolphin, F201, was examined. F201 was the calf of F193, a female documented over a number of years in Charlotte Harbor, Florida before moving to Sarasota. F201 and F193 inhabited mainly the southern portion
of the Sarasota Dolphin Research Program survey range, and were considered recent additions to the resident Sarasota Bay dolphin community. Although F193 has never been documented as engaging in depredation or angler interaction behavior, F201’s mother is the most common associate of BEGR, a notorious begging dolphin (Cunningham-Smith et al. 2006).

F201 was first observed as a young calf with her mother on 7 November 2005 and was last observed with F193 on 18 May 2006. F201 was next seen alone on 12 December 2006, with healed boat propeller wounds and trailing monofilament fishing line from its peduncle, when the survey team monitored the dolphin as it stayed very close to the port stern quarter of the vessel for about 40 min. F201 was again observed alone on 18 January 2007 and the monofilament line trailing from the peduncle had accumulated algae (Figure 3.1). The dolphin was monitored over the following days and a rescue was carried out on 30 January 2007.

Upon capture, it was determined that the dolphin’s wounds from the monofilament entanglement warranted further medical attention and F201 was subsequently admitted to Mote Marine Laboratory’s Dolphin Hospital. Later that day, hospital staff reported that F201 vomited some plastic and it was determined that the loops of monofilament around the peduncle that had cut through the flesh and were now constricting the bone would have to be removed through surgery (C. Manire, veterinary case synopsis). While recovering in captivity, auditory evoked potential (AEP) methods were used to measure the hearing abilities of F201. The dolphin was then further monitored post-release.
3.2 Methods

3.2.1 Auditory Evoked Potentials (AEP)

We tested F201’s hearing using auditory evoked potential (AEP) methods which have allowed researchers to determine the range of hearing capabilities for a number of odontocete species through a relatively brief, non-invasive method (Ridgway et al. 1981, Supin et al. 1993, Supin and Popov 1995, Nachtigall et al. 2004, Cook et al. 2006, Nachtigall et al. 2007, Houser et al. 2008) that has been standardized against behavioral audiograms (Szymanski et al. 1999, Yuen et al. 2005, Cook 2006, Finneran and Houser 2006, Houser and Finneran 2006a). For both captive and wild bottlenose dolphins, recent studies have focused on measuring hearing thresholds within the range of 5-150 kHz (Houser and Finneran 2006a, 2006b; Cook 2006, Finneran and Houser 2006). In-air auditory evoked potentials were used to measure the hearing of F201 on two test days: 12 and 19 March, 2007.

The same equipment and methods as used by Cook (2006) were used for testing F201. Data were collected using a Tucker-Davis Technologies (TDT) AEP workstation with SigGen and BioSig software on a laptop computer. AEP recording electrodes were 8 mm Ag-AgCl electrodes embedded in suction cups which were composed of silicone. Sound was delivered with a jawphone composed of an ITC-1042 transducer embedded in an RTV silicone suction cup. Hearing threshold measurements collected on F201 used an Envelope Following Response (EFR) procedure in which a 600 Hz amplitude-modulated rate was used to present 14-15 ms tone bursts at the same time as the auditory evoked potential was recorded. Calibrations were conducted underwater using a Reson
hydrophone placed 10 cm from the jawphone at 0.5 m from the surface. All signals were
digitized at 260 kHz. Detailed methods and procedures are described by Cook (2006).

F201’s AEP response was further measured while running click stimuli at two
rates (600 Hz and 1 kHz). There was significant destructive cancellation with the 1 kHz
click rate, so only the 600 Hz click rate was analyzed.

F201’s hearing was compared to mean threshold responses from 29 free-ranging
Sarasota Bay resident females (Cook, 2006). In-air AEP measurements for the 29
females used for comparison were collected and analyzed by Mandy Hill Cook (2006)
over five health assessments in Sarasota Bay: June 2003, February 2004, June 2004,

3.2.2 Post-Release Monitoring

F201 was closely monitored via a VHF radio transmitter and sighted 20 times
(12.4 hours of behavioral observations) between the release date on 28 March 2007 and
final observation on 1 May 2007. During post-release monitoring, F201’s vocalizations
were recorded with a HTI-96 hydrophone (sensitivity -164 dBV/µPa; 2 Hz-37 kHz) and
Creative Nomad Jukebox 3 at a sample rate of 48 kHz. I acquired acoustic recordings on
four different days and successfully recorded the dolphin whistling and echolocating.
Recordings were only taken when there were no other dolphins within viewing distance.
Data were visually inspected using Adobe Audition 2.0.
3.3 Results

Results indicated that F201 was hearing-impaired at high frequencies. When compared to baseline values for the Sarasota dolphin females, F201 was found to have hearing loss of approximately 50 dB or more at 40 kHz, 80 kHz, and 120 kHz (Cook 2006) (Figures 3.2). Hearing loss was confirmed by the results of the second test which showed hearing loss of 25 dB at 40 kHz and even weaker responses at 80 and 120 kHz when compared to mean Sarasota female dolphin thresholds. In comparison, F201’s hearing thresholds at 20 kHz appeared normal (Figure 3.2). F201’s click threshold was 112 dB_{peak}. The lowest detected AEP signal was at 112 dB_{peak}.

In all recordings, F201 was found to be either whistling or echolocating (Figure 3.3). On 17 April 2007, the animal was documented as scanning (a behavior usually indicative of echolocation) and the recording confirmed that the dolphin was indeed echolocating (Figure 3.3).

In the 20 sightings post-release, F201 was recorded as “with boat” in 45% of sightings. The dolphin was often observed milling near fishing boats and in areas such as small canals, yacht club basins, or boat rental facilities. The dolphin was seen foraging in 25% of sightings, but was only confirmed to successfully capture fish during one sighting. Post release, F201 remained mostly solitary, and was only sighted with at least one other dolphin in 15% of sightings.

On 13 April 2007, F201 again acquired monofilament, this time around the radio tag. The monofilament was not entangled around the dolphin and was relatively short, less than 40 cm in length. However, on 1 May 2007, F201 acquired more monofilament,
this piece trailing about 30 cm behind her fluke. F201 has not been sighted since 1 May 2007.

3.4 Discussion

The results from this study provide preliminary evidence for a link between dolphin associations with anglers and boats and hearing loss. F201 was severely hearing impaired at higher frequencies and based on her behavior and entanglement history, it appears the dolphin selected habitats with high risk of monofilament entanglements and concentrations of anglers and boaters.

It is still to be determined if higher hearing thresholds are a cause or result of angler interaction behavior. Dolphins could damage their hearing temporarily or permanently as a result of depredation if they select areas with more boats and thus greater anthropogenic noise (Au et al. 1999, Erbe 2002, Nachtigall et al. 2004). Noise from engines and depth finders may be affecting the dolphins’ hearing. An acoustic model created by Erbe (2002) for killer whales (Orcinus orca) predicted that engine noise would cause a temporary threshold shift (TTS) of 5 dB if the animal was within 450 m of a fast moving inflatable boat or 20 m of a slow moving boat for 30-50 minutes. Hearing was expected to return to normal within 24 hours if the killer whale avoided further contact with boats (Erbe 2002). Such avoidance would be nearly impossible for Sarasota Bay dolphins based on findings from a previous study showing that dolphins come within 100 m of a boat every six minutes during daylight hours (Nowacek et al. 2001).
Furthermore, the model showed that long-term exposure to noise from fast-moving vessels within 1 km or to slow moving vessels within 50 m could cause a permanent threshold shift (PTS) of 2-5 dB (Erbe 2002). The Erbe (2002) model and Nowacek et al. (2001) study suggest that depredating dolphins in Sarasota Bay have the potential to be effected by both TTS and PTS.

However, in the case of F201, hearing impairment was most likely not the result of angler interaction behavior but rather the cause. F201 was particularly young to have such a substantial hearing loss, thus suggesting that hearing loss was probably a genetic predisposition (Houser and Finneran 2006b). Dolphins, like F201, may resort to depredation and feeding on dead, injured, or provisioned fish because their hearing is already diminished and they are not successful at prey pursuit and capture using passive listening or echolocation. Evidence that F201 was struggling to find or capture prey is potentially supported by the fact that the dolphin vomited plastic upon admission to the hospital.

The effects of F201’s hearing loss on effective communication range was calculated assuming a cylindrical spreading loss model (10*log(1/distance)) and taking into account the two-way travel of echolocation (from dolphin to target; from target to dolphin). A dolphin with a hearing loss of 50 dB, normally able to echolocate an object 100 m away, would now only be able to detect the same object at 0.3 m distance. In terms of energy cost, depredation is a more efficient foraging strategy in that it requires little effort on the part of the dolphin, especially if provisioned.

Regardless of whether impaired hearing is a cause or effect of depredation, dolphin-angler interactions may increase the rate at which hearing is impaired. Optimal
foraging theory would predict that the benefit and available opportunities of being provided easy prey must outweigh the cost of foraging opportunities that will be lost as a result of hearing damage to the dolphin (Emlen 1966, MacArthur and Pianka 1966). However, depending on the dolphin’s rate of depredation and angler-interactions, it is probable that significant hearing impairment could take months to years to actually show noticeable effects to the dolphin, therefore making depredation a non-optimal strategy with high short-term energetic gains.

F201 was an example of how high frequency hearing loss can potentially increase a dolphin’s probability of becoming entangled or involved in angler interactions. F201’s high frequency hearing loss allowed only limited echolocation abilities over short distances and communication with conspecifics. It remains unclear the degree to which F201 could decipher received echoes especially over long distances. It may be possible that F201 was able to decrease the peak frequency of echolocation clicks in order to shift it within her hearing range as has been demonstrated with captive *Tursiops* and other odontocete species (Au *et al.* 1985, Moore and Pawloski 1990, Houser *et al.* 1999). Anecdotally, in visual inspections of some echolocation recordings, it appeared that F201 had a disproportionate amount of click energy focused in the lower frequencies than is typical for bottlenose dolphin echolocation.

The suspected relationship between hearing loss and angler interaction behavior as exemplified with F201 warrants further investigation as depredation is becoming a more prevalent behavior in Florida dolphin populations. To determine the relationship between higher thresholds, probability of depredation behavior, and entanglement risk, hearing of dolphins needs to be assessed on a more fine scale basis. In an ideal scenario,
measuring a dolphin’s hearing thresholds every year to two years while also closely monitoring individual depredation behavior would help determine the relationship between hearing impairment and depredation.

In Cook’s (2006) analyses of hearing in the Sarasota Bay dolphin community, only one female (F195) showed possible signs of hearing loss suggesting that hearing may be so valuable that if lost, animals may not survive and are quickly selected out of the population. F195, tested in 2005, died two years later. Due to its history of entanglement, premature separation from its mother, and high frequency hearing loss, F201 is presumed to have followed the same fate as F195. If death quickly follows hearing loss, depredation may be a last resort behavior that is employed in order to successfully acquire food when foraging strategies based on sensory modalities, such as passive listening and echolocation, fail. The circumstances surrounding the case of F201 offer preliminary evidence that hearing loss is linked to angler interaction behavior and death for wild dolphins. This preliminary evidence should prompt scientists and managers to continue to pursue this hypothesis in order to better understand the possible physiological causes or impacts of dolphin depredation behavior.
Figure 3.1 F201 photographed by the Sarasota Dolphin Research Program on 19 January 2007. The dolphin’s lower peduncle is entangled in monofilament encrusted with algae. Boat strike scars on the upper peduncle are also evident in this photo.
Figure 3.2  Comparison of F201 auditory evoked potential audiogram to the mean (± SD) audiograms measured for 32 male and 29 female free-ranging bottlenose dolphins in Sarasota Bay, Florida (Cook 2006).
Figure 3.3  Spectrogram of F201 echolocation click train followed by a whistle recorded on April 17, 2007 (post-release). Sample rate was 48 kHz.
4. Depredation Monitoring using Passive Acoustics

4.1 Introduction

Passive acoustic observation is an expanding technique for cetacean monitoring. The technique uses an instrument to record sounds from the environment (Mellinger et al. 2007). Passive acoustic recording devices in the forms of mobile hydrophones, fixed recorders, or attachable tags have been used to determine presence, abundance and distribution patterns (e.g. Stafford et al. 1998, McDonald and Fox 1999, Oswald et al. 2003, Mellinger et al. 2004, Barlow and Taylor 2005, Rankin et al. 2007), characterize a species’ vocalizations (e.g. Stafford et al. 2001, Nowacek 2005, Parks and Tyack 2005), and reconstruct dives for a number of cetacean species (e.g. Zimmer et al. 2003, Lammers et al. 2006, Tyack et al. 2006, Watwood et al. 2006, Stimpert et al. 2007, Aguilar Soto et al. 2008). Passive acoustic monitoring offers advantages over visual surveys by giving researchers the ability to monitor cetacean presence throughout night hours and poor environmental conditions as well as to accurately estimate the number of animals in the near vicinity (McDonald and Fox 1999, Barlow and Taylor 2005, Mellinger et al. 2007, Rankin et al. 2007).
Depredation behavior among odontocete cetaceans is increasing in frequency around the world (Read 2008). Depredation behavior creates an economic loss for fishermen, and endangers the life of the animal through risk of gear entanglement, gear ingestion or retaliation by anglers (Wells and Scott 1994, Gorzelany 1998, Read 2008, Wells et al. 1998, 2008). The ability to monitor depredation behavior in a cost-effective manner is essential for researchers and management agencies. Traditional behavioral observation methods are costly in terms of time, manpower and general boat costs (i.e. fuel, maintenance) when compared to passive acoustic techniques.

Studies comparing visual and acoustic effort typically found that acoustic surveys were more successful at detecting or determining numbers of cetaceans present (McDonald and Fox 1999, Mellinger et al. 2004, Barlow and Taylor 2005) and could be used to accurately identify cetacean species (Oswald et al. 2003, Rankin et al. 2007). Results from these studies show potential for effective passive acoustic monitoring of depredation at a particular site. However, one challenge of continuous passive acoustic observation is the huge volume of data that is generated and must then be analyzed in a timely manner. Automated sound detection is often considered to be the best option for dealing with this volume of data. A number of different techniques for automated detection have been developed such as image processing of spectrograms (Gillespie 2004) and energy calculations within a selected band (Oswald et al. 2004).

Passive acoustic observation of a problematic fishing pier was investigated in terms of reliability in monitoring the severity and frequency of the depredation behavior. This study also tested the efficiency and accuracy of the new MATLAB-based software, DSGLab, for building an automated echolocation detector. Dolphin presence around the
fishing pier was monitored by determining the number of echolocation clicks detected by
the automated program. Trends in echolocation click rates were examined for variations
by month and hour and compared to visual sighting data. This method has the potential
to create an inexpensive, universal option for assessing depredation by odontocetes.

4.2 Methods

4.2.1 Hydrophone Deployment and Setup

In June 2007, an HTI-96 hydrophone (sensitivity -164 dBV/µPa; 2 Hz-37 kHz)
was mounted at Anna Maria City Pier. Continuous recordings were taken through June
2008 with the exception of breaks in October 2007, November 2007, and March 2008
when the hydrophone was being repaired following vandalism, damage from fishing
gear, or equipment malfunction. Data were recorded continuously as 10 min files at a
sample rate of 44.1 kHz onto a computer with an external hard drive using
LoggerheadDT software. The hydrophone was suspended underneath, near the center of
the pier at a depth of approximately 1.3 m (of total depth of 2.8 m) above a sandy bottom.
The recording system was calibrated by recording 0.1 V-peak sine waves from 100 Hz to
22000 Hz and measuring the levels recorded in the wav files in MATLAB. The system
had a flat response from 100 Hz to 22 kHz.
4.2.2 DSGLab Automatic Echolocation Detection

Data were analyzed automatically using the MATLAB (version 6.5-7.4) based program DSGLab, which allows the user to customize an automated sound detector. An echolocation detector was built rather than a whistle detector because preliminary visual scans of over 19 hours of data (115 files) showed that echolocation occurred more often than whistles. Due to the infrequent presence of dolphins at the pier, the goal of the detector was to reduce the number of false detections.

In general, the echolocation detector worked by detecting click trains. Recording files were processed in 10 s segments. The detector first filtered the data with a 10 kHz high pass filter which eliminated much of the boat engine noise from files. The signal was further rectified, enveloped and then was thresholded at 2.5 times the root mean square (RMS) of the signal. This resulted in the detection of both echolocation and snapping shrimp clicks. Recordings were further processed by calculating the run length of possible echolocation trains and counting the number of clicks within the specified time frame. The program then output the number of times the criteria were met. If the output value was six or greater, the file was marked as with echolocation. Due to the regularity of clicks, snapping shrimp noise was mostly eliminated and echolocation was detected.

A trial run of the detector was conducted on 50 files with no echolocation present and 50 files with clicks present. Files in both categories were selected to include recordings with boat engine noise. It was determined that the click train needed to have at least six clicks to ensure the elimination of false detection on boat noise or snapping shrimp. During trial testing, the detector was successful at detecting 12% of files with
known click trains, with no false detections. As a further check, after the detector had completed analysis, 100 files with output values of six or more were randomly selected and visually inspected for echolocation. The program false detected echolocation clicks in six of the 100 inspected files. Detected click trains were those that had the highest signal-to-noise ratio.

Recordings from June 2007 to June 2008 were sub-sampled at 5% by analyzing one out of every 20 10-min files. The number of files with a maximum value of six or greater (i.e. those with echolocation) was totaled and then the percent of files with echolocation was calculated. A regression in StatSoft Statistica 6.1 was used to determine the predictability of monthly and hourly angler interactions rates based on echolocation click detections. Angler interactions were measured by the number of depredation events witnessed during pier surveys and were standardized by monthly or hourly effort (i.e. the average monthly or hourly depredation rate). A total of 11 depredation events by the male dolphin F106 was used to create the depredation curve for Anna Maria City Pier. Since only pier survey data with corresponding recordings were included, data were only available during daylight hours from 07:00 to 15:00, and so were not comparable across night hours. A Spearman R rank correlation in Statistica was used to compare hourly click detections to the mean number of dolphins sighted and mean fishing effort (mean number of lines) also determined during visual pier surveys.

4.2.3 Visual Surveys vs. Passive Acoustic Recordings

Dolphins were detected by visual surveys 27 times at the pier when sound data were also available. The acoustic recordings were analyzed manually to estimate the
effectiveness of the passive acoustic method in detecting dolphin presence at a fishing pier, specifically when dolphins were engaging in angler interaction behavior.

Corresponding 10-min acoustic recordings were compared to the 14.6 hours of visual sighting data from six days in the summer of 2007: 27-30 June, 3 July, and 11 July. Pier survey observation effort totaled 30.6 hours. All recordings were manually inspected for whistles and echolocation clicks in Adobe Audition 2.0. Mann-Whitney U tests in Statistica were used for comparisons of whistle and echolocation rates during depredation and non-depredation sightings.

4.3 Results

4.3.1 DSGLab Automatic Echolocation Detection

The DSGLab automated echolocation detector analyzed 87,746 segments of 10 s recordings. Of processed files, 0.13% met the criteria for echolocation. The month with the greatest percentage of files with echolocation was June 2007 (Figure 4.1). April and June 2008 had no files with detected echolocation (Figure 4.1). The correlation between peaks in echolocation and monthly depredation activity was marginally significant ($R^2=0.65, p=0.053$).

Detections were also analyzed on an hourly timescale. The highest percentages of echolocation clicks detected per hour were at 04:00 and 12:00 (Figures 4.2). Times 05:00, 07:00, 08:00, 21:00, 22:00 had no clicks detected (Figures 4.2). There was no correlation between detected hourly echolocation rates and dolphins visually sighted per
hour (R=-0.34, p=0.366) and a marginally significant correlation between hourly echolocation rates and fishing effort per hour (R=0.66, p=0.053) (Figures 4.3, 4.4). Detected echolocation rates were found to significantly correlate to the increase in depredation during mid-day hours (R²=0.53, p=0.027) (Figure 4.2).

4.3.2 Visual Surveys vs. Passive Acoustic Recordings

In 63% of 27 sightings, there was acoustic evidence (whistle or echolocation) of dolphin presence. In total, 103 whistles were recorded in 22% of sightings and echolocation was detected manually in 56% of sightings.

Of the total 27 sightings, 21 included the 26-year-old male dolphin, F106. F106 was solitary in 81% of these sightings and engaged in angler interaction behaviors in 91% of sightings. Acoustic evidence of the dolphin’s presence was detected in 63% of the sightings when F106 was engaging in angler interaction behaviors. Some of the whistles recorded during the F106 sightings were confirmed to be the animal’s signature whistle when compared to recordings from the Sarasota Dolphin Whistle Catalog (Courtesy of Laela Sayigh and Vincent Janik) (Figure 4.5). Furthermore, 36% of F106 depredation events were accompanied by echolocation within the minute surrounding the event. The dolphin produced echolocation clicks while engaging in both provisioning and scavenging. Mann-Whitney U tests did not find significantly more whistles (p=0.450) or echolocation clicks (p=0.719) during the 19 sightings with dolphin-angler interaction behavior than the nine sightings without this behavior (Table 4.1).
4.4 Discussion

Since sightings with dolphin-angler interaction behaviors were not found to contain significantly more whistles or echolocation than sightings without the behavior, passive acoustics cannot be used exclusively for determining depredation events at a fishing pier. Dolphins are most likely to whistle when socializing and the frequency of whistles also increases with larger group size (Cook et al. 2003). When F106 was engaging in depredation behaviors around the pier, the dolphin was usually solitary and because it was being provided with easy “prey”, the dolphin would not always have to seek it acoustically or coordinate with other dolphins to capture prey. These factors would reduce the dolphin’s necessity to whistle or echolocate, thus explaining the non-significance of the occurrence of whistles or echolocation between angler interaction and non-angler interaction sightings.

F106 was detected acoustically in 63% of sightings containing dolphin-angler interaction behavior and was found to echolocate during some provisioning and scavenging events. For dolphins that commonly depredate, like F106, depredation even with echolocation may be as successful, and at equal or lesser energetic cost as other more natural feeding strategies. To more clearly understand the role of echolocation in depredation, the use of echolocation during dolphin-angler interaction behavior should be further examined to include a greater number of known depredating dolphins at different piers. Also, sub-sampling the available data at a greater rate (i.e. 10%) will provide a larger sample size that may further increase the predictability of echolocation in determining dolphin presence and depredation behavior.
Peaks in echolocation were correlated to both monthly and hourly depredation events, suggesting that when dolphins are present around the pier there is a greater probability that depredation or angler interactions will occur. The hourly percent detected echolocation clicks show a small peak in the very early morning hours, but show the greatest peak at 12:00. This peak at noon was the height in F106 depredation activity at the pier. Dolphin echolocation is typically associated with foraging (Jones and Sayigh 2002, Nowacek 2005) and findings from previous studies show that dolphins feed more often in early morning hours (Shane et al. 1986, Shane 1990, Waples 1995, Allen et al. 2001). This shift away from the expected echolocation feeding patterns further suggests that depredation behavior changes the dolphin’s natural activity pattern.

If further studies reveal that echolocation or whistles are produced in the majority of odontocete depredation foraging incidents, passive acoustics could serve as a method for reducing commercial fisheries depredation and possibly bycatch. Active acoustic methods using pingers that emit tone pulses have been explored in attempting to reduce bycatch of marine mammals by deterring or alerting animals to the presence of fisheries nets (Kraus et al. 1997, Stone et al. 1997, Dawson et al. 1998, Bordino et al. 2002, Barlow and Cameron 2003, Cox et al. 2003, Monteiro-Neto et al. 2004). However, concerns arise with pinger use, since the constantly emitted pulses can act as a “dinner bell” leading to increased depredation from the nets, and potentially causing hearing damage for net interaction animals (Richardson et al. 1995, Bordino et al. 2002, Cox et al. 2003).

A recorder with the ability to broadcast in real time attached to long-lines, gill-nets, or other types of fisheries gear could alert fishermen to the presence of odontocete
cetaceans and potential acts of depredation. Fishers could either pull gear and terminate a set early or avoid the area when next setting fishing gear. Detection of whistles or echolocation could be automated therefore just alerting the fishermen to cetacean presence by alarm when echolocation or whistle rates crossed a threshold level. The advantages of developing such a device rather than using the traditional hydrophone are that fishermen do no have to be trained or hire additional personal to monitor the data in real time. Also, the device can be left on soaking gear but still broadcast information to fishermen that may be some distance away. Such a device may be expensive, however if proven successful, the cost of the device may outweigh the economic loss of damage to catch and the harm to marine mammals as a result of depredation.

I recommend both visual and acoustic surveys when monitoring dolphin presence around a fishing pier and assessing the rate of angler or fisheries interactions. Initially, visual surveys proved valuable when evaluating the severity of dolphin-angler interaction behavior at the pier and for identifying problem dolphins. However, passive acoustic monitoring was less expensive and time intensive than visual surveys, detected problem animal presence more than 50% of the time, and correlated echolocation with peaks in monthly and hourly depredation activity. Peaks in echolocation can alert scientists and managers to increases in dolphin presence that might be indicative of dolphin-angler interactions at the specific site. If cause for concern, scientists and managers could then employ more intense and costly monitoring methods (e.g. visual surveys) for precisely determining the extent and rate of depredation behaviors during times of peak echolocation. Passive acoustic monitoring has the potential to serve as an inexpensive and preliminary assessment of depredation behaviors at a specified site. More studies in
other areas with similar dolphin-angler interaction issues would be beneficial in further assessing the reliability of passive acoustics to monitoring depredation behavior.
Table 4.1 Summary of visual dolphin sightings and corresponding acoustic recordings over six days at Anna Maria City Pier. Dolphins were not found to whistle or echolocate significantly more in sightings with angler interaction behavior than without ($p=0.450$ for whistles; $p=0.719$ for echolocation).

<table>
<thead>
<tr>
<th>Date</th>
<th>Angler Interaction Behavior?</th>
<th>Sighting No.</th>
<th>Animal(s) Present</th>
<th>Whistle?</th>
<th>Echolocation?</th>
</tr>
</thead>
<tbody>
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<td>27-Jun-07</td>
<td>Y</td>
<td>101</td>
<td>F106</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Y</td>
<td>102</td>
<td>F106</td>
<td></td>
<td>X</td>
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<td>N</td>
<td>101</td>
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<td>29-Jun-07</td>
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<td>105</td>
<td>F106</td>
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Figure 4.1 The percentage of 10 s segments containing echolocation click trains per month at Anna Maria City Pier compared to the monthly depredation rate (determined by pier surveys) for Sarasota Bay, FL ($R^2=0.65$, $p=0.053$).
Figure 4.2  The percentage of 10 s segments containing echolocation click trains per hour at Anna Maria City Pier compared to the hourly depredation rate (determined by pier surveys) for Sarasota Bay, FL ($R^2=0.53$, $p=0.027$).
Figure 4.3 The percentage of 10 s segments containing echolocation click trains compared to the mean number of dolphins sighted per hour (determined by pier surveys) at Anna Maria City Pier. Data sets were not correlated ($R=-0.34$, $p=0.366$).
Figure 4.4  The percentage of 10 s segments with echolocation click trains compared to the mean number of total fishing lines per hour (determined by pier surveys) at Anna Maria City Pier. Data sets were marginally correlated (R=0.66, p=0.053).
Figure 4.5  Comparison of F106 signature whistles from the Sarasota Dolphin Whistle Catalog (top) (courtesy of L. Sayigh and V. Janik) and from pier recordings (bottom).
Literature Cited


NOAA. 2006a. Bottlenose Dolphins –Increase in depredatory (stealing) behavior and deaths associated with recreational fishing gear. NOAA Fisheries Services, Southeast Regional Office, October 2006.


