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MOVEMENTS, FISHERY INTERACTIONS, AND UNUSUAL MORTALITIES OF BOTTLENOSE DOLPHINS

by

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ABSTRACT

Bottlenose dolphins (*Tursiops truncatus*) inhabit coastal and estuarine habitats across the globe. Well-studied dolphin communities thrive in some peninsular Florida bays, but less is known about dolphins in the Florida panhandle where coastal development, storms, algal blooms, fishery interactions, and catastrophic pollution have severely impacted their populations. Dolphins can react to disturbance and environmental stressors by modifying their movements and habitat use, which may put them in jeopardy of conflict with humans. Fishery interaction (FI) plays an increasing role in contributing to dolphin mortalities.

I investigated dolphin movements, habitat use, residency patterns, and frequency of FI with sport fishing. Dolphins were tracked using radio tags and archival data loggers to determine fine-scale swimming, daily travels, and foraging activity. Dolphin abundance, site fidelity, ranging, stranding mortality, and community structure was characterized at Choctawhatchee and Pensacola Bays in the Florida Panhandle via small boat surveying and photo-identification. Reported increases in dolphin interactions with sport anglers were assessed at deep sea reefs and coastal fishing piers near Destin, FL and Orange Beach, AL. Results from these studies yield insights into the ranging and foraging patterns of bottlenose dolphins, and increase our knowledge of them in the northern Gulf of Mexico.

Dolphins were tagged with short-term Trac Pac tags (N=23) and bolt on radio-tags (N=5) during 1995-2007. Swim speeds averaged 1.6 m/s (±0.43 SD), which agreed with the predicted mean cost of transport. On average, 48% of their day was spent transiting between habitats. Swimming and activity rates did not vary significantly with time of day/night. Foraging and social interactions constituted 39% of their day. Increased foraging was detected by stomach temperature changes that revealed dolphins fed during daylight, but also at night with a peak starting just after sunset. Tagged dolphins exhibited behaviors suggesting ‘sleep’ during slow speed swimming, which represented 15% of their day on average. Dolphins made daily movements beyond their expected core area, heading up river tributaries, and to the open sea.

Surveys in Choctawhatchee Bay began in 2006 and later expanded to include Pensacola Bay in 2010 following concern of dolphin mortalities in concert with the Deepwater Horizon spill and two extremely cold winters. Photo-identification revealed dolphins moved frequently between the bays. Of 655 individuals identified in 2010-11, 22% were seen during all seasons, with highest abundance in the fall. Resident dolphins showed site fidelity to specific areas (42%) or traveled between parts of the bays (58%). Three communities of dolphins were identified from stable isotope analysis and photo-id: 1) tidal inlet associated, 2) estuarine specific, and 3) river delta associated. Dolphins traveled over 70 km via the near-shore Gulf between the inlets, and through the inshore waterways. The findings suggest dolphin communities in these bays overlap and many dolphins had a high probability of oil exposure in 2010.

I observed sport fishing trips to assess frequency and nature of FI over 28 months. FI was seen at 18% of fishing reef spots. Scavenging of discarded fish was seen most often, while depredation of catch occurred in 40% of FI observations. Of 103 dolphins identified on offshore reefs, 13% were encountered repeatedly. At coastal fishing piers, dolphins came within 100 m on 42% of visits, while FI was seen on 17% of visits. Most dolphins at the fishing piers were known inlet and estuarine residents, while offshore reef dolphins were never seen near the beach. This indicates that discrete communities are involved. Harmful interactions with dolphins on reefs and at fishing piers negatively affect these resident communities. Mitigation of FI is suggested by use of avoidance strategies, gear modifications, and improved fish release practices.

To boldly go where no man has gone before…
- Captain Kirk

Two roads diverged in a wood, and I,
I took the one less traveled by,
And that has made all the difference.
- Robert Frost

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ADF	Automatic Direction Finder
AFB	Air Force Base
ATL	Atlantic Coastal Sites (Beaufort, NC, and Coastal New Jersey)
BNC	Beaufort North Carolina
BSE	Bay, Sound, and Estuary Stock
CB	Choctawhatchee Bay
CBA	Choctawhatchee Basin Alliance
CNJ	Coastal New Jersey
COT	Cost of Transport
CZS	Chicago Zoological Society
ECB	Eastern Choctawhatchee Bay
ECWR	Emerald Coast Wildlife Refuge
FI	Fisheries Interactions
FST	Forestomach Temperature
GIS	Geographic Information System
HAB	Harmful Algal Bloom
HBOI	Harbor Branch Oceanographic Institution
HERA	Health and Environmental Risk Assessment
HI	Human Interaction
HTR	Heart and Temperature Recorder Data Logger
IRL	Indian River Lagoon

MMPA	Marine Mammal Protection Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Oceanographic Administration
OLE	Office of Law Enforcement
PDER	Precipitous Drop and Exponential Rise
RF	Radio Frequency
RTOMP	Red Tide Offshore Monitoring Program
SAR	Sarasota Bay, FL
SDRP	Sarasota Dolphin Research Program
SPi	Relative Sighting Proportion Index
STP	Stomach Temperature Pill
TDR	Time Depth Recorder
UME	Unusual Mortality Event
VTDR	Velocity Time Depth Recorder

CHAPTER ONE:
INTRODUCTION

Background

The bottlenose dolphin (*Tursiops truncatus*) is a flagship species distributed globally and commonly found along coastal regions of the USA Atlantic seaboard and Gulf of Mexico. Bottlenose dolphins are long-lived animals that maintain complex social relationships and occupy a variety of habitats ranging from offshore to estuarine waters (Odell and Asper 1990, Wells and Scott 1999, Waring *et al.* 2012). Many estuarine communities of bottlenose dolphins are well studied and known to consist of multi-generational residents (Scott *et al.* 1990, Wells 2003, Mazzoil *et al.* 2005). Mothers pass along skills and behaviors to offspring, including foraging traits and residency patterns (Mann and Sargeant 2003, Weiss 2006, Whitehead *et al.* 2004).

As an apex predator in the marine ecosystem, the bottlenose dolphin is a sentinel species for a broad measure of ecosystem integrity and viability (Wells *et al*. 2004, Bossart 2006). Dolphins are entirely marine animals that bio-accumulate nutrients, trace minerals, and pollutants from their prey, which appear in samples of their body tissues and have been linked to ecosystem health (Samuel and Worthy 2004, Wells *et al.* 2004, Houde *et al.* 2006, Fire *et al*. 2008, Fair *et al.* 2010, Balmer *et al*. 2011a, Wilson *et al*. 2012). While climate and weather patterns can influence dolphin distribution and movement (Walker *et al.* 2005, O'Shea and Odell 2008, Rosel and Watts 2008), human activities such as boating, coastal development, ecotourism, and fishing also play a significant role in modifying dolphin foraging ecology and habitat use in coastal regions (Nowacek *et al*. 2001, Samuels and Bedjar 2004, Powell and Wells 2011). Additionally, coastal and estuarine dolphins in the eastern USA have been subject to periodic unusual mortality events involving naturally occurring disease and biotoxins. Many factors interplay in the marine environment to complicate the effective conservation of this charismatic species.

Residency, Site Fidelity, and Habitat Use

Bottlenose dolphins exhibit site fidelity and long-term residency at numerous coastal locations in the eastern USA where they have been extensively studied (Wells 2003). Some dolphins remain within local habitats over many years while others have migratory patterns based on seasonal temperature variations (Urian *et al*. 1999, Read *et al*. 2003a, Hubard *et al*. 2004, Miller and Baltz 2009). Yet, even these migratory dolphins have been shown to regularly return to specific coastal regions over time (*e.g*., Urian *et al*. 1999). Movement of dolphins between various available habitat types within and between estuaries is an important consideration in studies investigating their ecological niche and habitat use.

Residency in estuaries puts dolphins in direct contact with many conditions that can contribute to ill health, mortality, and conflict with humans over prey and habitat resources (Gorzelany 1998, Bossart *et al*. 2003, Fair *et al*. 2010, Bowen 2011, Barros *et al*. 2013). Indirect health consequences from exposure to anthropogenic pollutants and decreased habitat quality have been documented (Adams *et al*. 2008, Balmer *et al*. 2011a) and strandings of dolphins as a result of human and fishery interactions have been on the rise in the southeast USA since the 1990s (Read 2005, Thoms 2006, Zollett and Read 2006, Wells *et al*. 2008, Powell and Wells 2011). Along the northern Gulf of Mexico coast, dolphins are more likely to experience thermal and climate effects caused by river and cold air flow from higher latitudes than are migratory dolphins on the eastern seaboard or dolphins in the Florida peninsula where fresh water input is restricted to warm sources of river water. Conservation of dolphins in these different regions is dependent on our understanding of their residency and site fidelity patterns, as well as awareness of various threats from natural events and human activities that impact survival of this species.

Movements and Ranging

Dolphins in many coastal estuaries display movement patterns that vary by season (Shane 1980; 2004, Wells and Scott 1999, Zolman 2002, Gubbins *et al*. 2003, Read *et al.* 2003a, Mazzoil *et al.* 2005, Miller and Baltz 2009, Toth *et al.* 2011). On the USA Atlantic coast, two stocks of bottlenose dolphins have been defined based on their migratory patterns (western north Atlantic coastal northern migratory and southern migratory), and 12 additional stocks have been described based on long-term site fidelity in estuaries between North Carolina and south Florida (Waring *et al*. 2012). Less is known about the east-west movement of dolphins between coastal estuaries along the northern Gulf of Mexico. These later stocks are delineated into general groups based on where they are found, *i.e.*, oceanic, coastal, and bay/sound/estuary, and they are believed to occupy spatially segregated regions on an east-west gradient (Waring *et al*. 2012).

Offshore bottlenose dolphins have been known to make long range movements in the Gulf (Mate and Worthy 1995, Wells *et al*. 1999), but estuarine dolphins more often exhibit site fidelity and residency in localized areas throughout the year (Shane 1980, Wells and Scott 1990, Hubard *et al*. 2004, Balmer *et al*. 2008). Another marine mammal species, the West Indian manatee (*Trichechus manatus*), is well known for its seasonal migrations along the west Florida coast during winter to warmer regions (Weigle *et al*. 2001, Deutsch *et al*. 2003, Flamm *et al*. 2005), but similar movements are not documented in dolphins. More information is needed on the ranging patterns and seasonal movements of estuarine resident dolphins along the northern Gulf coast, where only limited data have been available.

Swimming Speed and Daily Travels (Energetics)

The ecological needs of an animal (nutrition, shelter, social contact) are balanced against the cost of acquiring those resources (Stephens and Krebbs 1986). Dolphins select and use habitats in a manner to best optimize their energetic costs and benefits (Williams *et al*. 1992; 1996), and therefore may become specialists in their use of certain habitats (*e.g*., Wilson *et al*. 2013). The greatest energetic cost to dolphins in acquiring their daily resources is that of locomotion between habitat patches (Williams *et al*. 1996, Rosen and Trites 2002). Changes to habitat resources (prey availability, disturbance, and predators) or events that reduce dolphins' access to their preferred habitats can increase their average swim speeds and movement distances, and therefore their overall energetic costs (Williams *et al*. 1992, Clelland 2008). Fine-scale evaluation of dolphin swim speeds can improve our understanding of how cultural changes to estuaries are potentially affecting dolphins' long-term energetic balance.

Resting

It is generally believed that all animals require rest following sustained periods of vigilance (Dukas and Clark 1995, Bennington and Heller 1999). Dolphins are able to maintain constant vigilance while also engaging in restful swimming (Goley 1999, Gnone *et al*. 2001), engaged in "unihemispheric" sleep (Ridgway *et al*. 2006; 2009). Presumably, these animals only rest during times when external conditions allow a reduced state of awareness sufficient to maintain social affiliations, escape predators, and avoid injury from other threats (Goley 1999, Sekiguchi and Kohshima 2003). Unlike many land animals that exhibit regular crepuscular activity patterns, dolphins are active during all times of the day (Sekiguchi and Kohshima 2003), and may also forage in conjunction with increased fish abundance and activity during pre-dawn and post-dusk hours, as well as on tidal cycles that increase nocturnal fish abundance during spawning and reproductive aggregations (Luczkovish *et al*. 2000). Stressors in the environment that can interfere with resting opportunities, such as disturbances caused by human activities (*e.g*., boats, noise, construction) may have consequences on dolphin habitat use and movements by requiring long periods of vigilance that might impact fitness (Ridgway *et al*. 2009).

Impacts of Provisioning by Humans and Fishery Interactions

In some locations, intentional provisioning of dolphins has caused them to become dependent on human interaction, potentially placing them in jeopardy from a variety of threats ranging from nutritional deficit to injury from boats and propellers (Samuels and Bejdar 2004, Cunningham-Smith *et al*. 2006, Wells *et al*. 2008). Dolphins often prey on fish species that are of commercial or recreational value to humans, which can result in harmful interactions with anglers (Thoms 2006, Powell and Wells 2011). Conservation of fish stocks since the mid-1990s has required management regulations restricting take of certain fish species by size, season, or bag limit, resulting in a large discard and by-catch component in both recreational and commercial fisheries (Read 2005). Consequently, unintentional provisioning of dolphins has become common as animals learn that fishing vessels are often a reliable source of easy to acquire prey, which puts them in danger of entanglement or ingestion of fishing gear.

Reproduction, Juvenile Survival, and Dispersal

Bottlenose dolphins residing in coastal estuaries constitute closed populations with slow reproductive rates that are easily stressed by loss of only a small portion of the stock (Waring *et* *al*. 2012). This is of special concern in areas where mortalities resulting from biotoxins and disease outbreaks cause losses greater than the assumed population recovery rate (Gaydos 2006, Mullin *et al*. 2007). Increased mortality of breeding age adults and juveniles nearing age of maturity may depress local abundance and stability of a stock, forcing increased management efforts to protect coastal and estuarine dolphins from human interactions (NMFS 2004, NOAA OLE 2006a; 2006b, NOAA 2007, Mullen *et al*. 2007, Waring *et al*. 2012). Multiple algal bloom and pollution events in coastal bays along the northern Gulf of Mexico during 2000-2011 were implicated in causing unusual mortalities of bottlenose dolphins of all age classes (Twiner *et al*. 2012, Carmichael *et al*. 2013). Conservation of dolphins in this region would be well-served by reducing impacts of human interactions on juveniles and long-term resident, breeding age adults in order to insure continued recruitment of new individuals into the populations.

Foraging Implications

Dolphin prey resources within estuaries can become stressed due to unusual weather events, reduced water quality, and overfishing (Read 2005, Paperno *et al*. 2006, Gannon *et al*. 2009, Bowen 2011). As a result, dolphins may be forced to pursue foraging patterns that involve greater risk of human interaction (Powell and Wells 2011). For example, red tides caused by the toxic dinoflagellate *Karenia brevis* resulted in changes to fish assemblages that reduced common dolphin prey items in Sarasota Bay in 2004-07 (Gannon *et al*. 2009). In the years following the red tides, interactions between dolphins and recreational anglers in Sarasota and Tampa Bays became more numerous and the rate of stranded dolphins bearing signs of human and fishery interactions increased (Wells *et al*. 2008, McHugh *et al*. 2011). Bowen (2011) found that dolphins in the Florida panhandle showed differences in diet composition between red tide bloom and non-bloom periods based on stomach content analysis. Severe cold weather impacts in Matagorda Bay, Texas were implicated in the sudden deaths of 26 dolphins in 1990, which may have been complicated by depleted prey resources (Miller 1992). Another unusual mortality event in this location occurred in 1992 following heavy seasonal rainfall and a coastal freshet that abruptly reduced the salinity of the bay (Colbert *et al*. 1999). Although no direct link was established between increased industrial toxins present in the waters and the mortality event (Colbert *et al*. 1999), it was possible that low salinity caused a shift of prey availability that may have contributed to the dolphin deaths, similar to the 1990 event. More recently, Carmichael *et al*. (2012) suggested that the combination of extreme cold periods followed by sudden freshets impacted estuarine salinity levels along the northern Gulf that may have created a ‘perfect storm’ for the unusual mortality of over 80 near-term perinatal dolphins in the spring of 2011. The connection between environmental perturbations and anthropogenic pollutants with changes in dolphin prey availability require further study.

I undertook a series of projects to investigate approaches to conservation of bottlenose dolphins in areas where the issues detailed above are common. I conducted a fine-scale tagging study to examine dolphin swim speeds and daily ranging distances at four sites in the eastern USA, then focused on the population of dolphins in the Choctawhatchee Bay region of northwest Florida where mortality impacts had been escalating since 2000 due to harmful algal blooms, potential weather effects, human interactions, and the oil spill event resulting from the 2010 Deepwater Horizon disaster.

Methodology and Approach

I relied on commonly used techniques to undertake my research projects, each of which has been employed in other studies with well-demonstrated results. I present below a general introduction to the methods and approach I used in the different aspects of my investigations on dolphin movement, habitat use and site fidelity.

Radio and Satellite-Linked Tags

Researchers have relied on telemetry techniques to study dolphin movements for many years (Evans *et al*. 1972, Irvine *et al*. 1981, Scott *et al*. 1990, Lynn and Würsig 2002). Radio transmitter tags attached to dolphins' dorsal fins provide a means to repeatedly relocate animals in coastal environments. Although superior to visually finding the animals, radio tags are limited in transmission distance and duration of power supply, and thus provide short-term tracking capability of days to a few months (Scott *et al*. 1990, Speakman *et al*. 2006, Mazzoil *et al*. 2008b). Combined with focal animal behavioral follows (Mann 1999), radio tags allow a means to reliably relocate and monitor dolphins exhibiting short distance ranging patterns and conduct fine-scale examination of habitat use, ranging, and social activity.

Longer-term studies of animal movements have been greatly advanced through the use of satellite-linked tags that are attached to dolphins in a similar manner to radio transmitters (*e.g.*, Tanaka 1987, Stewart *et al*. 1989, Mate *et al*. 1995, Read *et al*. 1997, Balmer *et al*. 2011b). This technology allows remote tracking for periods of months and longer, such that seasonal migratory patterns can be elucidated. Satellite tags provide a coarse scale view of the animal's whereabouts, at best giving hourly updates and at worst providing only infrequent position data

(Read *et al*. 1997). Thus, satellite tags are not the most ideal method for evaluating short range daily movements and habitat use.

A technology that can be combined with telemetry tags is the inclusion of an archival data recorder. The earliest uses of such devices were on pinniped species that reliably returned to shore for molting and reproduction (Kooyman 1966 [see review by Goldbogen and Meir 2014], Hooker and Baird 2001, Kooyman 2007). Time-Depth-Recorder (TDR) devices opened up new avenues for measuring underwater activity of marine mammals and revealed previously unknown physiological adaptations that allow these animals to access the most remote habitats on earth (Hooker and Baird 1999, Williams *et al*. 2004, Tyack *et al*. 2006, Block *et al*. 2011, Scott *et al*. 2012). Short term applications of TDRs on cetaceans were rare until recent years with the advent of DTAG technology (Tyack *et al*. 2006) and other types of remotely applied recorders (*e.g*., Crittercam; Kooyman 2007). Advancements in satellite-linked tags allow incorporating some aspects of archival data logging that can be uplinked to a remote receiver, although data transmission limitations reduce the amount of information that can be stored compared to on-board archival recorders. To date, GPS-based tags have not been practical for use on small cetaceans due their brief surface respiration intervals that prevent position fixes to be made (Costa *et al*. 2010, Witt *et al*. 2010).

Not to be overlooked, inexpensive TDR tags attached to cetaceans can be a simple means of measuring physical parameters of an animal’s activity (*e.g*., diving, swim speed, acoustics, stomach temperature, heat flux) as well as external environmental conditions (*e.g*., temperature and light), especially when combined with radio tracking and focal observations (Townsend and Deckert 1995, Baird *et al*. 2001, Westgate *et al*. 2007, Scott *et al*. 2012). A major drawback that limits use of TDR tags on free swimming small cetaceans is the need to recover the device after deployment. Another potential disadvantage is that a tag may be lost to the environment, or may malfunction during the course of deployment – in such cases the researcher cannot confirm tag condition until it is recovered, which may be after a prolonged period of tracking. However, the successful application of a TDR in a radio-tracking study can provide a bonanza of fine-scale data (Westgate *et al*. 2007, Scott *et al*. 2012).

Tag attachment usually requires that the subject animal must first be captured and restrained briefly, a process that involves dedicated equipment, personnel, permits, and funding (Wells 2003). The most practical opportunity for the use of these tags has been during dolphin health assessment studies conducted periodically at various locations in the southeastern USA (*e.g*., Wells *et al*. 2004, Fair *et al*. 2006). Pre-calibrated tags can be reliably attached, and the animal can be radio tracked for periods of hours to days until the tag detaches and is recovered. Information collected from focal animal behavioral observation and archival data recorders provides a means of exploring a dolphin's habitat use, ranging, and underwater behavioral activity, even during nocturnal intervals. Combining TDRs with an ingestible temperature telemeter pill has been successfully used with pinnipeds (*e.g*., Kuhn and Costa 2006) and aquatic birds (*e.g*., Wilson *et al*. 1995) to acquire temporal records of foraging activity. The stomach temperature devices that were employed in pinniped studies are sufficiently robust for use on small cetaceans in capture-release studies where a telemeter pill can be introduced in the dolphin's forestomach under veterinary guidance.

Mark-Recapture Surveys

Using visible natural markings and scar patterns on dolphins to repeatedly identify them over time is a routine method for long-term study of habitat use, ranging, and social activity

(Wells and Scott 1990, Rosel *et al*. 2011). Photo-identification of dolphins has been used for decades to monitor individuals and groups (Würsig and Würsig 1979, Urian *et al*. 1999, Wells 2009a). An advantage of this method over tagging is the ability to sight dozens to hundreds of dolphins in relatively short periods of time. The non-invasive nature of observing animals from a distance allows the researcher to avoid altering their behavior (Mann 1999). Marks on dolphin dorsal fins usually persist across multiple years such that individuals can be continually recognized in longitudinal studies spanning generations (Wells 2009a).

Photo-id requires the observer to come into visual proximity of the study animals, therefore involving some amount of labor and intensive survey effort. Surveys are usually conducted from small boats with no special modifications. Designing systematic surveys gives the investigator the ability to utilize mark-recapture abundance estimation to assess populations and seasonal variations of habitat use (Conn *et al*. 2011, Rosel *et al*. 2011). Digital cameras and computer platforms for image processing are now very practical and inexpensive for use in this application, such that the proliferation of photo-id catalogs of individual dolphins in numerous study regions presents a vast data collection for collaboratively determining dolphin movements over grand scales (Urian *et al*. 1999).

Remote Dart Biopsy Sampling and Stranded Animal Tissue Collection

Small boat surveying provides a platform for acquiring remotely collected tissue samples from free-ranging dolphins. Remote dart biopsy techniques have been refined to safely recover eraser-size epidermal and blubber samples from dolphins to be used for genetic, stable isotope, and contaminant analysis (Hanson *et al*. 2004, Wenzel *et al*. 2010). Identification of the target individual using photo-id provides location-based data to link with the sample results (Mullen *et* *al*. 2007, Adams *et al*. 2008, Balmer *et al*. 2012). This methodology has led to improved ability to monitor populations of coastal dolphins, determine stock status, and identify threats from anthropogenic pollutants (Mullen *et al*. 2007).

Marine mammal stranding response organizations around the USA participate in the national effort to conserve species through tissue sampling and data collection on age, sex, and reproductive status of animals that come ashore or are in need of rescue. Research collaboration with stranded animal response allows evaluation of mortality and morbidity (Geraci and Lounsbury 1993, Rowles *et al*. 2001, Schwacke *et al*. 2010), and life history information from animal identification when matched with photo-id catalogs (Wells *et al*. 2008). Incorporating stranding response with longitudinal mark-recapture studies benefits the evaluation of population status by discovering loss of reproductive age animals and juveniles, as well identifying human activities that contribute to mortality (*e.g*., Barco *et al*. 2010).

Preview of Work

This dissertation was undertaken to identify and address many of the conservation challenges facing management of bottlenose dolphins in the southeastern USA, with specific focus on the northern Gulf of Mexico. I participated in a number of dolphin health assessment studies beginning in 1995 to develop a method of attaching archival data tags to dolphins, which resulted in the ability to measure individual dolphin’s fine-scale movements and activity. Later, I began to investigate dolphin residency patterns and stranding mortality in Choctawhatchee Bay on the Florida panhandle, and participated in the marine mammal stranding network to investigate mortality and threats from human interactions. A specific area of concern was the increasing rate of dolphin interactions with recreational fishing, which I addressed through a study to assess the nature of this problem, and sought to identify potential mitigation strategies. In 2010, the largest domestic marine oil spill in history occurred in the Gulf due to the explosion of the Deepwater Horizon platform, which resulted in a rapid response project to develop baseline abundance estimates for dolphins in Choctawhatchee and Pensacola Bays.

I used a combination of observational field studies, tissue sample collection, and basic mark-recapture methods to gain novel insights into how dolphins used their habitats and demonstrated residency in several coastal estuaries. My studies were intended to provide background data for informing the effective management and conservation of these animals. Specific goals of my dissertation project were to:

1) Describe fine-scale dolphin movements, activity and ranging
2) Determine nocturnal activity budgets and foraging
3) Assess residency and site fidelity in the Choctawhatchee Bay region
4) Develop a baseline abundance estimate for dolphins residing in the Choctawhatchee and Pensacola Bay estuaries using closed-population methods
5) Identify causes of mortality of bottlenose dolphins in the Florida panhandle
6) Assess Choctawhatchee Bay dolphin community structure and potential exposure to oil spill contaminants
7) Assess fishery interaction issues in the northern Gulf and identify solutions

This dissertation is constructed as five independent chapters that describe the investigations I conducted. The first two present my research on dolphin movements, ranging, habitat use/foraging, and swimming energetics resulting from the tagging projects done in conjunction with health assessment studies. Chapter 4 describes my initial study of dolphin residency and habitat use in Choctawhatchee Bay, including assessment of mortalities and threats from human interactions. In the next chapter, I present my research to characterize dolphin abundance and movement patterns in the Choctawhatchee and Pensacola Bay estuaries at the time of the Deepwater Horizon oil spill. Chapter 6 presents research on dolphin interactions with recreational fishing in the northern Gulf coast of Florida and Alabama. I conclude the dissertation with a brief summary of findings and suggestions for future work. The chapters were formatted using guidelines for publication in the journal *Southeastern Naturalist*.

CHAPTER TWO:
ARCHIVAL TAGS WITH STOMACH TEMPERATURE TELEMETRY FOR MEASURING FINE-SCALE TRAVEL AND FORAGING IN FREE RANGING BOTTLENOSE DOLPHINS

Introduction

Investigations of movement patterns of small cetaceans in the Southeast USA have been greatly facilitated through the use of satellite-linked and other radio tags to track individuals for prolonged periods (*e.g.*, Irvine *et al*. 1981, Scott *et al*. 1990b, Mate *et al*. 1995, Davis *et al*. 1996, Balmer *et al*. 2008; 2011a; 2011b, Mazzoil *et al*. 2008b). Assessing short-term dolphin ranging activity by remote tracking has limited spatial and temporal resolution, but this can be improved by monitoring radio tagged animals via aircraft or by following them in vessels to visually observe behavior states and foraging activity during daylight hours (*e.g.*, Altmann 1974, Mann 1999, Balmer *et al*. 2008).

Tag attachment methods and data logging technologies are continually evolving (*e.g.*, Irvine *et al*. 1982, Hooker and Baird 2001, Hart and Hyrenbach 2009, Johnson *et al*. 2009). Archival data logger tags have been remotely attached to free swimming cetaceans, providing fine-scale data on movement, swimming speed, diving, and echolocation activity (*e.g.*, Nowacek *et al*. 1998, Baird *et al*. 2001, Hooker and Baird 2001, Johnson and Tyack 2003, Tyack *et al*. 2006, Schorr *et al*. 2009). Remote attachments are usually made by launching the tag with a crossbow or placing it with a pole device, but this has proven difficult with small cetaceans such as bottlenose dolphins (*Tursiops truncatus*). The most secure tag attachments are made on dolphins that have been temporarily captured and restrained, such as during health assessments (*e.g.*, Scott *et al*. 1990, Wells *et al.* 2004, Fair *et al.* 2006). A short-term, non-invasive device called a Trac Pac was developed in 1994 as a means to easily attach a radio transmitter and instruments on small cetaceans to collect information on movement, temperature flux, and swim speeds (Townsend and Deckert 1995, Hansen and Wells 1996, Westgate *et al.* 2007). Inclusion of a Velocity Time Depth Recorder (VTDR) in the Trac Pac allowed focal observations to be correlated with swimming and diving records, as well as habitat characteristics and environmental conditions (Shippee *et al*. 1995).

Stomach temperature telemetry has been used as a method to determine foraging as indicated by the sudden temperature drop associated with ingesting relatively colder prey (*e.g.* in pinnipeds: Worthy 1985, Hedd *et al*. 1996, Andrews 1998, Austin *et al*. 2006, Kuhn and Costa 2006; in penguins: Ponganis *et al.* 2003, Ropert-Coudert and Kato 2006; in seabirds: Wilson *et al*. 1992; 1995, Catry *et al*. 2004). Stomach temperature telemetry in cetaceans was first used to determine body temperature (Fox *et al.* 1961, McGinnis 1968, Mackay 1970), eventually being employed to measure deep body temperature of *ex-situ* delphinids held in pools (Hampton *et al.* 1971; 1975, McGinnis *et al.* 1972, Whittow *et al.* 1974; 1978). An experiment conducted with a single bottlenose dolphin by the US Navy Marine Mammal Program in 1999 (Shippee *et al.* unpublished) demonstrated the suitability of using an ingested telemeter pill with an external data logger to measure body temperature and detect feeding in a free swimming dolphin. Studies using telemeter pills in captive dolphins all reported recovery of the devices from the animal’s enclosure (Table 1). Average retention time for pills in those studies was 30 hours. Recording forestomach temperature (FST) on free-ranging dolphins became practical when insertion of a telemeter pill could be made during health assessment studies. Follow-up tracking of the radio tagged animal could be done continuously through the night (Shippee and Hohn 2003). When combined with archival tag data, focal animal follows became a method of identifying activity (*e.g.* swimming, diving, foraging) correlated with location both during daytime and at night, despite limited visibility in the dark or when the dolphin was distant from the boat.

Table 1. Summary of Stomach Temperature Monitoring Studies in Small Cetaceans.

Species	Size of pill (cm)	Retention time (h)	Investigators
Spotted dolphin, *Stenella longirostris* Pacific bottlenose, *Tursiops truncatus gilli*	1.6 x 6.0	> 24 > 24	McGinnis *et al*. 1968
Common bottlenose, *Tursiops truncatus*	1.0 x 2.5	14 to 34	Hampton *et al.* 1971
Pilot whale, *Globicephala scammoni* Killer whale, *Orcinus orca* False Killer whale, *Psuedorca crassidens*	1.0 x 2.5	22, 26 & 60, 56	Whittow *et al*. 1974
Spotted dolphin, *Stenella longirostris*	1.0 x 2.5	9.7 to 31.5	Hampton and Whittow 1975
Rough-toothed dolphin, *Steno bredenensis*	1.0 x 2.5	27.5	Whittow *et al*. 1978
Common Bottlenose, *Tursiops truncatus*	2.0 x 5.5	21	Shippee *et al*. 1999

A collaborative approach to utilize Trac Pacs fitted with archival data loggers on free-ranging dolphins began in 1995 with National Marine Fisheries Service (NMFS) health assessments in Beaufort, North Carolina (Hansen and Wells 1996) and the Sarasota Dolphin Research Program (SDRP) health assessments in Sarasota Bay, Florida (Irvine *et al*. 1981). The initial success of this technique led to additional use in Sarasota Bay and eventually expanded to the Health and Environmental Risk Assessment (HERA) project in the Indian River Lagoon (IRL) on Florida's east coast (Fair *et al*. 2006). Application of Trac Pacs on dolphins in health assessment projects was deemed useful for comparing behaviors and habitat utilization among tagged individuals, and to improve understanding of short term ranging and site fidelity following release. When coupled with longer-term radio tracking and photo-identification studies in the same region, these findings could address fine-scale activity and movements during a dolphin's daily travels compared across study locations. Collection of archival swimming and FST data from free ranging dolphins during nocturnal intervals could potentially be used to assess foraging and resting behaviors when the animals were otherwise not able to be observed. This chapter describes the methodology, tag application results, and findings of foraging activity via FST monitoring of free ranging dolphins.

Methods

Health Assessments

Deployment of Trac Pacs and FST telemetry pills was conducted under National Marine Fisheries Service Scientific Research permits for dolphin health assessments in North Carolina during 1995 and 2000; at Cape May, New Jersey in 2002; dolphin health assessments in Sarasota Bay conducted by SDRP during 2000-06; and the HERA project conducted by Harbor Branch Oceanographic Institution (HBOI) and NMFS in the IRL, Florida during 2004-07 (Figure 1).

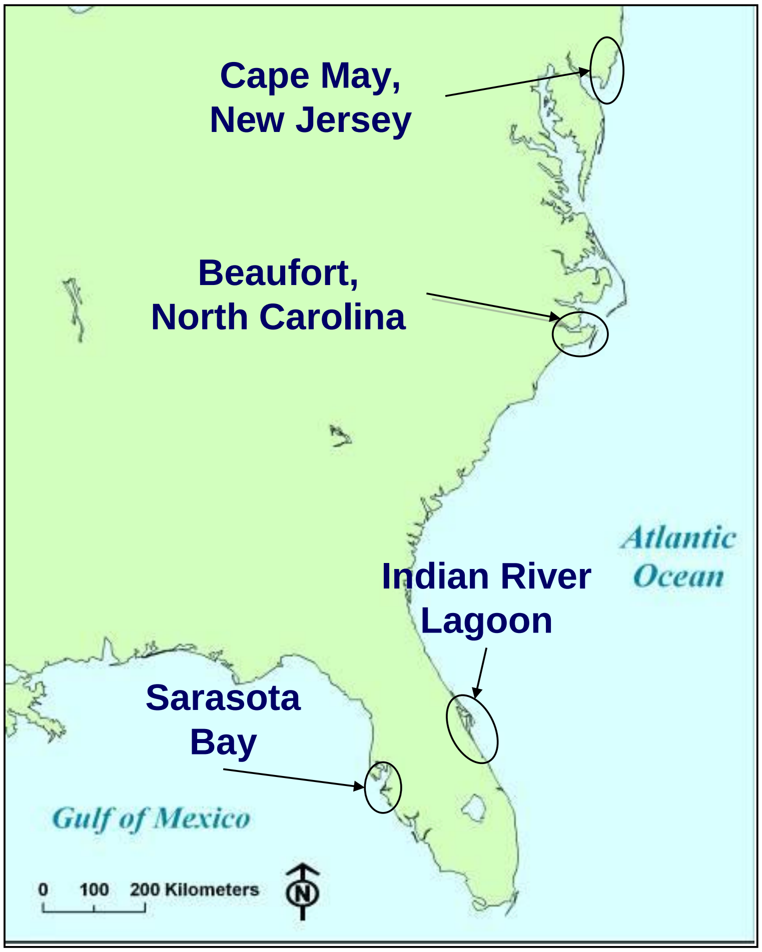


Figure 1. Study sites in the eastern USA where Trac Pacs were deployed.

North Carolina dolphin health assessment projects in 1995 and 2000 were conducted in the Bogue Sound, Newport River, Back Sound, and Neuse River - South River areas. Sarasota Bay health assessment collections were conducted throughout the Sarasota Bay estuary including the northernmost extent at Anna Maria Sound and southern regions in Little Sarasota Bay. The NMFS dolphin health assessment in New Jersey (2002) was centered around the Cape May peninsula from Delaware Bay to the Hereford inlet on the Atlantic coast. Tagging conducted in the IRL was focused on the central and southern regions from Melbourne to St Lucie Inlet. The Beaufort, Sarasota, and IRL sites shared common features of estuarine habitats containing resident dolphin communities (*e.g.,* Irvine *et al*. 1981, Odell and Asper 1991, Wells 2003, Gubbins *et al*. 2003, Read *et al*. 2003a, Mazzoil *et al*. 2008a); the Cape May site was distinct as it constitutes a seasonally occupied location by dolphins considered to belong to the northern coastal migratory stock (Toth *et al*. 2011, Waring *et al*. 2012).

Dolphins were temporarily captured in shallow water using a seine net technique (Wells *et al*. 2004, Bossart *et al*. 2006, Fair *et al*. 2006). Animals were gently restrained during the health assessment for 45-90 min while veterinary procedures were conducted to determine sex, age, morphology, reproductive status, and other health indicators. Tissue samples were collected for genetics, life history, bacteriology, virology, and gastric content. Following veterinary examinations, animals were held by attendants while tags were applied (including identification freeze brands). After tag attachment, dolphins were released by pointing them toward deeper water away from the shoreline.

Trac Pacs

Development of the Trac Pac design began in 1995 and was successfully tested by deployment on trained free-swimming bottlenose dolphins by the US Navy Marine Mammal Program in San Diego, California, and during wild dolphin health assessments conducted by SDRP (Townsend and Deckert 1995). A bolt-on design was successfully used to track a spotted dolphin (*Stenella attenuata*) for 28 d after rehabilitation and release by the Texas Marine Mammal Stranding Network (Davis *et al*. 1996). Westgate *et al*. (2007) designed a Trac Pac for short-term use to collect heat-flux measurements from the skin of free-ranging dolphins and made 55 deployments from 1999-2005. The tag used in the present study is a modification of the latter design.

The short-term Trac Pac is a molded thermoplastic, two-sided saddle lined with bath-mat style suction cups that adhere to the skin of the dolphin dorsal fin. The halves are firmly held together by a pin-fastened leading edge and a Velcro® strap around the trailing aspect. The device houses a radio transmitter and has custom fitted cavities in the plastic molding designed to securely hold archival data loggers (Figure 2). Several different tag designs were developed over the course of this project. A typical complete pack measured 25 cm long x 13 cm tall on each side of the dorsal fin and weighed approximately 670 g with the included instrumentation. The soft urethane suction cups lining the inward side of the tag measured 1.25 cm in diameter each and were arranged in four to five rows spaced 2.5 cm apart.

Each pack contained internal buoyancy composed of syntactic foam and was weighted to float with the radio antenna oriented above the water surface in all possible configurations. Advanced Telemetry Systems (Isanti, MN) radio transmitters (MM160B and MM150) were used in the packs. Average range of the radio signals at water level was typically 2 to 4 km with a standard VHF receiver. Transmission rates of 65-90 pulses per min were used, providing one to three radio “pings” on each dolphin surfacing.

Trac Pacs were designed to release through the dissolution of corrosive links that clamped together the leading edge. Galvanic links (International Fishing Devices, Inc., Northland, New Zealand) were generally A-5 and A-6 size with a calculated life span of one day, although the exact time period for dissolution was dependent on uncontrolled factors such as water flow over the links, salinity, and water temperatures. For most attachments done in the present study, the link duration was planned in expectation of 15-30 ºC water temperatures and salinities of 25-30 ppt. Due to the variable parameters across study sites and years, the ability to closely predict attachment times was imprecise and at best could be pre-determined as “short” (4 h), “one day” (12 h), and “overnight” (24 h).

Candidate animals were selected based on several criteria: they needed to exhibit sound health profiles; be independent (not nursing) and of subadult size or larger; and females could not be pregnant (determined by ultrasound) or supporting a dependent calf. Selected dolphins needed to be tractable during the health exam to allow attachment of the Trac Pac to their dorsal fin and insertion of a stomach telemeter pill, as deemed appropriate by the attending veterinarian.

Attachment of a Trac Pac was accomplished by fitting the saddle over the dolphin’s dorsal fin and securing the Velcro strap across the trailing edge to keep the two halves drawn tightly together (Figure 3). The fit of the leading edge was adjusted by changing the tightness of the galvanic links, which consisted of a magnesium barrel and two threaded steel eyebolts. Pack attachment and adjustment was accomplished in 1-5 min, and was usually done just prior to release of the animal following the health exam.

Archival Data Loggers

All data recorders used in this study in all the various pack configurations were manufactured by Wildlife Computers (Redmond, WA). Basic data loggers collected continuous samples of dive depth, water temperature, and luminosity. Some recorders also collected swim velocity and conductivity. In 1995, a MK6 Velocity Time Depth Recorder (VTDR) was housed in the Trac Pac. The pack used in 2000 contained a Heart Temperature Recorder (HTR) and a MK7 Time Depth Recorder (TDR) without a velocity sensor. During deployments in 2002-05 the packs contained a HTR and MK6 VTDR as well as a MK7 TDR. In 2006-07, a MK10 VTDR replaced the older MK6 unit. Standard Wildlife Computers software and interface components were used to initiate the data loggers each day prior to field deployment, and to download data following recovery. Internal battery refurbishing was made prior to each field season as warranted.

Stomach Temperature Pill and Data Logging

An inert metal temperature telemeter pill (Wildlife Computers STP) (Figure 4) measuring 5.5 cm long x 2 cm diameter and weighing 50 g was inserted via a sanitized esophageal tube into the dolphin's forestomach during the health exam. Pill insertion was always made under supervision of the attending veterinarian. The pill was dislodged from the tube into the forestomach by a pusher rod placed in the bore of the tube. The STP transmitted 5 MHz radio pulses at a rate that varied predictably with changes in the temperature of the pill casing. Telemetered data were received by the HTR data logger on the Trac Pac that was programmed to record stomach temperature readings every 10 s. A heart rate monitor watch was used to detect proper function of the STP once it was inserted into the dolphin's stomach. Proper functioning of the HTR data logger was signaled by a small flashing LED on the device, but this was often difficult to detect in bright sunlight, therefore the unit was usually activated prior to departure into the field. Once the STP was inserted, the Trac Pac was placed on the dolphin awaiting release. Recovery of archived data from the HTR depended on the successful retrieval of the Trac Pac, and data download was accomplished to PC using dedicated Wildlife Computers software (TDR-Tag Host Ver.1.07 to 1.22, 3M Ver.1.2, Hex Decoder V2.02, Strip Chart Ver.3.03, Zero Offset Correction Ver.1.25).

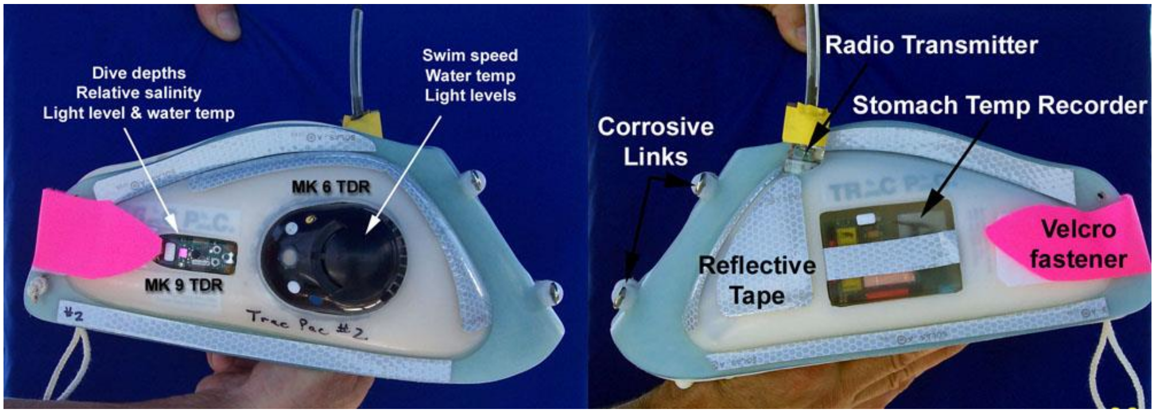


Figure 2. FST Trac Pac used in 2004-07 studies showing pack configuration.

Figure 3. Instrumented Trac-Pac on dorsal fin of FB984 in the Indian River Lagoon (2004).

Figure 4. Wildlife Computers Stomach temperature pill deployed in health assessment studies.

Tag Calibration

Trac Pacs were tested in a water tunnel in 1996 at the Naval Research and Development (NRAD) facility in San Diego, California, to determine drag area measurements and calibrate velocity readings of the MK6 VTDR (Appendix A). A correction factor was developed to adjust speed errors for the packs that were used in field deployments in 1995 and 2002. Water tunnel testing showed that the paddlewheel sensor of the MK6 VTDRs underestimated velocity of the mounted Trac Pac by 31-40% at speeds of 1.0-1.5 ms^{-1}, and that the error was reduced as faster speeds were achieved. Packs used in 2004-07 were field tested by placing them on a dorsal fin model mounted on a cylindrical tow body, and dragging the shape submerged through the water column behind a boat. Boat speed was recorded using a GPS unit as well as by recording time intervals over a measured distance between channel markers. The measured speed recorded by the Trac Pac was then compared to the boat GPS track to determine error and develop correction equations. Following deployments, recovered VTDR velocity readings were corrected *post-hoc* and then compared to the boat tracks of the corresponding focal follows to verify the calibration and VTDR reliability fell within 5% of the estimated travel speeds.

Dive depth sensors were tested by lowering tags to a measured depth in the field, and also by pressure testing in a hyperbaric vessel. TDR temperature sensors and STPs with external HTR recorders were tested for accuracy by immersion in a water bath and compared to temperature readings collected by a digital thermometer. Wildlife Computers STPs had an inherent ± 0.1 ºC variability between readings and showed a gradual drift in temperature over time; this error was noted but no adjustments to the values were made post-hoc. Water temperature sensors had an accuracy of ± 0.5 ºC on all the Wildlife Computers TDR tags and were non-adjustable.

Tracking and Data Collection

Radio tracking of the tagged dolphins was accomplished using an automatic direction finding unit (Advanced Telemetry Systems, Isanti, MN) enclosed in a custom weather-tight case. This was connected to an array of three element yagi antennas mounted on the tracking boat. A crew of two to three observers followed the dolphin, using outboard boats which varied from 5 to 6 m length depending on study site. All boats used in this study were capable of maneuvering in water depths of 0.5 m.

The tracking boat maintained a 50 m or greater distance from the tagged animal, and followed it throughout the attachment period as much as possible. Visual observations were recorded of the dolphin's behavior, interactions with cohorts, and with nearby human activities. Observers noted tides, water parameters, and meteorological conditions. Observations were logged using continuous scan sampling (Altmann 1974, Mann 1999); photographs and video were also collected throughout the focal follows. Nocturnal observations were aided by use of a spotlight to illuminate reflective tape on the Trac Pacs. On moonlit nights, dolphins usually could be visually sighted without lights. Behavioral data was classified based on the predominant behavior of the tagged dolphin, or the majority of dolphins that comprised the group that the tagged animal was accompanying. Travel was identified by periods when animals were swimming in a directed manner at a steady pace for a constant period of time in excess of 5 min. This was distinguished from foraging (and socializing) by observations of rapid swimming with swirling, splashing, or making long dives underwater while remaining in the same general location. When the tagged dolphin was with one or more individuals, it was not possible to discriminate between socializing and submerged group foraging unless there was evidence of feeding such as fish jumping or a dolphin surfacing with fish in the mouth (Waples 1995).

Continuous location data were collected on the tracking boat using two independent GPS receivers: a Garmin GPSMap 76 for observer waypoint entry, and a Garmin GPSMap 176C for continuous navigational tracking and boat position logging. The boat's depth sounder provided bottom depth and bottom clutter information. GPS tracks and waypoint data were managed with Garmin Mapsource marine navigation software using a laptop PC. Waypoints with time stamps were recorded at all behavioral observations and data collection locations.

The tracking team recovered the Trac Pac as quickly as possible once it released from the dolphin, and then continued to make visual observations of the animal for 10-30 min to watch for unusual behaviors. After return to the field station, data were securely downloaded and the data loggers were reprogrammed. New galvanic links were installed to ready the Trac Pac for repeat use. STPs were expended since they remained in the dolphin's forestomach until eventually being vomited at sea.

Recordings of Potential Prey Fish Acoustics

Underwater acoustic recordings were made from the side of the boat on deployments conducted in Sarasota Bay. During June 2004, an amplified hydrophone system (David Mann, USF, pers. comm. 2004) was used to record underwater sounds with a Hi-8 Video camera in locations where dolphins were observed foraging or socializing. During 2005-06 deployments, an Olympus S711 microcassette recorder unit connected to an amplified underwater hydrophone system (Aquarian Audio Products, Anacortes, WA) was used to record sounds. The hydrophone was attached to the end of a 1.25 m PVC pipe that was suspended from the side of the boat at a depth of 1.0 m beneath the surface. All recordings were made with the boat stationary and engine off. Recordings were subsequently digitized using Microsoft Media Player on a Dell Inspiron

5100 Laptop PC and converted to WAV file format for analysis with digital editing software (Audition Ver. 2.5, Adobe Corp, San Jose, CA).

Analyses

Archived data recovered from the Trac Pac were downloaded to a computer using software and protocols developed by Wildlife Computers (MK9 Host, HexDec, 3M, and Hyperterm) and then converted to an Excel spreadsheet (Microsoft Corp., Redmond WA). Behavioral and GPS location data were combined with archived TDR data for analysis using Garmin Mapsource software, and by creating graphs in Excel. Track coordinates were exported to ArcMap 10 (ESRI, Redlands, CA) for production of maps. Graphs were created for each deployment showing dive depths, swimming speeds, respiration rates, surfacings, stomach temperature, ambient water temperatures, and relative conductivity. Graphic data was coupled with the visual observations, photographs, video, acoustic recordings and location data to create a time-synchronized log of movements, diving and swimming effort, foraging events, relative exposure to temperature and salinity, locations of socializing with other dolphins, association with physical features in the environment, behavior around human activities and man-made features in the environment, rest/sleep behaviors, and movements relating to tides and currents.

Analyses of FST data were conducted by averaging temperature readings across 30 s to 60 s intervals. Aberrant electromagnetic spikes in the temperature record (*e.g.*, ± >5 ºC single point errors) were filtered out. Mean temperature was determined from point of stabilization (*i.e*. once the FST had reached an asymptote that agreed with expected core body temperature of ~37 ºC) to the end of the data record for each dolphin. Hysteresis within the STP was expected to cause gradual deviation from 37 ºC over time. Detection of STP being vomited by the dolphin was made if the FST record fell instantaneously from the mean core temperature to a constant lower reading. This was further verified by observation of the dolphin with the Trac Pac still in place and *post-hoc* if the other data streams from the TDRs continued to record activity data. Probable feeding events were scored from the graphed FST data by determining “precipitous drops followed by an exponential rise” (termed PDER, Wilson *et al*. 1992, 1995). PDER events were defined as described in Austin *et al*. (2006) and Kuhn and Costa (2006): ‘single feedings’ (ingestion of one large prey item or several small items in rapid succession) were indicated by only one FST deflection to minimum temperature followed by a recovery curve; ‘bout feedings’ were indicated by several FST deflections to minimum during the entire period of a PDER event. Pre-feeding stomach temperature, minimum temperature, time to reach the minimum temperature, time to return to pre-feeding temperature, rate of temperature decrease (amplitude of temperature drop / time to minimum temperature) and time between the end of one feeding event to the onset of the next were measured for each feeding event (Austin *et al*. 2006).

Since ambient water temperatures during summer were within 7 ºC of core body temperature, it was not possible to distinguish between small prey intake and possible water ingestion with certainty, however, the shape of the PDER curve and length of the recovery interval could be scored visually to flag suspect events. Therefore, any PDER changes less than 0.5 ºC or shorter than 10 min duration were not considered sufficient deviations to indicate prey intake (modified from Kuhn and Costa 2006). Comparison of the TDR readings of water temperature and diving activity were made to each PDER event to elucidate behavioral activity and habitat variables associated with presumptive foraging. Analysis of the data to determine meal size (*e.g*. Bekkby and Bjorge 1998) was not considered here since FST calibration information for bottlenose dolphins is lacking, and because of the compounding variables of prey size and shape, variable heat transfer, stomach churning, fullness, along with the potential insulation of the STP by large amounts of swallowed prey (Andrews 1998, Austin *et al*. 2006).

Summary data are reported as means ± SD, unless otherwise indicated. Statistical analysis was conducted with Excel Data Analysis Toolpak and SPSS software (Ver 13, 2004). Test for significance of means used Student's t-test assuming unequal variances. Contrasts were considered significantly different at $p < 0.05$.

Results

Trac Pac Deployments

During 1995-2007, 23 Trac Pac deployments were accomplished (Table 2). One pack was lost and never recovered (FB707 in 1995). In total, 256.7 h of tag data were collected during focal follows of dolphins across 1,150 km of waterway. Successful attachments lasted 0.9 – 41.2 h (mean = 11.2 h). 61% of the tagged animals (14) were males, since females caught in health assessments were often either pregnant or supporting young calves and therefore were not eligible for tagging. Four tagged animals (FB185, FB986, FB940, and FB133) were classed as subadults based on their length or known age from prior sampling events. Seven deployments exceeded 10 h with nine extending into night periods resulting in a total of 83 h of nocturnal observations and tag data. TDR and/or FST recorder malfunctions occurred on 5 deployments resulting in partial data recovery, or complete lack of tag data in one case (FB432). VTDR swim speed data was incomplete on 9 deployments due to either the dolphin swimming across shallows where the fin remained above water, or intermittent clogging of the paddlewheel sensor by floating debris, resulting in questionable sections of the velocity records of 10 min to 7.3 h.

Initial work during 1995-2002 deployed Trac Pacs with VTDRs, achieving mean attachment durations of 9.3 h (Table 3). Although the first tag was lost and no archival data was recovered, swim speed and ranging distance was estimated from the focal follow. Three other deployments resulted in 27.2 h of VTDR data. In April 2000, the first use of a forestomach temperature pill on a free ranging dolphin was made in Beaufort. The pack collected 7.2 h of data before releasing, although the dolphin was not visually observed during the last 5.5 h of the track. The FST readings showed that feeding had taken place (Figure 5). The same pack was used in two additional deployments during June 2000 in Sarasota Bay. Tag deployments at Cape May during September 2002 each used a VTDR, HTR, and STP. VTDR data was only recovered from one animal and the HTR recorder malfunctioned on both deployments such that no FST readings were collected. Swim speed and ranging distance for FB432 (with the malfunctioning VTDR) was estimated from the overnight focal follow; FB435 was also followed overnight northward along the coast before ending the track after 20.5 h; the pack was recovered on the beach the next day with 24.5 h of recorded VTDR data.

Improved Trac Pac designs with new VTDR and FST technology were used in health assessment studies during 2004-07 in Sarasota Bay and the IRL (Table 4), resulting in 14 successful deployments; 13 returned VTDR data, and 12 were in conjunction with STPs although FST telemetry failed on two dolphins. Attachment durations ranged from 0.9 to 41.2 h (mean 12.4 h) and tracking distances averaged 55.4 km with a maximum of 164 km.

Table 2. Summary of Trac Pac Deployments at Four Study Sites in the Eastern USA.

Study Site	No of tags	No of Males	No of Females	Tags w/ FST data	Mean attached time (h)	Maximum attached time (h)	Total night hours (h)	Total tracked distance (km)	Mean tracked distance (km)	Maximum tracked distance (km)
Beaufort	5	2	3	1	7.8 ± 3.7	14.2	7.5	177.2	35.4	59.9
Sarasota	8	3	5	7	10.4 ± 13.4	41.2	24.5	336.6	42.1	142.0
Cape May	2	1	1	0	18.3 ± 8.8	24.5	21.0	179.9	90.0	105.0
Indian River Lagoon	8	8	0	5	12.2 ± 12.4	35.8	30.0	466.4	58.3	164.0
Overall	23	14	9	13	11.2 ± 11.0	41.2	83.0	1160.1	50.4	164.0
Study Period Summary										
1995-2002	9	4	5	3	9.3 ± 6.9	24.5	28.5	384.8	42.8	105.0
2004-07	14	10	4	10	12.4 ± 13.1	41.2	54.5	775.3	55.4	164.0

Table 3. Individual Trac Pac Deployments during 1995-2002.

Deploy #	Date	Dolphin	Sex	Length (cm)	Age (y)	Location	Tracked distance (km)	Total tag time (h)	Link Plan (h)	Night (Dark) hours	Type of Data Logger used	# FST changes (Feeds)	Velocity	Depth, Water Temp, Light	Conductivity	FST Pill	Time to Recover Pack
1	7/15/1995	FB707	F	247	> 15	Beaufort	22.1	4.5	4	0.0	MK4	N/A		*			Never
2	7/16/1995	FB716	M	230	> 10	Beaufort	26.2	6.9	4	0.0	MK6	N/A	√	√			<1hr
3	7/18/1995	FB720	M	222	> 10	Beaufort	29.0	6.1	4	0.5	MK6	N/A	√	√			<1hr
4	7/19/1995	FB717	F	206	> 6	Beaufort	59.9	14.2	12	7.0	MK6	N/A	√	√			<1hr
5	4/21/2000	FB419	F	>200	N/A	Beaufort	40.0	7.2	12	0.0	MK7 HTR	3		√		√	20hrs
6	6/13/2000	FB25	F	270	22	Sarasota	5.5	1.4*	4	0.0	MK7 HTR	0		√		√	<1hr
7	6/15/2000	FB174	M	254	36	Sarasota	22.2	6.5*	12	0.0	MK7 HTR	1		√		√	<1hr
8	9/13/2002	FB432	M	>200	N/A	Cape May	74.9	12.0	12	10.5	MK6 HTR	0*		*		√	<1hr
9	9/19/2002	FB435	F	>200	N/A	Cape May	105.0	24.5	12	10.5	MK6 HTR	0*	√	√		√	>24hrs

Link plan = intended attachment duration; FST = Forestomach Temperature; MK4 and MK7 = Wildlife Computers (WC) time depth recorder (no velocity); MK6 = WC velocity time depth recorder; HTR = WC heart rate and temperature pill recorder; √ = device recorded this parameter; *= attachment failure, hardware malfunction or loss of data.

Table 4. Individual Trac Pac Deployments during 2004-2007.

Deploy #	Date	Dolphin	Sex	Length (cm)	Age (y)	Location	Tracked distance (km)	Total tag time (h)	Link Plan (h)	Night (Dark) hours	Type of Data Logger used	# FST changes (Feeds)	Velocity	Depth, Water Temp, Light	Conductivity	FST Pill	Time to Recover Pack
10	6/2/2004	FB181	F	245	29	Sarasota	11.6	1.7*	4	0.0	MK6 MK9 HTR	0	√	√	√	√	<1hr
11	6/3/2004	FB185	F	223	4	Sarasota	86.5	16.1	12	9.5	MK6 MK9 HTR	2	√	√	√	√	<1hr
12	6/8/2004	FB114	M	259	16	Sarasota	7.5	1.2*	12	0.0	MK6 MK9 HTR	0	√	√	√	√	<1hr
13	6/28/2004	FB984	M	257	19	IRL	164.0	35.8	24	14.0	MK6 MK9 HTR	0*	√	√	√	√	<1hr
14	7/1/2004	FB950	M	272	27	IRL	106.0	25.0	12	9.0	MK6 MK9 HTR	0*	√	√	√	√	<1hr
15	2/4/2005	FB189	F	253	32	Sarasota	142.0	41.2	24	11.5	MK6 MK9 HTR	10	*	√	√	√	<1hr
16	6/21/2005	FB986	M	200	6	IRL	20.6	4.8	4	0.0	MK6 MK9 HTR	N/A	√	√	√		<1hr
17	6/27/2005	FB940	M	213	8	IRL	7.8	0.9*	4	0.0	MK6 MK9 HTR	0	√	√	√	√	<1hr
18	6/8/2006	FB100	M	257	17	Sarasota	39.1	10.0	12	3.5	MK10 MK9 HTR	2	√	√	√	√	<1hr
19	6/16/2006	FB133	F	217	7	Sarasota	22.2	5.3	4	0.0	MK10 HTR	N/A	√	√	√		<1hr
20	6/22/2006	FB9C0	M	242	> 15	IRL	10.9	2.4*	12	0.0	MK10 HTR	0	√	√	√	√	<1hr
21	6/27/2006	FB9D2	M	265	> 20	IRL	79.2	15.7	12	7.0	MK10 MK9 HTR	11	√	√	√	√	<1hr
22	6/30/2006	FB946	M	262	20	IRL	45.0	8.1	12	0.0	MK10 MK9 HTR	2	√	√	√	√	<1hr
23	6/22/2007	FB948	M	248	12	IRL	32.9	5.2*	24	0.0	MK10 MK9 HTR	1	√	√	√	√	<1hr
	Overall from 1995-2007:						1160.1	256.7		83.0		13	17	21	14	17	

Link plan = intended attachment duration; FST = Forestomach Temperature; MK4 and MK7 = Wildlife Computers (WC) time depth recorder (no velocity); MK6 = WC velocity time depth recorder; HTR = WC heart rate and temperature pill recorder; IRL = Indian River Lagoon; √ = device recorded this parameter; *= attachment failure, hardware malfunction or loss of data.

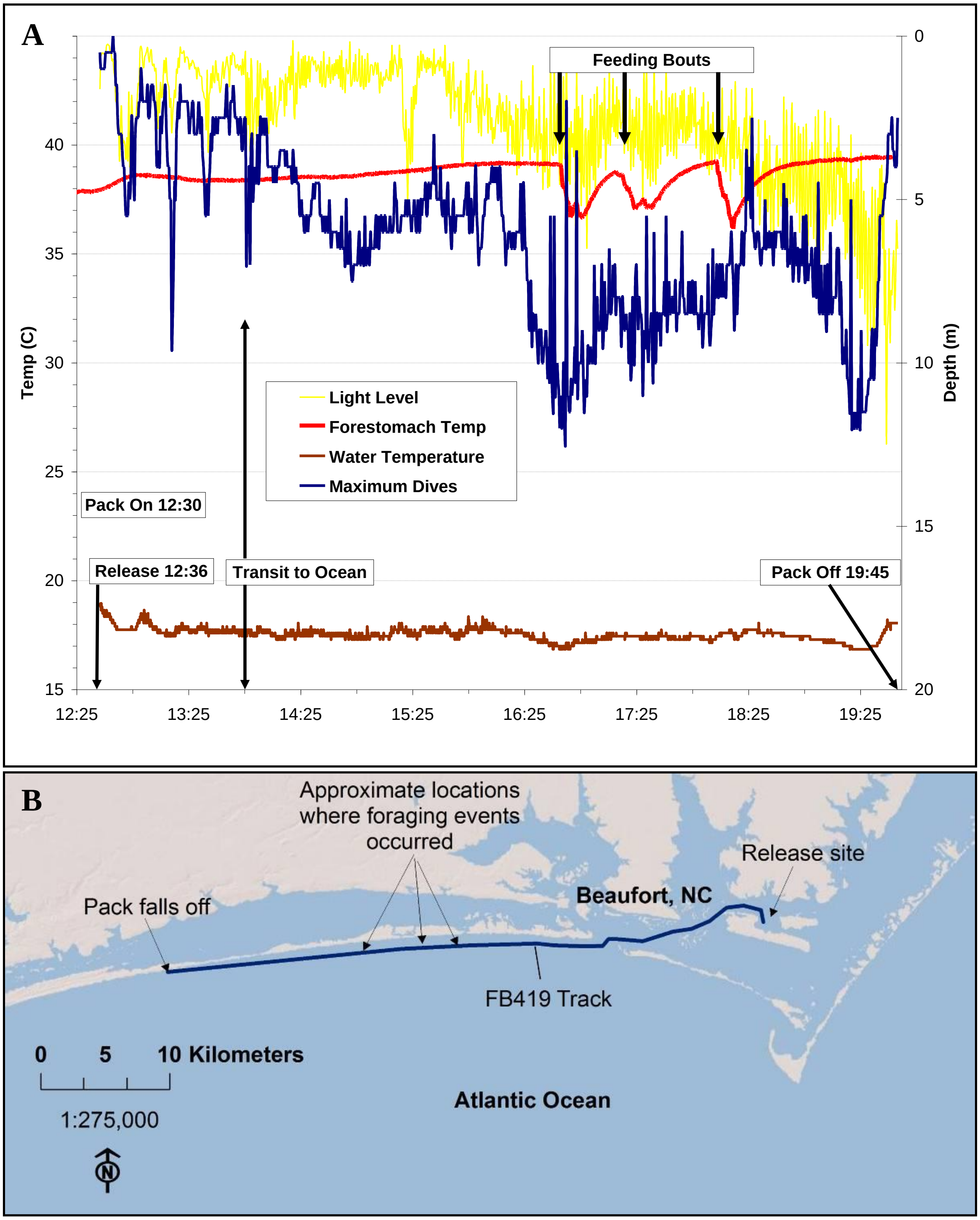


Figure 5. First deployment of FST Trac Pac on FB419 in Beaufort, NC.

(A) Significant Forestomach Temperature changes (red line) noted by arrows indicate feeding events. Light level is non-dimensional, upper boundary = daytime. Depth shown on inverted scale. (B) Map shows position of dolphin during radio tracking from release to pack detachment.

Radio tracking of tagged dolphins revealed short-term movements between estuaries and riverine or oceanic habitats. Two dolphins in North Carolina traveled between rivers out to the Atlantic coastal shoreline; FB419 departed the estuary and swam out to sea during inclement weather and could not be followed by boat so radio tracking was accomplished from shore and the pack was found the next day washed up on the beach. Three dolphins in Sarasota made journeys into the Manatee River, and 3 others ventured beyond the inlets to the nearshore Gulf. Two IRL dolphins traveled into the St Lucie River, while two others milled within Sebastian Inlet, but none exited the estuary into oceanic waters. Two coastal dolphins in New Jersey traveled along the Atlantic coast, but one made an overnight foray into the back-barrier estuary through the inlet at Atlantic City.

Follow-up observations were reported from SDRP in Sarasota Bay and HBOI in the IRL for four of the dolphins with long attachment times (FB100, FB185, FB950, and FB984). None of these animals exhibited unusual behaviors or signs of physical injury caused by the Trac Pacs. Images of the animals showed that the fins appeared normal except for recent freeze brands and rototag attachments (Figure 6). FB100 was discovered stranded one month after the tagging event with injuries caused by fishing interaction unrelated to the Trac Pac or health assessment (R.Wells, pers. comm. 2006).

Figure 6. FB 984 two days after release of Trac Pac that was attached for 36 h.

Photograph taken under the authority of NMFS Permit No. 998-1678, issued under the authority of the Marine Mammal Protection Act. The internal reference for the photo is: 2004 07 01 S2040.

Archival Velocity, Time, Depth Tag Data

Fine-scale swim speed data were collected from 17 deployments of Trac Pacs containing VTDRs. Estimated swim speeds were available from all 23 deployments based on the observed locations of the animals relative to the tracking boat. All tagged dolphins had similar transit swimming speeds (mean = 1.54 ± 0.19 ms^{-1}; ~5.5 kh^{-1}). Dolphins usually moved quickly away from the capture site immediately after release and maintained a significantly faster mean speed for the next 30 to 60 min (1.93 ± 0.38 ms^{-1}; t=4.05, df=40, $p = 0.0001$). Depth, light, and temperature data were available from 21 tags; one tag was lost; and one malfunctioned. Tags used in 1995-2002 had lower resolution dive sensor capabilities (± 2.0 m) than those deployed in 2004-07 (± 0.5 m), and therefore were not able to detect fine-scale changes in depth. MK7, MK9 and MK10 tags provided sufficient sensitivity to allow detection of 0.5-2.0 m dives as well as surfacing intervals. Since the majority of deployments were on estuarine resident dolphins that rarely encountered depths greater than 5 m, there were few dive events that would allow meaningful dive analysis. However, three dolphins made ventures into deeper waters and exhibited brief dive bouts reaching 10-15 m (Figure 7 and Figure 8).

Stomach Temperature (Foraging) Results

In total, 17 deployments were made with Trac Pacs equipped with HTR data loggers where STPs were inserted into the dolphin's forestomach. Four deployments failed to produce useable data, either due to HTR or STP malfunctions. The hardware functioned correctly on 13 deployments yielding 110.6 h of FST data (Table 5).

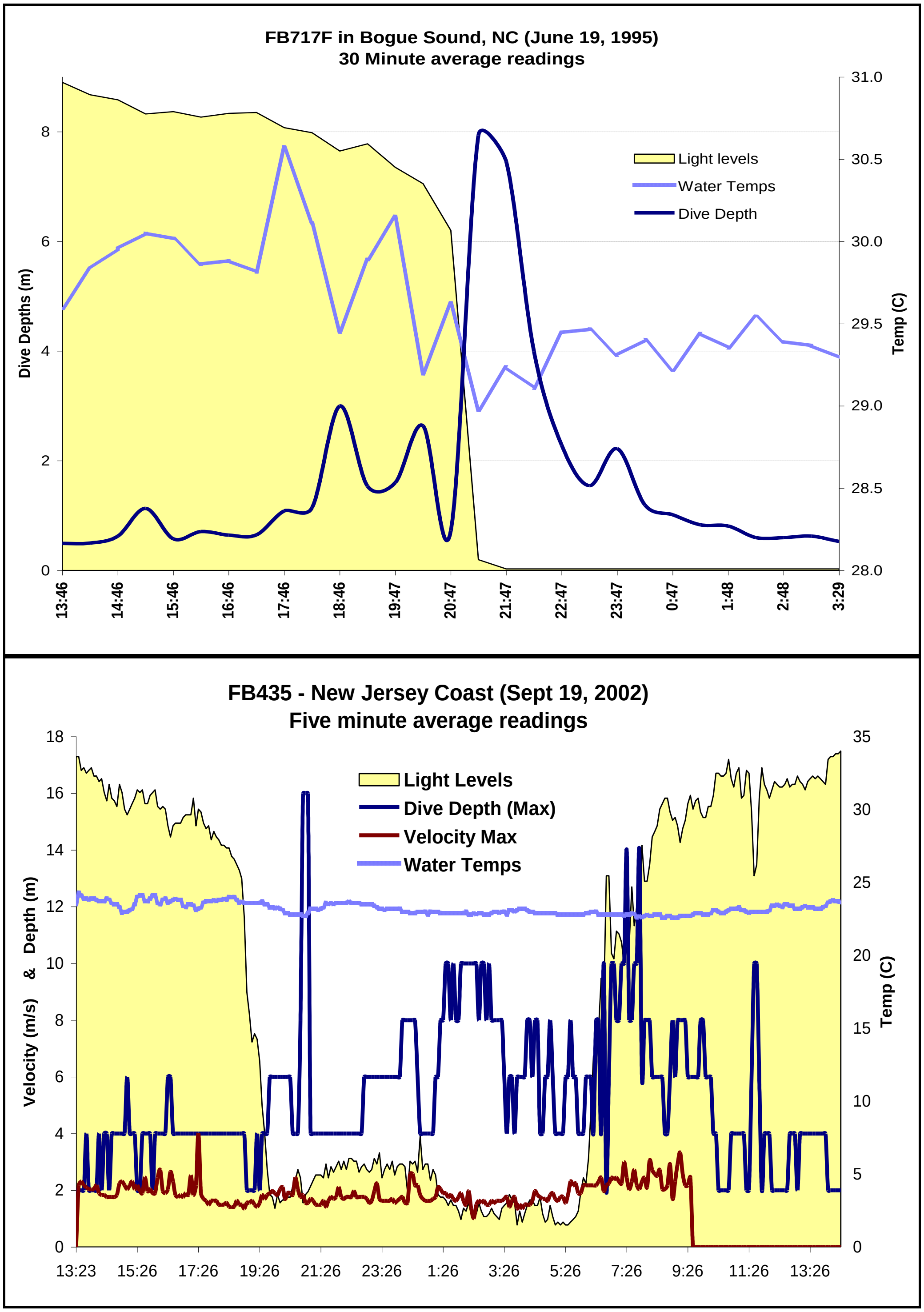


Figure 7. TDR data records for two dolphins exhibiting dive bouts after sunset.

Lower axis indicates time of day. Light readings are dimensionless, upper boundary = daytime, lower boundary = dark. Velocity (swim speed, black line) in lower figure ended abruptly at 9:30 am.

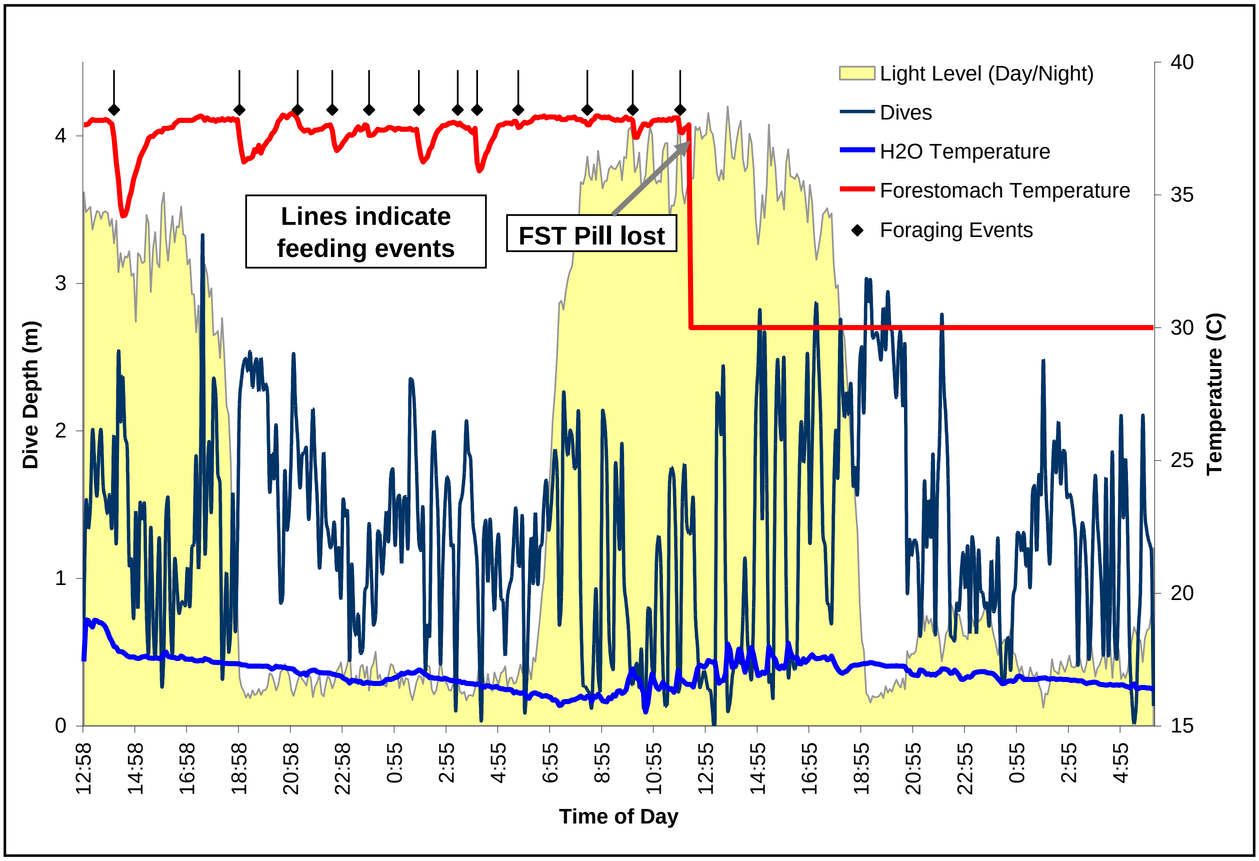


Figure 8. Composite archival data from MK7 TDR and HTR loggers over 41 h.

FB189 in Little Sarasota Bay, February 4-5, 2005. Sudden drop in Forestomach temperature indicates stomach telemeter (FST) pill was expelled. Light levels are dimensionless (left Y axis 0 = dark; 4 = daylight).

Table 5. Forestomach Temperature Data Collected from Tagged Dolphins.

Dolphin	Season	Site	TDR time (h)	Night time (h)	FST Pill Expelled (h)	# FST drops	# Night Feeds	Mean FST (°C ± SD)	FST± from mean (°C)	Mean H2O (°C ± SD)	H2O± from mean (°C)	Δ Mean FST-H2O (°C)
FB419	Spring	NC	7.2	0.0	No	3	n/a	38.6 ± 0.61	-2.3 : 0.8	17.5 ± 0.27	-0.7 : 0.9	21.1
FB25	Summer	SAR	1.4	0.0	No	0	n/a	37.6 ± 0.12	-0.6 : 0.4	30.6 ± 0.59	-1.3 : 2.0	7.1
FB174	Summer	SAR	6.5	0.0	No	1	n/a	37.7 ± 0.25	-0.7 : 0.7	29.6 ± 0.55	-0.6 : 2.6	8.1
FB181	Summer	SAR	1.7	0.0	No	0	n/a	37.3 ± 0.11	-0.3 : 0.3	31.4 ± 0.47	-0.6 : 1.5	5.9
FB185	Summer	SAR	16.1	9.5	11.2	2	2	37.7 ± 0.10	-0.5 : 0.2	31.0 ± 0.74	-3.0 : 2.0	6.7
FB114	Summer	SAR	1.2	0.0	No	0	n/a	37.9 ± 0.13	-0.3 : 0.3	30.2 ± 0.22	-0.7 : 0.5	7.7
FB189	Winter	SAR	41.2	12.3	23.4	11	8	37.5 ± 0.62	-3.5 : 0.7	16.9 ± 0.67	-2.2 : 2.1	20.6
FB940	Summer	IRL	0.9	0.0	No	0	n/a	38.2 ± 0.22	-1.0 : 0.4	29.6 ± 0.24	-0.3 : 1.0	8.6
FB100	Summer	SAR	10.0	3.5	No	2	1	37.2 ± 0.27	-3.4 : 1.4	29.1 ± 0.31	-1.0 : 1.2	8.1
FB9C0	Summer	IRL	2.4	0.0	No	0	n/a	37.5 ± 0.18	-0.3 : 0.5	30.6 ± 0.34	-1.6 : 1.0	6.9
FB9D2	Summer	IRL	15.7	7.0	No	9	4	37.1 ± 0.26	-1.1 : 0.5	28.9 ± 0.42	-1.2 : 2.3	8.2
FB946	Summer	IRL	8.1	0.0	No	2	n/a	37.4 ± 0.41	-6.8 : 0.8	30.7 ± 0.44	-1.4 : 1.0	6.7
FB948	Summer	IRL	5.2	0.0	No	1	n/a	37.1 ± 0.2	-0.7 : 0.5	30.4 ± 0.24	-1.7 : 0.8	6.8

NC = Beaufort, North Carolina; SAR = Sarasota Bay, Florida; IRL = Indian River Lagoon, Florida.. TDR = Archival data logger collection period; FST = Forestomach temperature; FST drops = events where stomach temperature declined signifying feeding had occurred.

Discrete PDER events were recorded during deployments on 8 dolphins; the other 5 dolphins did not show any change in FST. A total of 41 PDER events in stomach temperature were recorded; 31 were scored as indicative of ingestion of prey. Distinct changes in FST that suggested prey ingestion ranged from 0.5 to 3.6 °C below the average FST reading. Mean duration of PDER events was 60.7 ± 42.8 min. The most notable cases with 2.3 °C and 3.6 °C drops occurred during the winter and spring (FB419 and FB189) where ambient water temperatures, and thus probable prey temperatures, were 21.1 ± 0.7 °C and 20.6 ± 1.0 °C below average dolphin body core temperature. The other 11 successful FST deployments took place in summer months in Florida when ambient water temperatures were 7.3 ± 0.8 °C below body core. The gradual increase over time of the average FST in the longer deployments was explained by the inherent magnetic hysteresis of the internal circuitry in the telemeter pill (Wildlife Computers, pers. comm. 2006). This varied as much as 0.5 °C but did not obscure the discrete drops in FST attributed to ingestion of prey or water.

Contrasting FST records between nocturnal and diurnal foraging activity did not reveal any significant differences in the six measures of PDER events (Table 6). The single significant difference (T_{core}) was due to FB419's FST record showing core temperatures above 39 ºC, which I attributed to the STP hysteresis rather than from physiological conditions.

Table 6. PDER[1] Analysis using Six Measures of Foraging Type (per Kuhn and Costa 2006)

Foraging Events	Day	Night	*df*	*t*	*p*
N	17	14			
Duration (min)	61.8 ± 50.7	58.9 ± 30.5	28	0.17	0.433
Mean T_{core} (ºC)	37.8 ± 0.7	35.2 ± 9.2	23	1.80	0.043*
Mean T_{min} (ºC)	36.7 ± 0.8	34.5 ± 9.0	27	-0.16	0.436
Mean Δ T (ºC)	1.1 ± 1.0	0.8 ± 0.4	22	1.37	0.093
Mean t_{min} (min)	16 ± 18.1	16.4 ± 12.5	29	-0.06	0.478
Mean t_{rec} (min)	45.8 ± 41.1	43 ± 24.7	28	0.24	0.407
Mean $t_{between}$ (min)	35.1 ± 49.6	31.4 ± 32.1	28	0.35	0.365

[1] PDER=Precipitous drop and exponential rise, indicating ingestion of prey. Values are means ± SE. T core is the mean core temperature for all attachments in the bin; T min = mean minimum temperature; Δ T = mean difference between core and minimum temperature; t min = mean time for FST to reach minimum value following feeding events; t rec = mean time for FST to regain stable values near core temperature between feeding events; t between = mean interval between foraging events. * indicates significant difference.

Foraging frequency varied between animals. Time from release to first feeding event ranged from 24 min to 9.5 h (mean = 2.6 ±3.0). On deployments with multiple PDER events, mean time between FST changes was 0.78 ±0.9 h. The greatest number of distinct FST changes indicative of feeding in any one deployment was 12 over a 23.4 h period (FB189) before the telemeter pill was vomited, indicated by sudden discontinuation of FST readings (Figure 8). Another FST record of 11.2 h (FB185) also showed an abrupt data loss indicating the pill was expelled. Other deployments with FST records were complete through the point of Trac Pac jettisoning, with one of 15.7 h (FB9D2) showing 9 distinct PDER events. Four FST records included focal follows with night time intervals, all of which showed nocturnal changes in FST that ranged from one suspect event (FB185) while in a freshwater river, to at least 8 distinct events in dredged channels and at an inlet to the Gulf (FB189).

Visual observations of foraging activity were made during focal follows that in some cases mirrored changes in the FST record. FB189 was observed swirling water in an area where a slow-moving mullet was seen at the surface, which coincided with a large PDER event. FB174 displayed sudden dive activity where birds were seen diving on fish schools immediately before a PDER event occurred in the FST record. On three deployments in Sarasota, underwater acoustic recordings gave evidence of soniferous fish species present during observed foraging bouts (D. Mann and D. Odell, pers. comm. 2005). PDER events were seen immediately after a sudden change in ambient water temperature in eight cases, in concert with the animals' passing through either a deeper channel or at the mouth of a creek. Foraging activity at dusk was both visually observed as well as measured in the FST record on six of the deployments, constituting 23% of the total PDER events scored as probable feeds. Only one dolphin (FB185) did not show a PDER event at sunset out of the six that included this time interval; two others appeared to begin feeding at sunset, evidenced by a drop in FST resembling the beginning of a PDER event (rapid decline toward a minimum temperature) before the abrupt end of the data record coinciding with the Trac Pac releasing from the dorsal fin.

Discussion

Data collection using Trac Pacs and archival tags has proved beneficial in assessing movements and foraging activities of tagged dolphins. All individuals shared similar patterns of transit swimming between foraging patches, traveling at mean speeds of 1.54 ms^{-1} (5.5 km/h). Animals initially maintained a significantly faster mean speed for the first 30 to 60 min post-release before slowing to routine travel speeds. This initial behavior has been observed in prior studies (Rohr *et al*. 2002) and suggests a temporary flight response that may diminish as individuals become acclimated to subsequent recapture events (Wells 2003). Continuous radio tracking revealed unexpected movements during the dolphins' daily travels. Six of the tagged dolphins swam to locations in shallow bay and riverine waterways during both night and day: two dolphins traveled distances of greater than 15 km up into rivers, three estuarine dolphins spent time in inlets and swam out into coastal waters, and one presumed coastal dolphin in New Jersey swam into an estuary during the evening hours. Five animals made long transit swims between different habitat areas covering linear distances of 20-84 km in one day. These extensive movements may have been a temporary response by the dolphins to the Trac Pac or the health assessment procedures; however, it may also reflect their normal ranging patterns. SDRP tracking studies subsequent to this study have shown similar movements beyond the range of the standardized survey areas (R. Wells, unpublished). This suggests that estuarine dolphins may have far greater ranges than predicted by mark-recapture studies, especially given that observations presented here included fine-scale overnight tracking.

Dolphins with FST tags engaged in both diurnal and nocturnal foraging bouts. Observation of slow-speed swimming during transits that suggested the animals were engaged in uni-hemispheric rest (*e.g.* Gnone *et al*. 2001, Sekiguchi and Kohshimah 2003, Ridgway *et al*. 2006) occurred both during day and night. Further analysis of the swimming, ranging, and activity patterns of these dolphins is treated in Chapter 3.

Hardware and technique: Use of a suction-attached Trac Pac to hold instrumentation on the dolphin eliminated the need to recapture the animal in order to recover archived data. This has been a positive evolution of many remotely placed tags and greatly expanded *in situ* data collection on a variety of marine species (Hooker and Baird 2001). Other studies using remotely attached tags containing VTDR units (*e.g*., Hooker and Baird 1999, Baird *et al*. 2001) reported relative velocity readings but not actual swim speeds due to the inconsistency of orientation and position of the tag on the animal. Newer DTAG designs utilizing accelerometers provide an improved method for dead reckoning velocity but are nonetheless subject to positional errors over time (Johnson and Tyack 2003, Johnson *et al*. 2009). Westgate et al. (2007) used a Trac Pac containing a VTDR and reported relative velocity data, but did not attempt to verify swim speed accuracy. Calibration of Trac Pac VTDRs was possible since the device was held in a fixed orientation and was attached in a uniform position on each dolphin dorsal fin. In the present study, packs were tested in a water tunnel and *in situ* to determine velocity errors caused by hydrodynamic characteristics of the packs and recorders, and the resulting data was corrected and validated by comparison to the observed boat speeds to attain an accuracy of ± 5%.

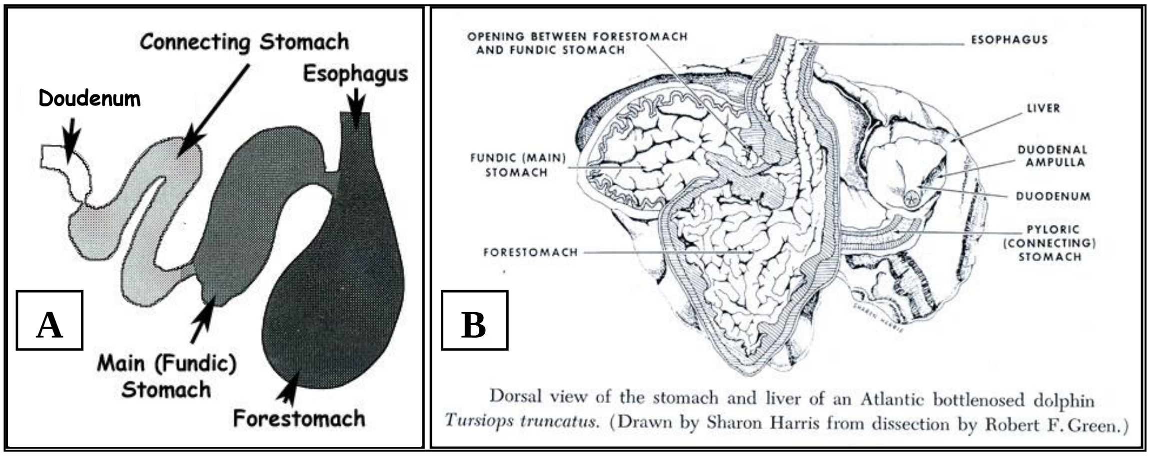
The majority (n = 17) of Trac Pacs released as intended by dissolution of the magnesium links; 6 tags released prematurely either by direct action of the dolphins or failure of the closure strap. Trac Pacs that did not have a good fit with the dorsal fin (n = 3) were shed within 12 min after animal release and were therefore not included in the results. Four animals were able to dislodge their packs by vigorous leaping and splashing, however, their behavior was typical of the normal range of activity for bottlenose dolphins. In contrast, eight animals were observed making energetic jumps without loss of the pack, suggesting that the proper fit of the device to the fin played an important role in insuring it remained in place.

Intended tag attachment durations varied between deployments depending on a variety of factors (weather forecasts, time of day of the capture, etc.) and therefore mean attachment time of 11.2 h for the 23 successful tag deployments does not reflect the true potential for future use of this technique. Long attachment times of 24 up to 41 h were accomplished during this study. By comparison, Westgate *et al*. (2007) used an almost identical galvanic-link Trac Pac design and accomplished 55 tag deployments; 43.6% jettisoned in less than 1 h, 49.1% lasted 1-4 h, and 7.3% were attached longer than 8 h (mean = 4.4 h) with a maximum duration of 23 h. In that study, the optimal attachment period for data collection was 9 h. The availability of corrosive links with an estimated dissolution time allowed flexibility in predicting the length of focal follows, but experience proved this was unreliable and packs often stayed attached longer than planned. During the present study, unplanned sleepless nights and days challenged the ability of observers to closely monitor dolphins in the later hours of the longer focal follows.

Archival data loggers (Wildlife Computers TDRs and VTDRs) used in the present study provided a fine-scale record of swimming, diving, and surfacing activities for the tagged animals. It was possible to interpret environmental conditions each animal experienced from recorded water temperatures, light levels, and relative conductivity on the TDRs. Trac Pac designs used in 2004-2007 included both the smaller MK7&9 TDRs and a VTDR in the same pack, thereby increasing data collection potential. Resolution of all TDR dive depth sensors was not sufficient for dive analysis since estuarine dolphins primarily reside in shallow bays with depths of 1-3 m, but several animals displayed noteworthy repetitive dive bouts while in deeper waters.

Wildlife Computers VTDRs used in the present study measured speed by assessing revolutions of a flywheel spun by water flowing through ports on the device. These devices experienced occasional clogging caused by particulates in the water column or perhaps from the animal rubbing on the sediment. This resulted in periods of time during 5 deployments where velocity readings disagreed with the observed speed of the dolphin, or fell to zero for a period of minutes to over seven hours. Despite this flaw, the useable velocity readings provided sufficient integrity to compare with distance-averaged movements of animals taken from the boat GPS locations to verify reliability of the data. Post-hoc corrections of VTDR velocity data provided a means to adjust any errors caused by hydrodynamic characteristics of the packs and recorders.

Stomach pill telemetry hardware did not always function as planned, either due to operator error or hardware failure. FST measurements were therefore not collected on all dolphins that had an STP inserted into their forestomach. In one case (FB435) the FST data logger failed to receive the transmitted STP signal due to electrical interference from a separate data logger placed on the dolphin (as also noted in Bloomqvist *et al*. 2004). Nonetheless, a total of 120.5 hours of FST data were collected from successful deployments. It was assumed that ingested stomach pills were eventually vomited and FST records provided conclusive evidence showing that two pills were lost at 11 and 24 h, respectively. In one dolphin (FB189), a continuous 24 h record of stomach temperatures was acquired providing a complete record of overnight activity, demonstrating the potential of this method for collection of daily foraging data in this species.



Dorsal view of the stomach and liver of an Atlantic bottlenosed dolphin *Tursiops truncatus*. (Drawn by Sharon Harris from dissection by Robert F. Green.)

Figure 9. Bottlenose dolphin stomach compartments.

A) Cartoon depiction of general arrangement of 4 stomach compartments; B) anatomical drawing of forestomach and main stomach (from Ridgway 1972 by permission).

Foraging and FST Monitoring: The forestomach of a bottlenose dolphin (Figure 9) is a non-glandular storage compartment for ingested prey (Ridgway 1972, Geraci 1978). The temperature of this compartment remains close to core body temperature, except when the animal has swallowed prey of a cooler temperature. Foreign objects may remain in the forestomach for considerable periods of time and typically will not pass into the main stomach (Sweeney 1978). Small innocuous foreign objects may be vomited within a few days, and generally are not considered to cause ill effect (Sweeney 1978). Two animals in the present study presumably vomited the STP during the course of their deployment, consistent with expectations. One dolphin (FB100) was discovered entangled in fishing gear one month after the health assessment; no sign of the STP was found in the stomach.

FST data collected in the present study demonstrate that tagged dolphins often engaged in feeding activities within hours of release. Although five of the tagged dolphins did not display PDER events, none of those records were longer than 2.5 h; the shortest time to first feed after release was 24 min (FB9D2); one other dolphin fed 60 min after release (FB189), and the remainder took over 90 min to first feed (mean = 2.6 h). This may be explained by the flight response seen in all the dolphins for the first hour after release, suggesting that foraging probably was not a priority immediately after the capture event.

Since the majority of Trac Pac deployments occurred during summer months, the small (~7 ºC) difference between ambient water temperatures and stomach temperatures resulted in relatively small PDER events. Due to lack of available reference data for *Tursiops*, it is not advisable to draw conclusions about meal size from these FST records, however, initiation times and frequency of feeding events can be explored. Despite the small deviation of FST from mean core temperature during PDER events (0.5 - 3.6 ºC), it was possible to score them as probable feeding events. Overall, 51% of PDER events showed sequential drops in FST after the beginning of a recovery period, suggesting that several prey items were taken during feeding bouts. Duration of recovery intervals (60.7 ± 42.8 min, range 15-215 min) in all cases provided strong evidence for consumption of significant meals. Telemeter pills used in the present study showed a response of 11 ºC in 60 s, implying the measured PDER events involved lengthy and persistent stomach temperature changes. By comparison, one study using stomach temperature recorders on pinnipeds (Kuhn *et al*. 2009) defined feeding bouts in northern elephant seals off the California coast by temperature drops of > 1.0 ºC lasting longer than 10 min. Their data indicate that PDER events of -3.0 ºC from the mean stomach temperature of ~36 ºC were typical in these animals when making deep foraging dives in ambient ocean temperatures of < 10 ºC.

Likewise, Kuhn and Costa (2006) noted recovery intervals of less than one hour during their detailed calibration studies of stomach temperature loggers with sea lions and elephant seals.

Contrasts for six measures of PDER events did not reveal differences between nocturnal and diurnal foraging activity. These results suggest that daytime and night time prey ingestion rates were consistent and that dolphins spent equal effort feeding in the two time periods. Assuming foraging success can be elucidated from the PDER variables, this also suggests that prey acquisition was relatively constant temporally.

Use of instrumented Trac Pacs on dolphins to collect archival data provided valuable insights into habitat use, movement patterns, and nocturnal foraging activities of these apex predators. Many potential health problems facing dolphins may be linked to low grade persistent stressors in the habitat, such as anthropogenic noise, fragmentation, disturbance from boating, and reduced foraging opportunities. Short-term Trac Pacs provided a fine-scale means to assess impacts on dolphins, and were a complement to the health assessment studies. Tag data revealed that swimming speeds varied from initial release following capture to more relaxed speeds as the animals transited their range. Repetitive dives just after sunset suggestive of foraging bouts were made by some animals, and FST data consistently showed feeding occurred with equal frequency during day and night. Also, foraging occurred during transit swimming between habitat patches. The present study was the first known use of stomach temperature monitoring on free ranging dolphins. Archival data logger hardware and tag attachment methods continually improve over time, and potential future uses of these tracking techniques over longer duration intervals are expected to provide new information about dolphin foraging and prey resource utilization.

CHAPTER THREE:
FINE-SCALE SWIM SPEEDS, MOVEMENTS, AND HABITAT USE OF FREE-RANGING BOTTLENOSE DOLPHINS

Introduction

Coastal and estuarine bottlenose dolphins (*Tursiops truncatus*) are known to have strong residency patterns and site fidelity in estuaries in the southeastern USA (*e.g*., Shane 1980; 1990; 2004, Odell and Asper 1990, Scott *et al.* 1990, Barco *et al.* 1999, Maze and Würsig 1999, Caldwell 2001, Quintana-Rizzo and Wells 2001, Gubbins 2002, Zolman 2002, Read *et al.* 2003a, Wells 2003, Hubard *et al.* 2004, Mazzoil *et al.* 2005, 2008a; Balmer *et al.* 2008, Wilson *et al.* 2012). Despite these residency patterns, dolphins may range over considerable distances in search of prey, shelter, or social contact with conspecifics. These animals have been known to exhibit ranging patterns that vary across time as individuals mature (Odell *et al.* 1999). Dolphin communities along the US mid-Atlantic coast occur in a complex of stocks with some individuals making seasonal migrations between distant estuaries (*e.g.*, Garrison *et al.* 2003, McLellan *et al.* 2003, Rosel *et al.* 2009, Mazzoil *et al.* 2011, Toth *et al.* 2011, Waring *et al.* 2012). Similar movements in and out of estuarine regions have been noted in the Gulf of Mexico (*e.g.*, Maze and Würsig 1999, Hubard *et al.* 2004, Balmer *et al.* 2008, Miller *et al.* 2010). Although much is known about bottlenose dolphin movements on a coarse scale over long intervals, fewer data are available about their fine-scale movements on a daily basis (Bailey and Thompson 2006).

Foraging theory predicts that animals attempt to maximize energetic gains by leaving a foraging patch when net energy intake decreases below a point of equaling the cost of staying (Stephens and Krebbs 1986). Dolphins presumably should move between habitat patches to optimize foraging gains timed with the most beneficial moments of using a particular patch (Wilson *et al.* 1997, Hastie *et al.* 2004, Bailey and Thompson 2006). Environmental conditions such as salinity, water temperature, dissolved oxygen content, currents, depth and tide stage are likely controlling factors in prey density, availability, and quality (Shane 1980, Irvine *et al*. 1981, Gannon 2003, Spitz *et al.* 2012). Dolphins frequently prey on soniferous fish that they detect by passive listening (Barros and Odell 1990, Barros and Wells 1998, Gannon 2003, Gannon *et al*. 2005, Berens McCabe *et al.* 2010). A variety of Sciaenid fish, such as drums, croakers, and seatrout have spawning calls that may increase following sunset (Luczkovich *et al.* 2000), suggesting that dolphin foraging activity should have a nocturnal component. In addition, prey densities change seasonally with mating and spawning cycles, thus dolphins might seek widely spaced habitat patches during particular times of day and in different seasons when soniferous prey are likely to be most abundant or active (Barros and Odell 1990, Luczkovich *et al.* 2000, Hastie *et al.* 2004, Gannon *et al.* 2005).

An understanding of fine-scale habitat use and energetic expenditures of free-ranging dolphins is necessary to better define foraging patterns, critical habitats, and movement corridors. The greatest daily energetic expense for estuarine bottlenose dolphins is that involved in transiting from place to place across their range (Williams *et al*. 1996, Williams 1999, Rosen and Trites 2002). Williams *et al.* (1992; 1993) predicted the cost of transport (COT) for bottlenose dolphins is optimal at swim speeds averaging 2.1 ms^{-1} but quickly doubles at speeds approaching 2.9 ms^{-1}. Various studies have calculated mean sustained travel speeds for *Tursiops*, ranging from 1.4 – 4.8 ms^{-1} (Würsig and Würsig 1979, Irvine *et al*. 1981, Videler and Kamermans 1985, Shane 1990, Mate *et al.* 1995, Rohr *et al.* 2002, Clelland 2008). Short-term (daily) ranging distances of dolphins have been estimated from 23.7 to 67.0 km via resighting of individuals over time and from radio and satellite tracking studies (Irvine *et al*. 1981, Odell and Asper 1990, Mate *et al.* 1995, Balmer *et al.* 2008, Mazzoil *et al.* 2008b). Clelland (2008) compared the fine-scale swimming speeds of estuarine and coastal bottlenose dolphins in South Carolina and reported mean speeds of 1.38 ± 0.1 (SE) ms^{-1} and 1.76 ± 0.2 ms^{-1}, respectively. However, there is a lack of data on the fine-scale routine swim speeds or daily travels of estuarine and coastal dolphins to compare between multiple habitats in the eastern USA.

Awareness of dolphin residency patterns over short and long term periods is critical to conservation of populations and their habitats that have been impacted by anthropogenic disturbance and contaminants (*e.g*., Hansen *et al.* 2004, Mazzoil *et al*. 2008a, Balmer *et al.* 2011a, Wilson *et al*. 2012). Additional challenges for apex marine predators could result from increasing patchiness of formerly contiguous grassbeds and marshes resulting in increased energetic cost to travel between foraging spots, and loss of foraging opportunity (Allen *et al*. 2001, Rosen and Trites 2002, Burns *et al.*, 2006). In addition, human activities on the waterways (*e.g.*, boat traffic, dredging, construction, noise, pollutant discharge, and fishing) present obstacles to travel that may require extra energetic effort to avoid or circumvent (Allen and Read 2000, Nowacek *et al*. 2001, Buckstaff 2004, Buckstaff *et al*. 2013). The impact of disturbance and waterway obstructions on dolphin home range patterns likely represents a low-grade stressor that indirectly contributes to higher energetic costs and decreased long-term fitness of individual animals (Nowacek *et al*. 2001, Rosen and Trites 2002). Declining prey abundance can also potentially lead to risky, and more energy intensive, foraging strategies such as increased use of predator dominated regions (McHugh *et al*. 2011), depredation of fishing gear (Noke and Odell 2002, Powell and Wells 2011), and dependency on provisioning (Cunningham-Smith *et al*. 2006).

To estimate variables associated with daily energetic costs, swimming, diving, and foraging data were collected from free-ranging dolphins by deploying short-term archival data loggers during health assessment studies (see Chapter 2). Bolt-on radio transmitters (*e.g.*, Scott *et al*. 1990) were attached to dolphins in the Indian River Lagoon, FL, to allow longer-term tracking for comparison of activity and movements to the short-term archival data. Tagging was done at three sites targeting estuarine dolphins and at a fourth site investigating coastal migratory dolphins. Swim speed measurements are used to determine if dolphins moved at cost efficient speeds during daily travels or if they went at speeds that might incur additional costs. Mean sustained speeds above a predicted optimum (*e.g*., Williams *et al*. 1992) might suggest a response to stressors that could have long-term fitness implications; slower than predicted speeds could suggest they used optimal travel speeds that allow better exploration of their habitat for locating prey, or that they reduced overall energetic expense by spending a portion of their day at idle rest. Comparison of measured actual travel distance with average linear range allows evaluating how closely remote tracking (*e.g*., satellite-linked and periodic radio-tag location) estimates a dolphin's daily movements. In this chapter, I also address the tagged dolphins' habitat use, foraging, and daily activity budgets. Here, habitats are defined by environmental variables (salinity, depth, tidal influence). Behavioral focal animal observations determined when and how often dolphins engaged in distinct activities with different energetic cost (traveling, socializing and foraging, and resting). The combination of movement, habitat selection, and activity allows evaluating how dolphins' daily energetic costs are met. Here, I use these data to elucidate routine travel speeds and movement distances of the tagged dolphins at these four different locations and address habitat use, foraging, and daily activity budgets.

Methods

Study Sites

Each location in this study was by invitation to participate in ongoing dolphin health assessment projects. Tagging was conducted at four sites (see Chapter 2, Figure 1).

North Carolina health assessments in 1995 and 2000 were conducted in the vicinity of Beaufort, NC (BNC). A distinct stock of estuarine dolphins (southern North Carolina estuarine system) is resident in this region, as are dolphins of both northern and southern migratory coastal stocks during portions of the year (Gubbins *et al*. 2003, Read *et al*. 2003a, Waring *et al*. 2012). Estuaries in the region comprise a connected network of Bogue, Back, and Core Sounds, separated from the Atlantic Ocean by a series of barrier islands. Three river tributaries empty into the sounds. Water depths throughout the sounds and rivers are shallow (1-3 m) except for the maintained channels of the Intracoastal Waterway. Oceanic depths along the Atlantic coast increase from 4 m to over 15 m within 3 km of the shore.

Health assessments in Sarasota Bay, FL (SAR) have been conducted annually since the 1980's. Bottlenose dolphin residency and movements have been extensively studied in the Sarasota Bay region and a resident population of about 160 animals is recognized (Irvine *et al*. 1981, Scott *et al*. 1990, Wells 2003; 2009). This 90 km long coastal lagoon is comprised of one large bay segment of 1-4 m depth, and several smaller shallow embayments. Four inlets open to the Gulf of Mexico through the barrier islands. The Intracoastal Waterway courses through the estuary with dredged channel depths of 2 to 3 m. Gulf waters outside the inlets gradually increase to 10 m at approximately 3 km offshore. Sarasota Bay opens northward into Tampa Bay through Anna Maria Sound. Within Tampa Bay, water depths of 5 to 8 m are typical. The

Manatee River empties into Tampa Bay at the eastern margin of Anna Maria sound. Water depths within the river gradually decrease from 4.5 m at the western end to less than 1 m eastward of Bradenton, FL.

The 2002 NMFS dolphin health assessment project along coastal New Jersey (CNJ) was centered around the Cape May peninsula from Delaware Bay to the Hereford inlet on the Atlantic coast. This region was selected because the New Jersey shore was thought to be the northern extent of the summer migratory range of coastal *Tursiops* along the Atlantic seaboard (Toth *et al*. 2011). The Cape May region is a mosaic of marine and estuarine waters that include barrier island shorelines, a back-barrier lagoon system with shallow marshlands of 1–4 m depths, and tidal mudflats on the Delaware Bay shore. The Atlantic coast barrier beach and back-barrier lagoon system extends for 154 kilometers N-S along the New Jersey coastline.

Tagging conducted on the east coast of Florida in 2004-07 was focused in the southern Indian River Lagoon (IRL), in the region from Melbourne to St. Lucie Inlet. At least three distinct resident communities of bottlenose dolphins have been described inhabiting the Indian River Lagoon estuary (Mazzoil *et al*. 2008a, Browning *et al*. 2014). There is little evidence to suggest that dolphins in the IRL move between the estuary and Atlantic Ocean (Odell and Asper 1990, Noke Durden *et al*. 2011, Mazzoil *et al*. 2011). The IRL is a shallow estuarine system that consists of three interconnected bodies of water; the Indian River, Banana River and Mosquito Lagoon that span a linear distance of 250 km from Ponce de Leon Inlet to Jupiter Inlet. There are five passes to the Atlantic Ocean and the width of the lagoon varies from less than 0.93 km at the southern end to 9.30 km in the north. The majority of the estuary is shallow (< 2 m at high tide) but depths greater than 5 m exist in some of the dredged basins, inlets, and Intracoastal Waterway.

Tag Attachments

Fine-scale swimming, foraging, and movement data were collected on 23 dolphins tagged with Trac Pac dorsal tags fitted with archival data loggers (see Chapter 2), comprising velocity & time depth recorders (VTDRs and TDRs) and a radio-telemeter logger (HTR) that recorded forestomach temperature (FST) readings. Instrumented Trac Pacs attached for 1 - 41 h were used to radio-track and monitor dolphins during 1995-2007 in conjunction with health assessment studies (Wells *et al*. 2004).

Bolt-on tags were applied during the 2007 summer Health and Environmental Risk Assessment Project in the IRL (Fair *et al*. 2006). Individual “marked” dolphins with sighting histories ranging from 2-12 y (mean = 8.0 ± 2.9 SD) were selected for tagging. One dolphin was dual-tagged with both a Trac Pac and a bolt-on radio tag. A VHF radio-transmitter (MM120, Advanced Telemetry Systems, Inc.) was attached to each animal via a thermoplastic sleeve (Trac Pac Inc., Ft. Walton Beach, FL) attached to the trailing edge of the upper, middle, or lower third of the dorsal fin (Figure 10). Transmitters broadcast 90-100 pulses/min at ~166 MHz for an expected duration of 90 d. The attachment site on the fin was first cleansed with betadine scrub, followed by administration of a local anesthetic. A sterile 5 mm biopsy punch was used to pierce the fin 23-42 cm from the trailing edge, through which a sterilized 6.4 mm delrin pin was passed to fasten the transmitter sleeve with a corrodible nut and stainless steel washer designed to eventually fall free. Minimum number of transmission days and minimum number of days the tag remained attached to the fin were calculated for each individual from resightings. Minimum tag transmission was defined as the number of days from tag application until the last day of signal reception, and minimum tag attachment was calculated as the number of days from attachment to the last day the animal was seen with an attached transmitter.

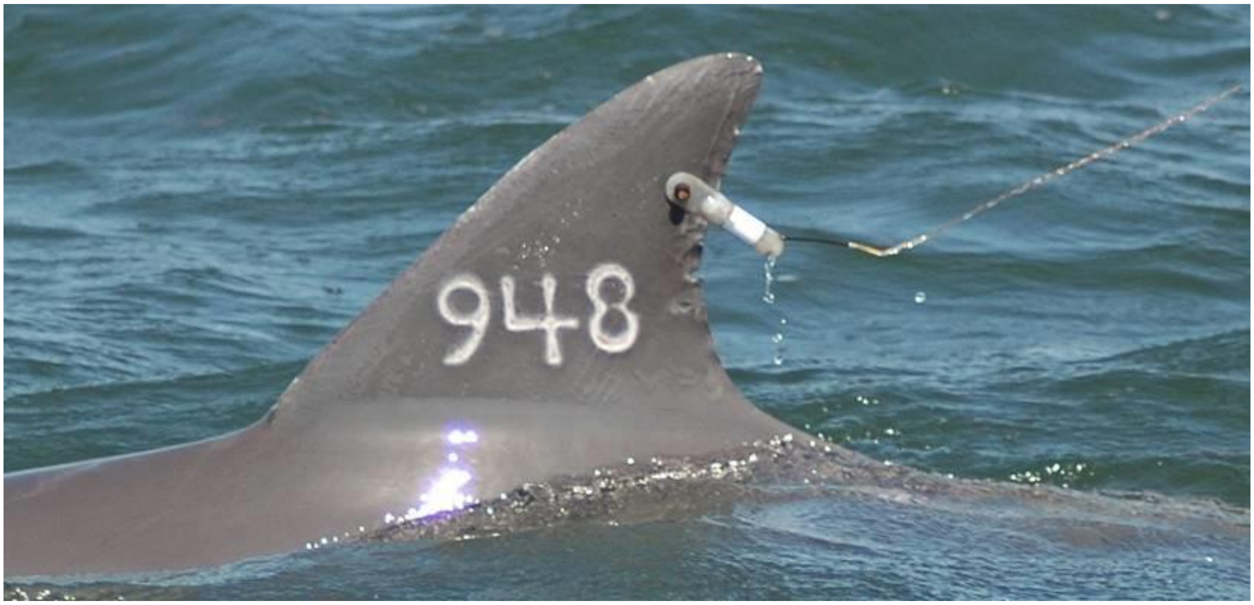


Figure 10. Bolt-on radio tag used in IRL during 2007.

Focal Animal Behavioral Follows and Data Collection

Tagged dolphins were radio-tracked from either 5 or 6 m outboard boats equipped with an automatic direction finding unit. Radio signals were found by scanning the tag frequencies while searching the waterway, and then slowly approaching the signal source to visually sight the tagged dolphin. The boat followed the dolphin from a 50 m or greater distance. During Trac Pac deployments, the dolphin was followed continuously; when tracking relocated radio-tagged animals, the boat would follow for 1-10 h periods. Boat movements were always minimized and done at idle or slow speed to avoid influencing the animal's swimming and foraging activity. Continuous GPS locations were collected on the tracking boat and water depths were noted via a depth sounder. Tide stage, water parameters, and meteorological conditions were recorded. Habitat types were described by observing proximity to local geographic features, water depth, and parameters (salinity, temperature, turbidity). Underwater acoustic recordings to detect soniferous fish were made during focal follows in Sarasota Bay. Coordinates were recorded at all behavioral observations and data collection locations. Boat tracks and waypoint data were managed with Garmin Mapsource marine navigation software (Ver. 6.15 or later).

Continuous scan sampling using visual observations were recorded of the animal's behavior, interactions with other dolphins, and reactions to man-made features such as bridges, docks, passing boats, and construction activity (Altmann 1974, Mann 1999). Activity was classified by the predominant behavior of the focal dolphin occurring for a period of at least one minute. In some instances, the tagged animal was a member of a group engaged in similar activity (*e.g*., directional swimming), in which case the group activity was described. Three activity states were defined: 1) transit swimming, 2) socializing and foraging, and 3) resting. Activity states required a minimal duration of 1 min to be identifiable. Transit swimming was identified as periods when animals were swimming in a directed manner at a steady pace for more than 5 min. Socialization and foraging activity were often indistinguishable since the behaviors often occurred when submerged, therefore these behavioral states were combined. Because dolphins engage in uni-hemispheric sleep while swimming, resting has been described as slow speed movement in a constant direction while exhibiting relaxed exhalations and shallow diving (Goley 1999, Gnone *et al*. 2001, Sekiguchi and Kohshima 2003). Dolphins in a group may sleep while transit swimming, where they exhibit close-rank formations with synchronized surfacings (Sekiguchi and Kohshima 2003). In the present study, rest was identified during focal follows when noting a reduction of swim speed from a routine transit pace combined with the observation of rhythmic and quiet respirations every 15-20 s, especially when observed as a group of individuals surfacing together in close formation.

Analyses

Summary data are reported as means ± SD unless otherwise indicated. Statistical analysis was conducted with SPSS software (Ver 13, 2004) and Microsoft Excel Data Analysis Toolpak. Means testing used ANOVA and Student's t-test, with Tukey's HSD *post hoc* comparison; significant differences were set at $p < 0.05$. FST data were averaged into 60 s intervals for analysis of foraging. Visual observations of foraging were correlated with changes in FST when those data were available. Locations were time-synchronized with observation data to determine activity and habitat use. Dive analyses were not feasible given the TDR resolution (0.5 to 2.0 m) in the shallow estuaries where the tagged dolphins traveled.

Swim speed and ranging: All swim speeds are expressed as $m \cdot s^{-1}$. VTDR speed data were averaged into 10-sec intervals for each individual. Calibration adjustments to speeds were made *post-hoc* and corrected by two methods: 1) derived from water tunnel or in-field calibration of the velocity meter on the Trac Pac tags (see Chapter 2 and Appendix A); and 2) by comparing to distance-averaged speed determined by GPS positions of the animal taken during tracking. Questionable sections of VTDR data were excluded from analysis (*e.g.*, periods where the speed sensor malfunctioned or the animal swam in shallows with its fin above water). Estimated speeds of animals tracked only by boat (*e.g.*, IRL radio tagged individuals in 2007) were derived entirely by GPS locations. To evaluate if movement varied at different times of day, swim speeds of each animal were divided into periods of first hour post-release, remainder of daytime until sunset, sunset to 2 hrs after sunset, and remainder of nighttime until sunrise. Ranging distances were derived from animal positions recorded during tracking. Mean travel distances per h were determined for each time interval and reported as movement rate in km/h.

Habitat use: dolphin movements between habitats were distinguishable by measured environmental variables, grouped into four distinct types: 1) bay/sound, 2) riverine, 3) oceanic, and 4) inlet. Bay/sound was defined as estuarine water of mixed salinity connecting to open seas by a tidal inlet; riverine refers to low salinity waters above a zone of tidal influence dominated by fresh water sheet flow from a river (*e.g.,* Manatee River in SAR, St. Lucie River in IRL, and the Newport River at BNC); oceanic refers to coastal near-shore waters (either Gulf of Mexico or Atlantic Ocean); and inlet refers to habitat zones where variable daily tidal flow occurs between high salinity oceanic waters and lower salinity estuarine waters. Individual dolphin track maps were clipped to determine time spent and distance traveled within each habitat type using Garmin Mapsource (Ver. 6.15), and values were exported to a spreadsheet to calculate average habitat use by individuals and for an overall mean.

Activity budgets: Behavioral observations were divided in three categories: 1) transit swimming; 2) socializing and foraging; and 3) resting. Other studies have considered additional behavioral states such as milling and play (Waples 1995, Clelland 2008), but these are similar in energetic expense to socializing and foraging. Start time and end time was determined for each behavioral state for each individual to derive length of total observation in min. Group means were used to summarize overall results.

Results

Trac Pac Archival Data

In total, 256.7 h of archival and observational data were collected in 23 deployments during 1995-2007 (Table 7). Radio tracks of tagged dolphins spanned 1,150 km. Each dolphin's track was mapped by estimating its known location relative to the boat (Figure 11 - 13). Seven deployments each exceeded 10 h duration. Nine tracks included nocturnal periods providing 83 h of night-time observational and tag data. VTDR swim speed data were collected from 17 tags providing 184 h of data. Inaccurate or zero readings occurred on 9 tracks ranging from 7 min to 7.3 h totaling 19.5 h of data missing from the tracks (10.6% of total tag attachment time). 17 deployments were made with Trac Pacs equipped with HTR data loggers where FST pills were inserted into the dolphin's forestomach; 13 returned data totaling 120.5 h of FST records.

Bolt-On Radio Tags

Bolt-on radio tags were deployed on five male IRL dolphins in addition to one Trac Pac during June 2007 (Figure 14). Animals were re-located and radio tracked a total of 70 times over an 85 d period. FB94A was never relocated by radio signal but was seen one time with the tag still attached. FB948 with the Trac Pac was followed the first day until the pack detached, and was subsequently reacquired by radio signal 12 times over the next 41 d. The other three dolphins were located 8 to 37 times. FB948 and FB942 were frequently together in the same areas. In total, there were 64 resightings of tagged dolphins, including two of animals shortly after shedding their tags. Four transmitters appeared to have migrated out of the fins and the fifth ceased operating after 85 days but remained attached for 97 d (Noke Durden *et al*. in prep). Data from 42 boat tracks totaling 84.5 h were used to analyze ranging and movements (Table 8).

Table 7. Trac Pac Deployments on 23 Dolphins at Four Study Sites.

Animal ID*	Tracked time (h)	Travel distance (GPS km)	Linear extent (km)	Mean speed (ms^{-1} ± SD)	VTDR used
Beaufort, NC					
FB707	4.5	22.1	13.8	1.35 ± 0.8	No
FB716	6.9	26.2	23.1	1.76 ± 0.5	Yes
FB720	6.1	29.0	18.8	1.61 ± 0.6	Yes
FB717	14.2	59.9	48.3	1.53 ± 0.5	Yes
FB419	7.2	40.0	39.1	2.36 ± 0.8	No
Coastal NJ					
FB432	12.0	73.5	46.4	1.45 ± 1.1	No
FB435	24.5	105.0	61.4	1.90 ± 0.4	Yes
Sarasota Bay, FL					
FB25	1.4	4.8	5.5	1.53 ± 0.8	No
FB174	6.5	22.2	13.5	1.31 ± 1.1	No
FB181	1.7	11.5	7.7	1.76 ± 0.6	Yes
FB185	16.1	86.5	34.8	1.56 ± 0.5	Yes
FB114	1.2	6.8	5.7	1.84 ± 0.6	Yes
FB189	41.2	136.0	31.7	1.57 ± 0.9	No
FB100	10.0	14.1	0.0	1.03 ± 0.7	Yes
FB133	5.3	21.4	15.2	1.31 ± 0.5	Yes
Indian River Lagoon, FL					
FB984	35.8	187.0	120.0	1.48 ± 0.4	Yes
FB950	25.0	106.0	57.5	1.39 ± 0.6	Yes
FB986	4.8	20.0	12.1	1.19 ± 0.4	Yes
FB940	0.9	7.8	6.4	1.79 ± 0.6	Yes
FB9C0	2.4	10.8	7.6	1.46 ± 0.3	Yes
FB9D2	15.7	76.7	53.5	1.41 ± 0.6	Yes
FB946	8.1	45.0	34.5	1.53 ± 0.7	Yes
FB948	5.2	29.9	17.0	1.78 ± 0.9	Yes
Overall Mean	11.2	49.7	29.3	1.61 ± 0.4	17 w/ VTDR

* See Chapter 2 (Tables 3 and 4) for animal details. VTDR = Velocity Time Depth Recorder.

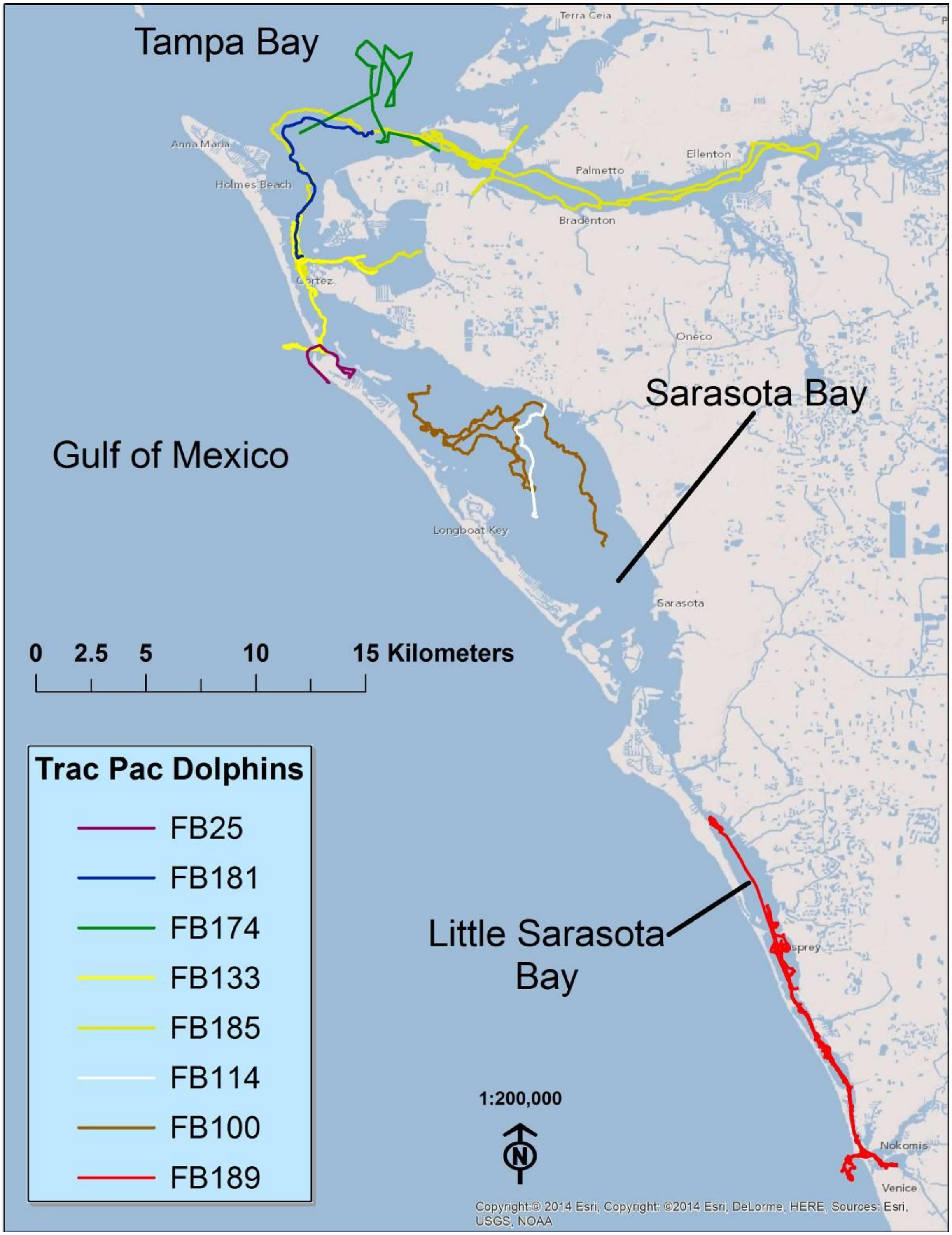


Figure 11. Dolphin behavioral focal follow tracks at Sarasota Bay, FL.

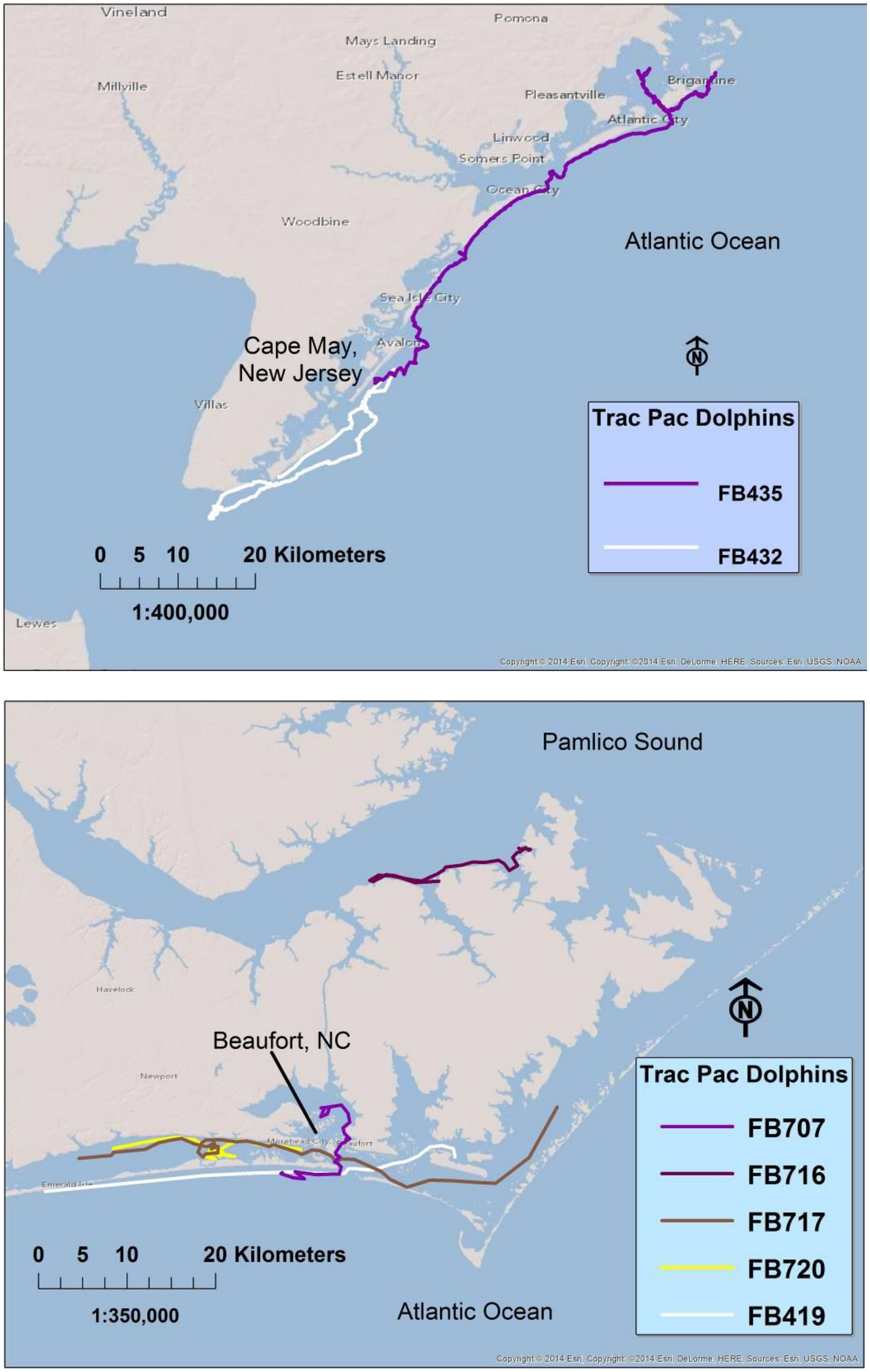


Figure 12. Dolphin behavioral focal follow tracks at New Jersey and North Carolina

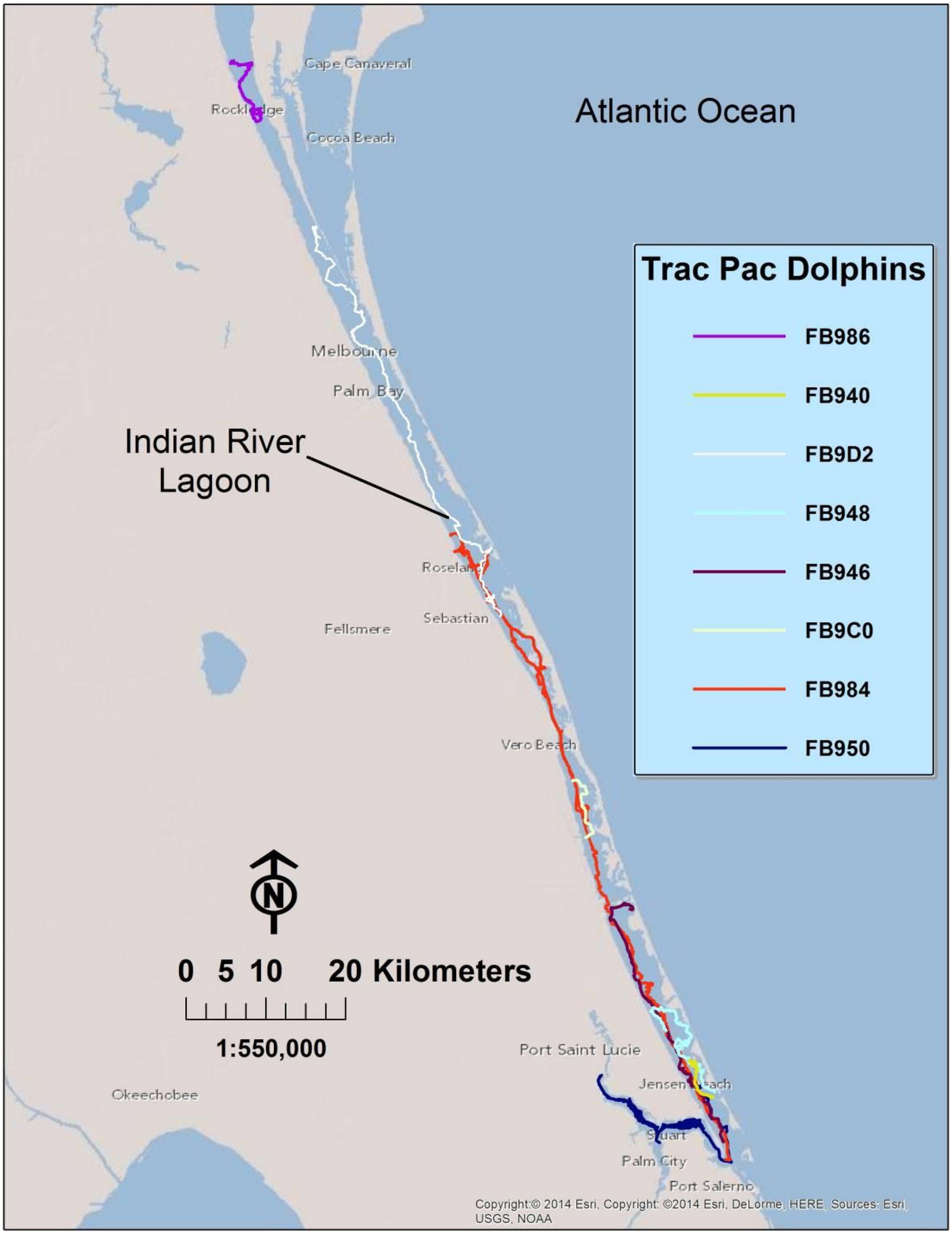


Figure 13. Dolphin behavioral focal follow tracks in the Indian River Lagoon, FL

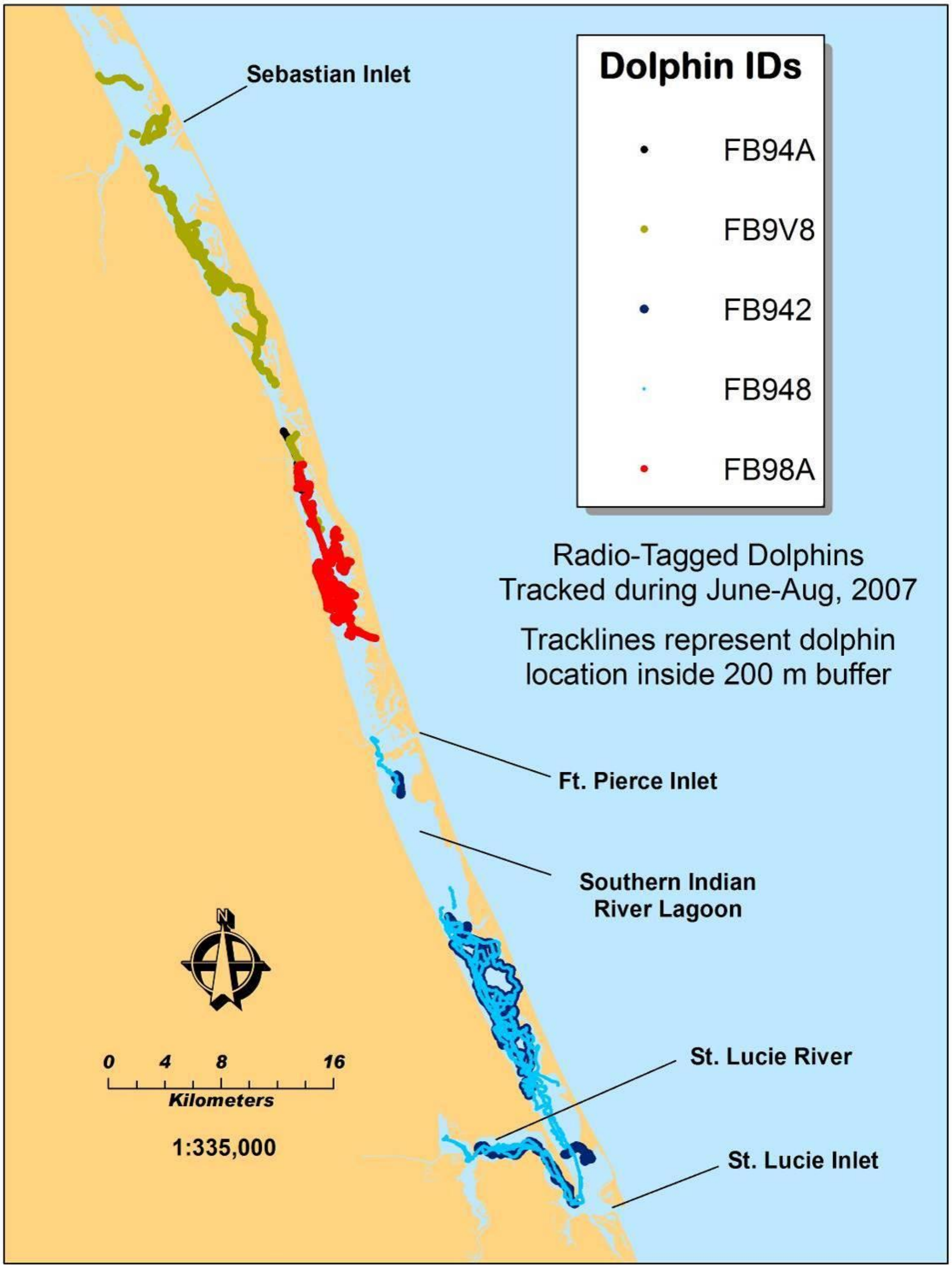


Figure 14. Behavioral focal follow tracks of dolphins with bolt-on radio tags

Table 8. 2007 Bolt-on Radio Tag Summary
(Subset of Sightings used in Analysis).

Animal ID	Length (cm)	Age (y)	Tag Date	Min no. days attached	Total tracked time (h)	No. of sightings	Mean speed (ms^{-1} ±SD)	Mean range (km/h ±SD)	Linear extent (km)
FB9V8	283	17	20-Jun	36	14.6	8	1.30 ± 0.3	4.52 ± 1.1	35.6
FB948	248	12	22-Jun	42	36.2	13	1.65 ± 0.2	5.59 ± 1.0	41.9
FB942	243	14	22-Jun	32	18.1	8	1.69 ± 0.6	5.45 ± 2.6	46.5
FB94A	282	>14	27-Jun	15	0.6	1	2.15 ± n/a	7.52 ± n/a	n/a
FB98A	222	7	28-Jun	97	15.3	12	1.27 ± 0.3	4.19 ± 0.7	13.4
Overall	…	…	…	…	84.8	42	1.61 ± 0.4	5.45 ± 1.3	34.4 ± 14.7

Dolphin Swim Speeds

Data from 23 Trac Pac deployments were used for fine-scale analysis of dolphin swimming speeds. Seventeen of those included velocity measurements from VTDR recorders, and the remaining six had estimated speeds based on GPS locations of the animal. Mean speeds were divided into first hour, remainder of daytime, 2 h after sunset, and remainder of night, comprising 73 separate observations (Figure 15). Thirteen deployments spanned only single day diurnal periods; 10 deployments included subsequent nocturnal periods. Five tags extended into second daytime periods and 2 had second night periods; these data were combined into the corresponding bin for analysis.

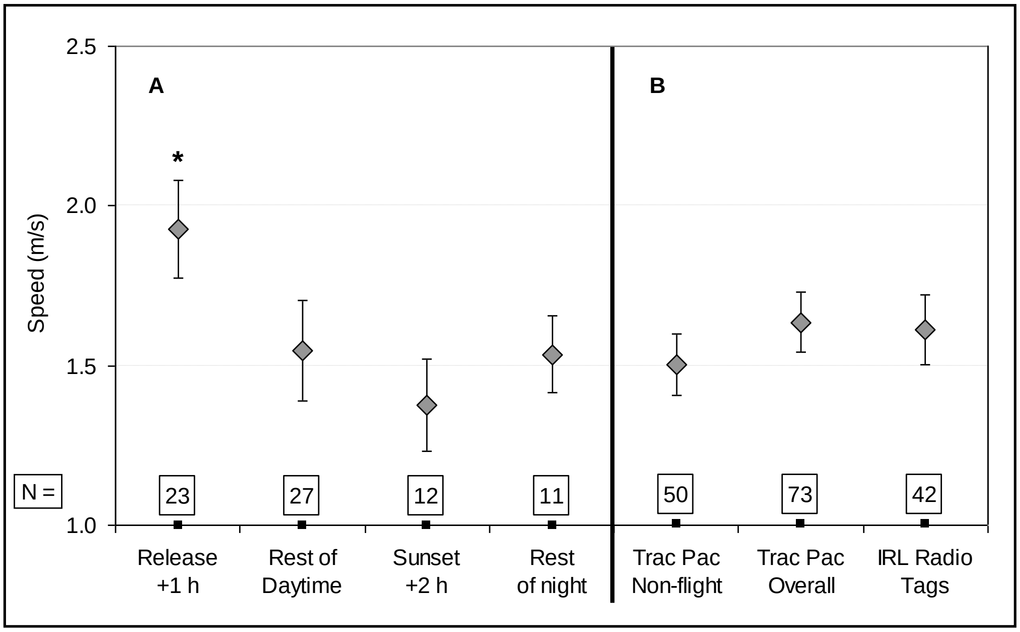


Figure 15. Mean swim speeds of tagged dolphins.

(A) Trac Pac results divided into four time periods. (B) Comparison of Trac Pac tags to IRL radio tags. Non-flight refers to swim speeds combined for the portions of tracks not including the 1st hour following release. Error bars signify 95% confidence intervals, * indicates significant difference.

Overall mean speed for all 27 tagged dolphins combined (Trac Pacs and IRL radio tags) was 1.57 ± 0.43 ms^{-1}. Radio tagged IRL dolphins (n=5) had an overall estimated mean speed of 1.50 ± 0.40 ms^{-1}, while Trac Pac dolphins (n=23) had a mean speed of 1.61 ± 0.44 ms^{-1}. The subset of dolphins with VTDR Trac Pacs (n=17) provided fine-scale on-board measurements, with an overall mean speed of 1.54 ± 0.19 ms^{-1}. Most dolphins exhibited an initial burst of speed leaving the capture-release site once released, and exhibited an increased swim speed for 30-60 min afterwards (mean = 1.93 ± 0.38 ms^{-1}). Overall mean speed combined for the three subsequent periods (daytime, sunset+2h, night) was 1.50 ± 0.35 ms^{-1}. ANOVA showed a significant difference between time period groups ($F_{(3, 68)} = 8.08$, $p = 0.0001$) and Tukey post-hoc comparisons indicated that dolphins swam significantly faster immediately after release than during the rest of the tracks; the other daily periods were not significantly different in mean speed. Estimated swim speeds for the IRL radio tagged dolphins were not grouped by time of day since there were no observations after sunset; rather a mean speed was calculated for each of the focal follows. There was no significant difference found between mean speeds estimated for the 42 focal follows of IRL bolt-on radio tagged dolphins and measured speeds of VTDR Trac Pac dolphins ($t = 0.41$, $df = 57$, $p = 0.68$).

Burst speeds above 3.5 ms^{-1} were rare; five dolphins exhibited fast swim speeds for periods totaling 3 to 12.5 min. Three dolphins (FB950, FB946, and FB984) had brief intervals with swim speeds in excess of 5.0 ms^{-1} for a total of 1.0, 2.2, and 6.8 min, respectively. Deployment durations were divided into three groups: those lasting less than 3 h (short), those lasting 4-9 h (day), and those over 10 h (long) (Figure 16). The short duration tags (0.9, 1.2, 1.8, and 2.4 h respectively) averaged speeds of 1.71 ± 0.17 ms^{-1}, reflecting the higher proportional role of post-release "flight response." However, one-way ANOVA did not reveal a significant difference of mean speed between the three categories of duration ($F_{(2,14)} = 2.64$, $p = 0.12$).

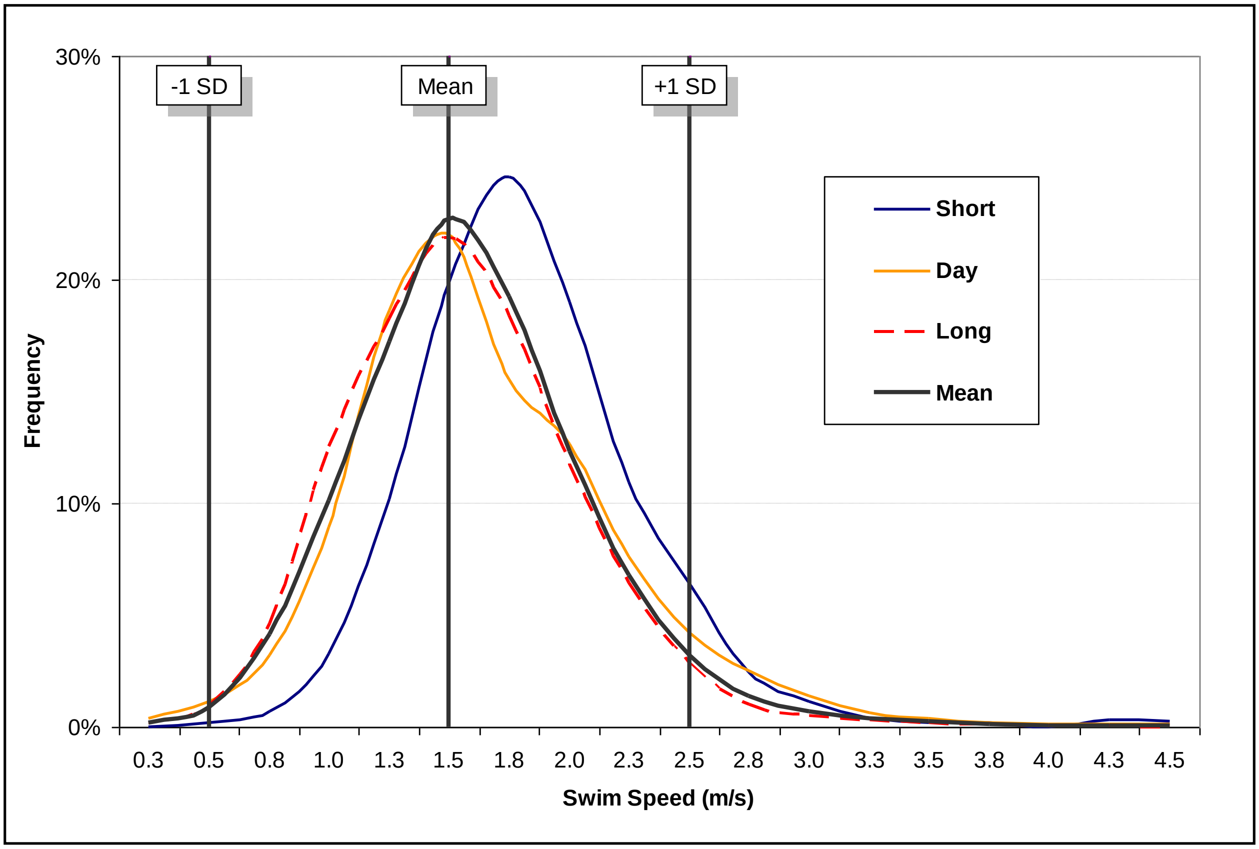


Figure 16. Distribution of swimming speeds divided into three categories of tag duration.

No significant differences were found between means in the tag attachments.

Mean swim speeds were compared between study sites (Table 9). For this analysis, BNC and CNJ tagged dolphins were grouped together into a combined category as an Atlantic group (ATL). Mean swim speeds of Trac Pac dolphins in the various study sites (ATL = 1.58 ms^{-1}; SAR = 1.58 ms^{-1}; and IRL = 1.50 ms^{-1}) were not significantly different ($F_{(2, 14)} = 0.38$, $p = 0.69$) across regions, but did occur in the first hour post-release compared to rest of track (Figure 17).

Table 9. Comparison of Swim Speeds and Ranging Rates between Study Sites.

Period:	Release			Daytime			Night		
Location:	ATL	SAR	IRL	ATL	SAR	IRL	ATL	SAR	IRL
Mean speed (ms^{-1})	2.12	1.79	1.90	1.70	1.45	1.42	1.55	1.54	1.36
± SD	0.28	0.40	0.40	0.47	0.28	0.18	0.23	0.51	0.20
Max speed (ms^{-1})	5.30	4.75	6.61	5.13	5.38	6.40	6.20	4.42	4.37
Mean range (km/h)	6.79	5.43	6.02	4.31	3.98	4.97	4.74	4.21	4.66
± SD	1.94	1.26	1.34	0.84	1.52	0.66	1.44	0.92	0.91
N=	7	8	8	8	9	9	5	10	8

ATL = Combined values for two study sites on east Atlantic coast at Beaufort, NC, and Cape May, NJ; SAR = Sarasota Bay, FL; IRL = Indian River Lagoon, FL. Swim speeds expressed in ms^{-1}; range expressed in km traveled per hour.

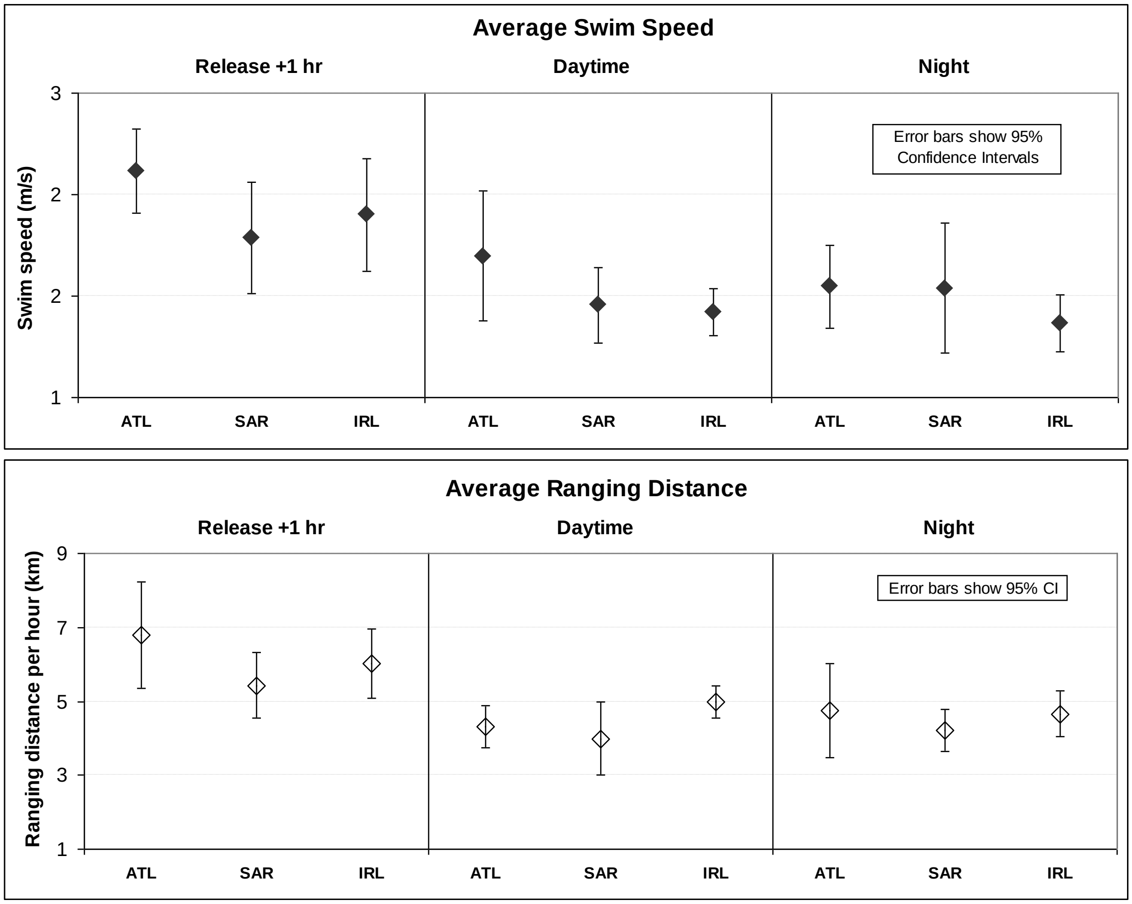


Figure 17. Swim speeds and ranging distances of Trac Pac tagged dolphins by time of day.

Sites with error bars that do not overlap are significantly different (95% confidence intervals).

Ranging and Movements

All 23 Trac Pac dolphins were followed by the tracking boat for the majority of the tag deployments; in three cases the boat departed 2 to 4.5 h prior to release of the tag resulting in uncertainty of the animal position during the end of those tracks. IRL radio tagged dolphins were also followed closely by boat on the 42 independent occasions used in this analysis.

Tracked distances of Trac Pac dolphins ranged 4.8 - 164 km (mean = 49.7 ± 44.2 km). Since tag attachment varied from 0.9 to 41.2 h, the most meaningful comparison of movement was a measure of the average rate of travel per hour of each track, divided into the discrete time intervals of release, daytime, sunset+2h, and night (Figure 18). Overall average rate of movement for all observations combined (including IRL radio tags) was 4.98 ± 1.45 km traveled during each hour of the day (95% CI = 4.71 to 5.24 km). The general trend for greater rate of movement was evident in the first hour post-release (6.05 ± 1.6 km), and was found to be significant ($F_{(3, 68)} = 8.53$, $p = .0001$). Other travel rates during the subsequent time intervals were not significantly different from each other. Contrasting ranging distances between study sites (ATL, SAR and IRL) shows that overall, the first hour post release period was significantly higher than the following periods ($t = 4.32$, $df = 32$, $p = <.001$), and that ranging rates were similar within and between groups for the day vs night periods ($t = 0.13$, $df = 35$, $p = .45$). Tukey HSD showed mean speeds of Trac Pac dolphins not including the first hour (“non-flight”) were significantly different from the IRL radio tag dolphins, but their overall speeds including the first hour periods were not.

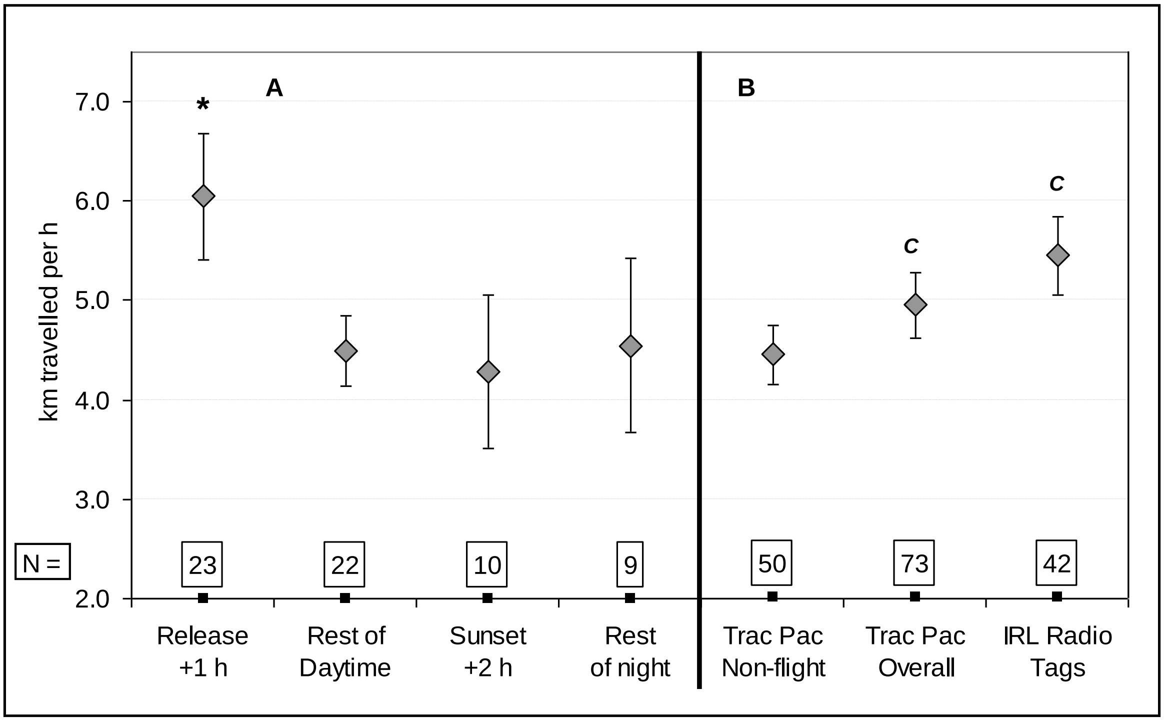


Figure 18. Ranging distances averaged by study site and time period.

Ranging expressed as average of distance traveled per hour in each interval. (A) Trac Pac ranging results divided into four time periods. (B) Comparison of ranging for Trac Pac tags to IRL radio tags. Non-flight refers to the portions of tracks not including the first hour following release. Error bars signify 95% confidence intervals. *= significantly different from others; *c* = not significant.

Linear ranging distances were calculated for each Trac Pac and Bolt-on tagged dolphin by bounding focal follow tracks within a polygon and then measuring across vertices from edge to edge to sum for each animal. In some cases, the animal reversed course and swam over previously covered habitat, therefore that travel was included. This produced a linear estimate of ranging for each individual dolphin to compare with actual distance traveled determined from the focal follow track (Table 10). On average, linear range distances underestimated actual distances traveled by as much as 62% in SAR due to the more convoluted nature of that estuary compared with the narrower confines of the IRL and BNC region, as well as the straight Atlantic coastline at New Jersey. Overall, linear ranging underestimated actual travel distances by 59%.

Table 10. Distances Moved by Tagged Dolphins.

Travels	GPS Tracks	Linear Distance	Accuracy
Sarasota Bay (SAR) *n* = 8			
Mean (km)	37.9	14.3	37.7%
Total (km)	303.3	114.1	37.6%
Total time (h)	83.4		
Mean km·h^{-1}	3.6	1.4	38.9%
Indian River Lagoon (IRL) *n* = 8			
Mean (km)	60.4	38.6	63.9%
Total (km)	483.2	308.6	63.9%
Total time (h)	97.9		
Mean km·h^{-1}	4.9	3.2	65.3%
Beaufort and New Jersey (ATL) *n* = 7			
Mean (km)	50.8	35.8	70.5%
Total (km)	355.7	250.9	70.5%
Total time (h)	75.4		
Mean km·h^{-1}	4.7	3.3	70.2%

GPS tracks = focal follows of the tagged dolphins (measured by GPS); Linear = approximate range using straight line measurements to edges of the polygon bounding the GPS track; Accuracy = agreement between linear measurement and actual tracked distance (linear/GPS Tracks).

Activity Budgets

A subset of 8 Trac Pac dolphins with tag attachment times exceeding 8 h was used for activity analysis (Figure 19). Each dolphin had a nocturnal component during the focal follow. Archival data records indicated points in the tracks where increased diving, foraging, and resting events were discernable (Figure 20 and Figure 21). This was combined with visual observation data to produce a summary of time spent in transit swimming, foraging & socializing, and resting. Dolphins spent approximately half of each day engaged in transit swimming, and another third foraging and socializing with conspecifics. Resting comprised less than 14% of their daily activity budget. On average, IRL and SAR dolphins were similar in amount of time spent transit swimming (49% and 47% respectively), and foraging & socializing (40% and 38% respectively), but were seen in rest-swim behavior less often (11% vs 15%). FB435 in coastal New Jersey had a very different activity profile, spending only ~16% of time foraging and 73% traveling, while resting was comparable to IRL dolphins (11%).

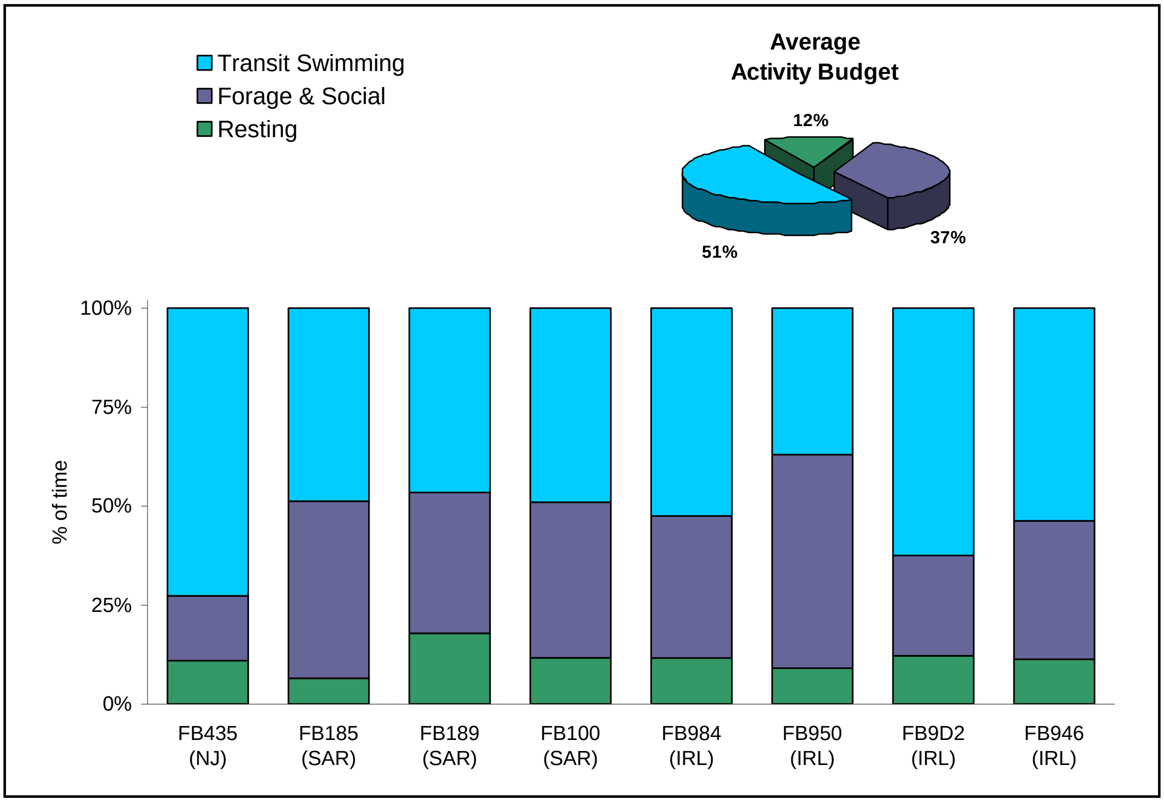


Figure 19. Activity budgets for Trac Pac dolphins that had nocturnal intervals.
NJ = New Jersey Coast; SAR = Sarasota Bay; IRL = Indian River Lagoon.

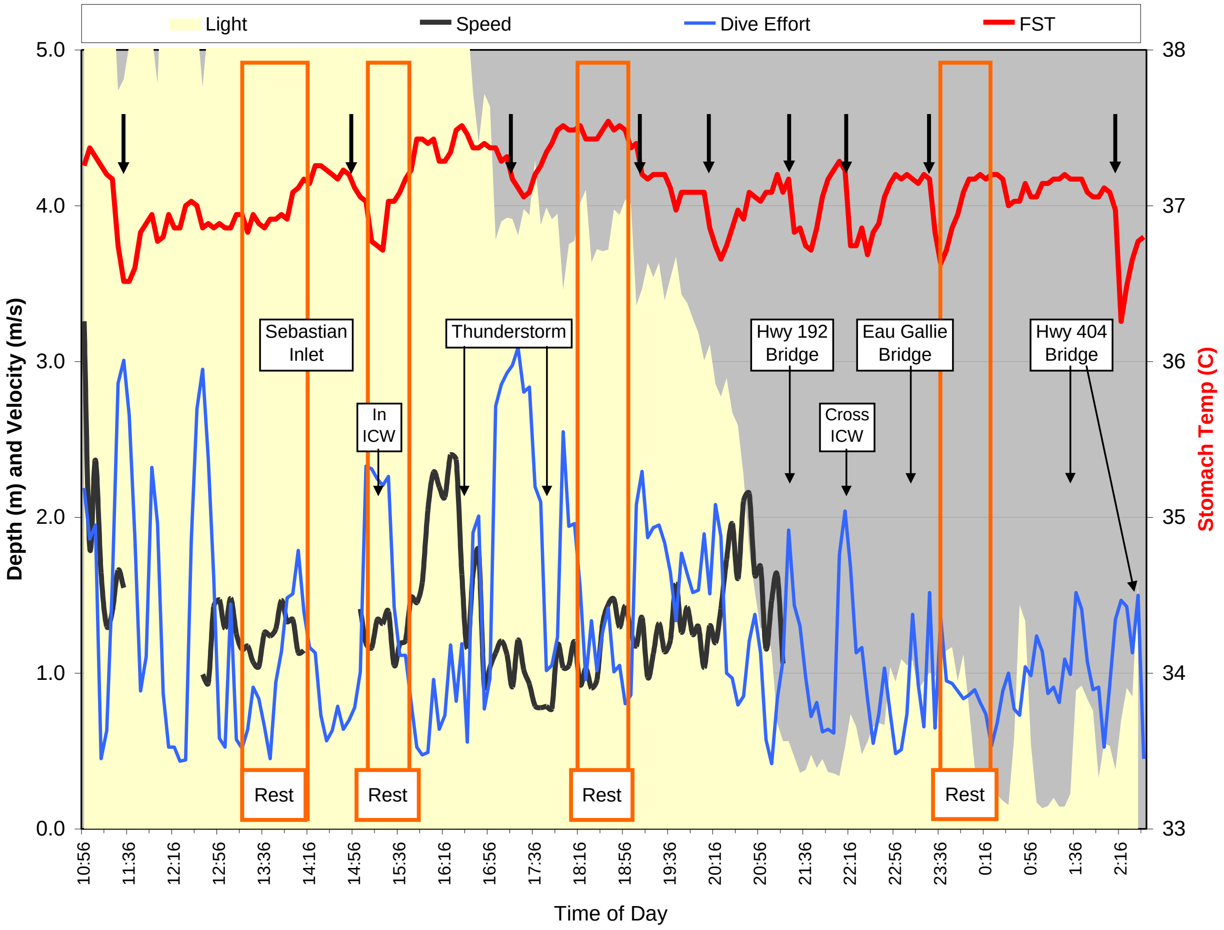


Figure 20. VTDR record of FB9D2 with discernable activity periods.

Tracking occurred in the Indian River Lagoon on June 27, 2006. Line legends at top of graph. Arrows above red line indicate probable foraging events (FST = Forestomach temperature). Readings are averaged over 5 min intervals. Swim speed (velocity) data stopped at 21:16 due to velocity meter clogging. Units for light are dimensionless: low level (night) compared to daytime. Rest periods determined by behavioral change observed from boat, and by reduction in swimming speed.

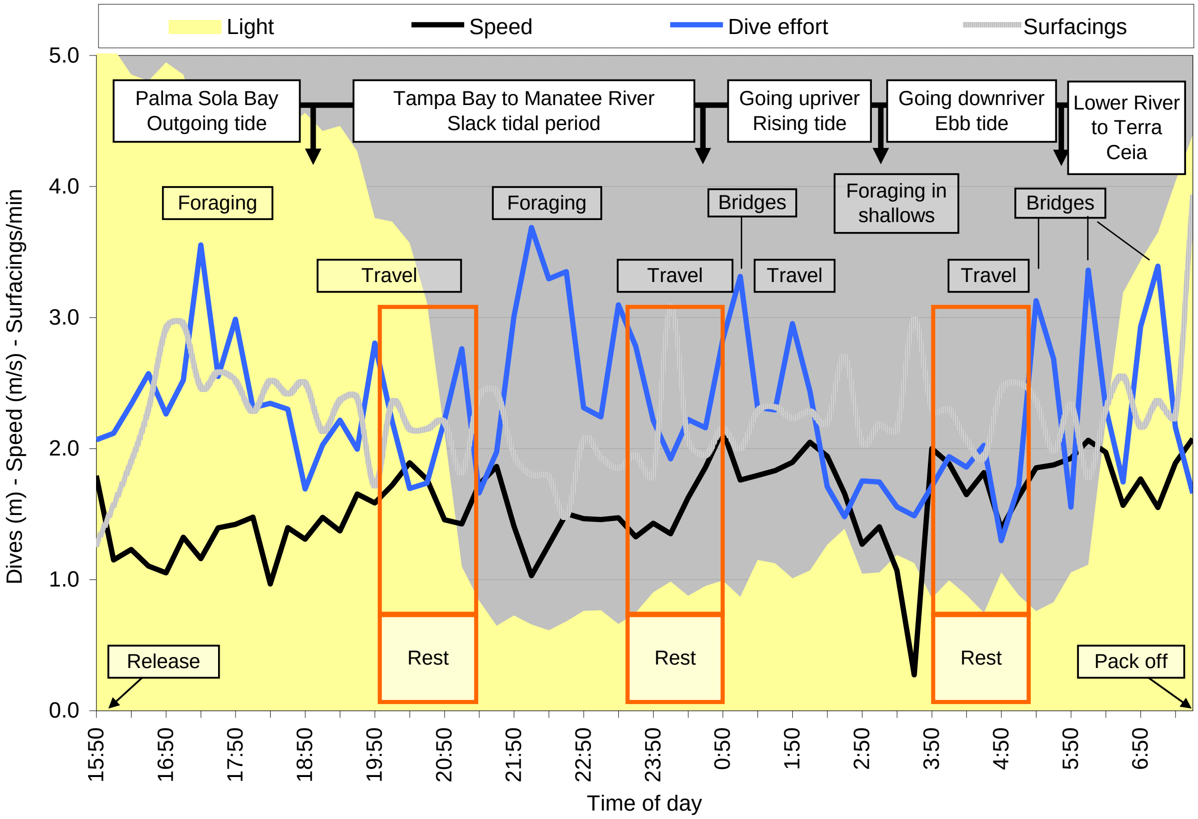


Figure 21. VTDR record of FB185 with discernable activity periods.

Tracking occurred in Sarasota during June 2004. Line legends at top of graph. Surfacings indicate dolphin frequency of coming to surface of water. Readings are averaged over 5 min intervals. Units for light are dimensionless: low level (night) compared to daytime. Rest periods determined by behavioral change observed from boat, and by reduction in swimming speed.

Habitat Use

The majority of the tagged dolphins (25/27) were thought to be estuarine-residents. Two animals, FB432 and FB435, were caught in near-shore coastal waters in southern New Jersey where dolphins are not frequently sighted within estuaries. Dolphins were tracked for 339.9 h. Each individual's habitat use was summarized as distance traveled within each habitat zone. With the exception of CNJ dolphins, the animals spent the majority of their time in Bay/Sound habitat zones (Figure 22). In addition, six entered riverine habitats, seven ventured into oceanic habitats, and eight spent time in inlets.

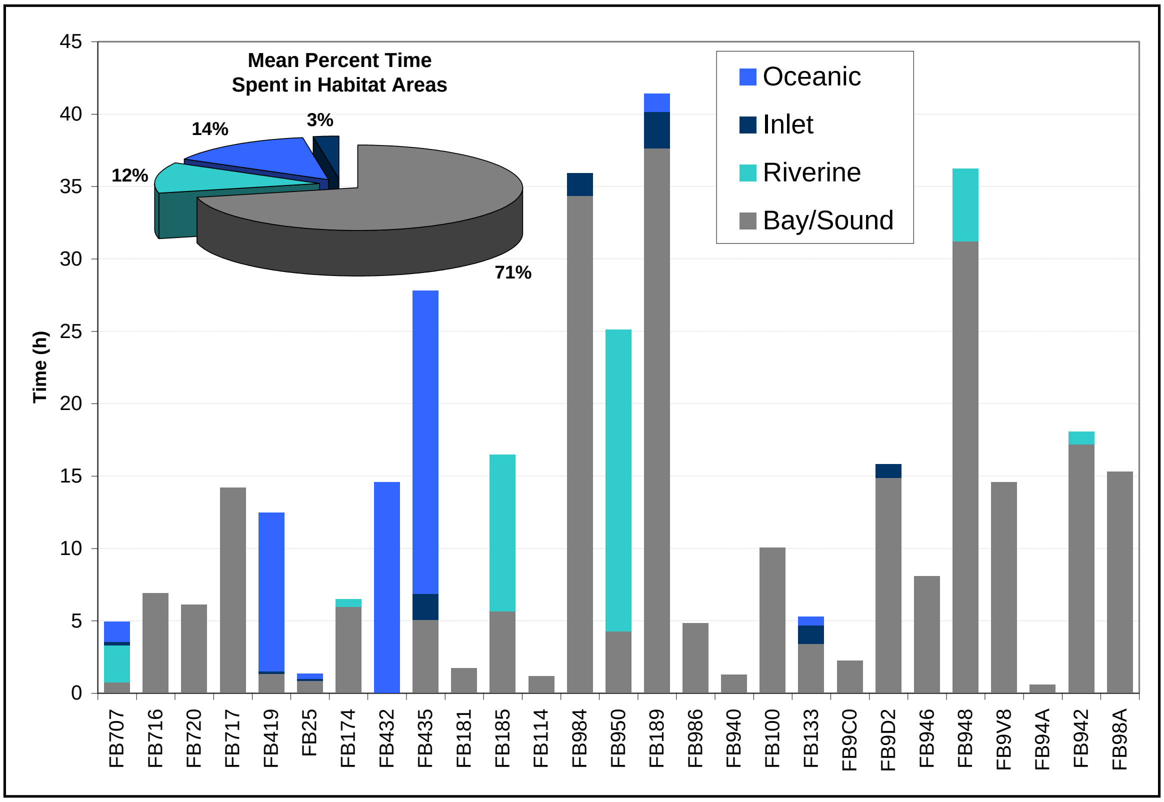


Figure 22. Habitat use by 27 individual dolphins in four habitats with different salinity ranges.

Inlet and Oceanic = higher salinity; Riverine = low salinity; Bay/Sound = brackish.

Due to the dolphins' residency within shallow estuarine waters of 1–5 m, the resolution of TDR sensors was insufficient for dive analyses. However, three dolphins spent some portion of their time in water depths of 10–20 m where dive bouts were recorded: FB719 in BNC made 40 repeat dives to over 10 m depth during a 70-min period just after sunset (Figure 23); FB174 made frequent dives of 2-4 m in southern Tampa Bay throughout a 6 h focal follow; and FB435 made 4 repeat dives lasting 2.0-2.5 min each to 16 m just after sunset in the coastal waters off Atlantic City, NJ (Figure 24).

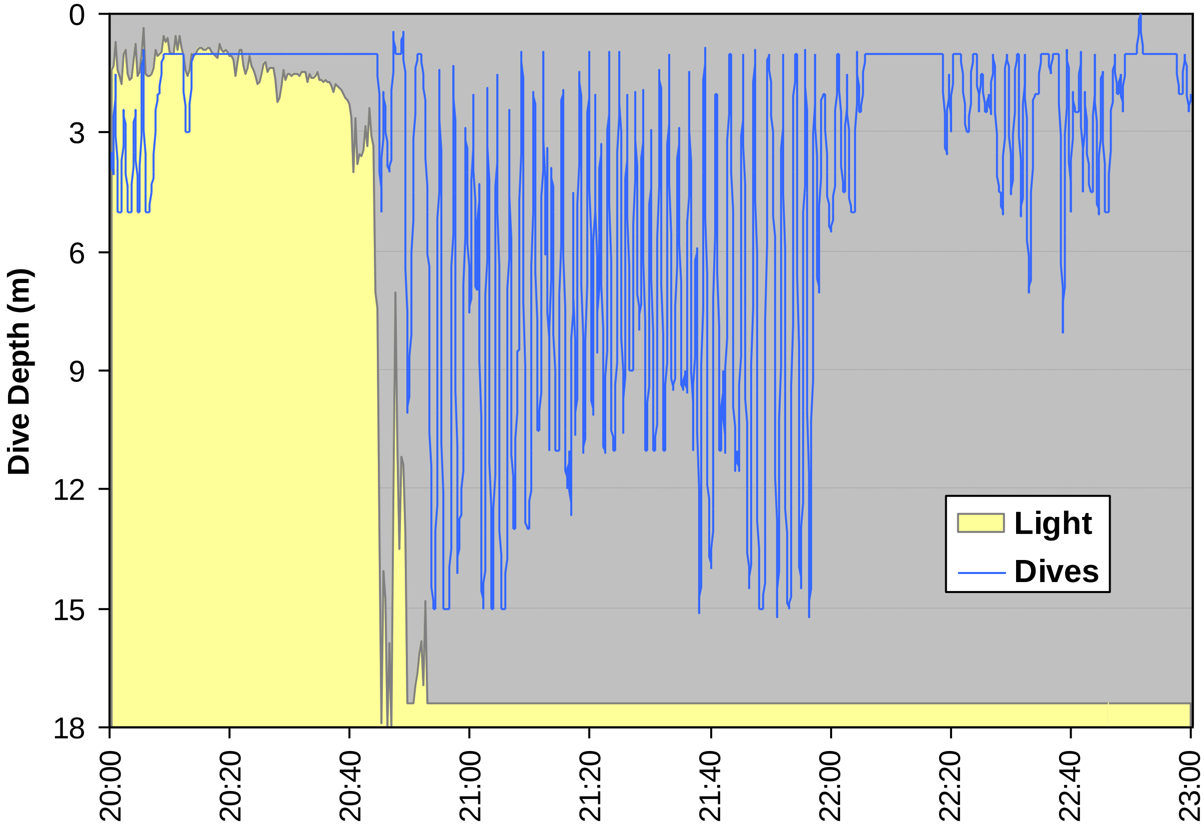


Figure 23. FB719 dive records after sunset in Beaufort, NC.

Dive depths shown on inverted scale (0=surface). Units for light are dimensionless: low level (night) near bottom axis compared to daytime at upper end of scale.

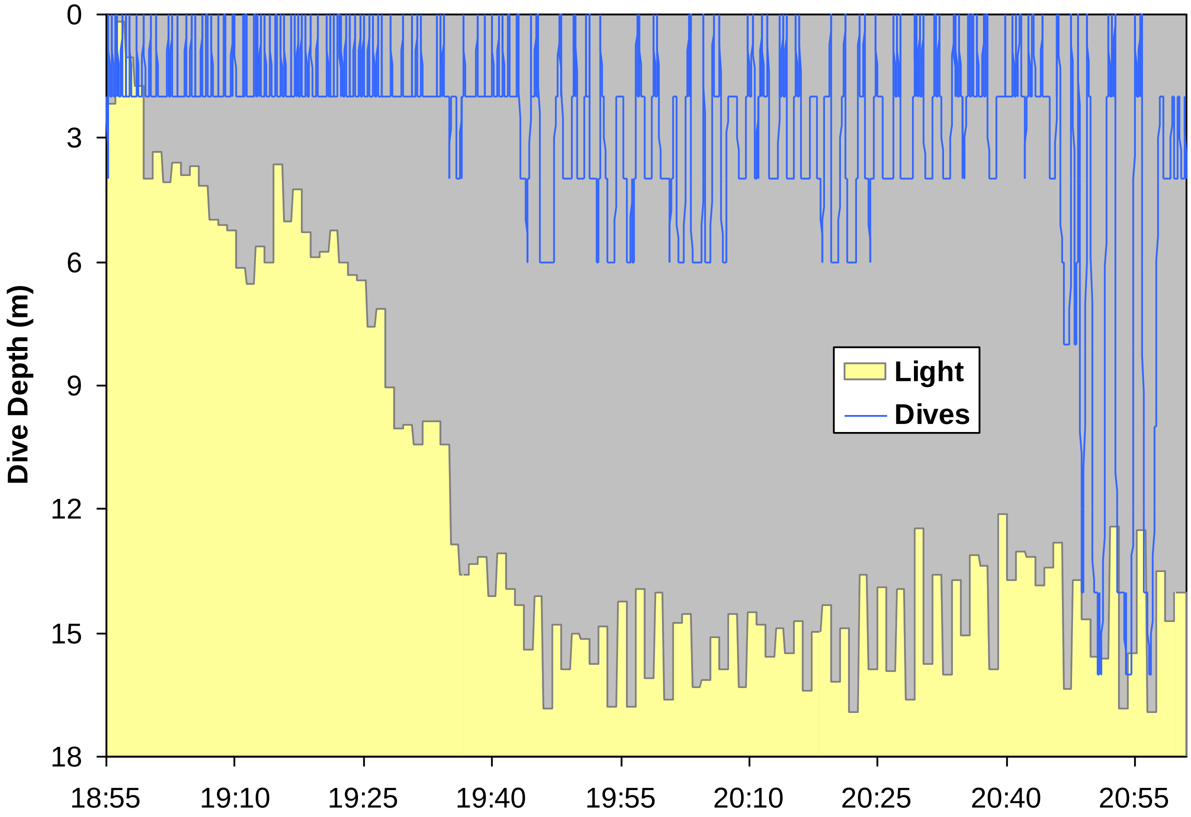


Figure 24. FB435 diving off New Jersey Coast following sunset.

Dive depths shown on inverted scale (0=surface). Units for light are dimensionless: low level (night) near bottom axis compared to daytime at upper end of scale.

Discussion

Data Collection Methods: Archival tag attachments accomplished in the present study with short-term non-invasive suction cup Trac Pacs produced useful fine-scale measurements. Although some VTDR data were excluded, calibrated measurements of speed data allowed fine-scale analysis of movements exhibited by tagged dolphins. Bolt-on radio tags used during 2007 allowed evaluation of movements and site fidelity across longer time intervals than Trac Pacs, albeit without the resolution of fine scale swimming, diving, and foraging data. Resightings of these animals showed that the radio tags released as planned, either by pin separation or by migration through the fin edge (Shippee *et al*. 2008). Four of the bolt-on tagged dolphins were frequently relocated by radio signal, and presumably the fifth tag either failed or the animal moved out of the study area during the time of the tracking project, although it was visually seen once, and the radio signal was faintly detected once by aerial survey (M. Mazzoil and W. Noke Durden, pers. comm. 2007). Bolt-on durations varied, with those placed lower on the fin surviving longer than those up high on the fin (Shippee *et al*. 2008). Bolt-on satellite-linked and radio tag placements were later shown to benefit by single-point anchors placed in the lower third of the fin trailing edge for optimal duration and signal performance (Balmer *et al*. 2011b).

Dolphin swim speeds, ranging, and energetics: Results from the present study compare well with findings of open water swim speeds reported in the other studies; Trac Pac dolphins with VTDRs exhibited mean speeds of 1.54 ± 0.19 ms^{-1}. Williams *et al.* (1993) predicted COT for bottlenose dolphins based on studies with open-water trained animals, and animals working against a load cell. They found that a swim speed of 2.1 ms^{-1} was energetically similar to resting values (heart rate, respiration rate, and post-exercise blood lactate concentrations were not significantly different), while energetic costs doubled at speeds approaching 2.9 ms^{-1}. Videler and Kamermans (1985) reported that routine swimming speeds in captive bottlenose dolphins range between 1.8 – 3.2 ms^{-1}. Yazdi *et al.* (1999) calculated that lowest COT for *Tursiops* was 2.5 ms^{-1}, yielding an optimal range speed between 1.9 - 3.2 ms^{-1} determined from a study of dolphins trained to exercise in a pool. Würsig and Würsig (1979) reported observed swim speeds for open water *Tursiops* in the South Atlantic ranging 1.4 – 4.8 ms^{-1} (mean = 1.7) correlated with water depths, while Shane (1990) estimated average travel speeds of 5.5 km/h (1.53 ms^{-1}) for dolphins at Sanibel Island, Florida. Mate *et al.* (1995) measured a ‘highest minimum’ mean swim speed of 1.36 ms^{-1} over a 1.6 h period from a satellite tagged dolphin in Tampa Bay, FL. Clelland (2008) conducted fine-scale transit speed comparisons measured by pacing free-ranging dolphins in a boat both in an estuary and in nearshore coastal waters, with mean speeds of 1.38 ± 0.1 (SE) and 1.76 ± 0.2 ms^{-1}, respectively.

Free ranging dolphins likely have greater energy conservation needs compared to trained dolphins in human care (*e.g*., Williams *et al*. 1993b, Yazdi *et al*. 1999). This may be a result of living in habitats with patchy prey resources or due to anthropogenic disturbances, but their daily transit speeds nonetheless should fall within an optimal threshold of distance traveled between foraging spots balanced against energy gained from successful foraging (Williams *et al*. 1996). Most dolphins in the present study were tagged during the summer, when foraging resources and human activities on the waterways were quite different compared to winter and early spring. Further, the majority were males, which may have skewed the data. Reproductive activity and mate competition is heightened in the spring (Scott *et al*. 1990), while mid-summer may be a time of relaxed energetic demand on adult males reducing their nutritional needs (Waples 1995).

Overall mean swim speeds for the first hour post-release were significantly faster than during the rest of the tracks. It is a reasonable expectation that dolphins would display a flight response following their temporary capture. A similar response was reported by Tanaka (1987, discussed by Mate *et al*. 1995) who found that oceanic *Tursiops* in Japan fitted with satellite-linked tags moved faster in the immediate post-release period compared to other times. In that study, maximum transit speeds of 2.1 ms^{-1} were reported. Dolphin swim speeds at time of release from health assessments measured from an aerial platform in Sarasota Bay likewise confirmed rapid departures from the capture-release site ranging from 1.6 – 5.6 ms^{-1} (Rohr *et al*. 2002).

Fish and Rohr (1999) reviewed studies describing estimated maximum sustained speeds for *Tursiops*, which varied between 6.1 and 10.3 ms^{-1} depending on duration. The maximum burst speed capability for *Tursiops* was calculated for very short intervals in the range of 8.2 – 11.2 ms^{-1} (Rohr *et al.* 2002). In the present study, maximum swim speed recorded for a 10 sec interval was 7.7 ms^{-1} for a dolphin in the IRL; longest period of sustained swimming at greater than 5.0 ms^{-1} was 2.2 min. These findings agree with the suggestion of Rohr *et al*. (2002), that despite the ability of *Tursiops* to achieve rapid swim speeds, most will rarely exhibit this level of sustained exertion *in situ* even after exposure to high stress levels, such as from being captured and restrained for a period of time. Although flight responses reported here were significantly faster than normal swimming speeds, the increase was only 0.43 ms^{-1} on average, and remained within the predicted optimal COT for this species (*e.g.*, Williams *et al*. 1993b, Yazdi *et al*. 1999).

Clelland (2008) hypothesized that estuarine dolphins may follow a behavioral strategy to conserve energy over time, while oceanic dolphins conserve energy over distance traveled. Differences in water depths between these habitat types may account for this discrepancy. Dolphins that swim primarily in shallow waters may be forced to use a higher COT at a slower speed due to wave drag (Rohr *et al*. 2002) but also might benefit from frequent anthropogenic sources of wave energy by hitching rides on passing boat wakes (Williams *et al*. 1992). Oceanic dolphins have a greater vertical regime and can travel submerged to depths where wave drag is eliminated, thereby reducing COT (Williams *et al*. 1996, Clelland 2008). Estuarine dolphins in shallow regions are unlikely to engage in non-aerobic dives, and although they may spend some portion of their day submerged in search of prey they should not have a considerable component of their swimming effort dedicated to vertical movement (Williams 1999, Clelland 2008). Further, it is likely that estuarine resident dolphins are habituated to anthropogenic disturbances and have learned to avoid or evade short-term stressors, thereby lowering their motivation to exhibit pronounced flight response (Nowacek *et al*. 2001, Rohr *et al*. 2002).

Daily ranging distances of dolphins have been estimated via resighting individuals over time from short-term radio and satellite-linked tracking studies, and from focal follow methods. Dolphins in the IRL were observed to have mean ranging distances of 32.8 ± 18 to 84.1 ± 12 km (Odell and Asper 1990). One dolphin in Tampa Bay with a satellite-linked tag (Mate *et al.* 1995) made average daily movements of 23.7 ± 2.4 km, with a maximum distance traveled in one day of 50.2 km. Mazzoil *et al.* (2008b) reported a rehabilitated dolphin traveled 67 km from the release site after being reintroduced in the IRL. Balmer *et al.* (2008) detected movements of animals over 70 km from their release location near St. Joseph Bay, FL, with mean linear ranging distances of 59 ± 25 km in 2005 and 40 ± 14 km in 2006. In the present study, ranging distances did not vary significantly between study sites, and averaged 4.58 km traveled in each hour of the day for the non-flight response intervals. During the 1st hour post-release, the average range across all study sites was 6.05 km. These findings suggest that *Tursiops* routinely travel over 100 km in a day, and may move over 145 km when traveling at a sustained "flight" speed of 1.9 ms^{-1}. Indeed, the farthest distance traveled by a dolphin in this study was FB984 in the IRL, covering 164 km in a 35.8 h period (82 linear km from N to S). While the present study is the first known to report this great a range of daily movement by estuarine bottlenose dolphins, there have been examples of coastal and offshore *Tursiops* making extensive long-range movements over multiple weeks. Two rehabilitated dolphins released off the Texas coast traveled distances of 2,875 km in 35 d and 4,640 km in 107 d, respectively (Mate and Worthy 1995), and two other rehabilitated dolphins released in Florida waters made movements along the US Atlantic coast of 2,050 in 43 d and 4,200 km in 47 d, respectively (Wells *et al.* 1999). Combined, these observations result in mean daily movements of 65.6 ± 23.5 km, albeit across substantially wider linear expanses. However, the daily travel rates of these oceanic dolphins is in general agreement with the daily ranging distances reported in the present study.

Habitat use: Since dolphins were randomly selected during health assessments, there was no intent to tag animals that might demonstrate habitat preference. All but two tagged dolphins were presumed to be estuarine residents, yet 80% of those made forays into oceanic and riverine habitat patches. FB707 in BNC spent several hours in the lower Newport River before moving into Bogue Sound and then went directly out Beaufort Inlet into the Atlantic Ocean. In SAR, FB189 and FB133 made journeys through inlets into the Gulf for brief periods before reentering the bay; FB174 and FB185 made nocturnal trips into the Manatee River commencing at sunset. FB948, FB950, and FB942 in the IRL spent portions of their days within the St. Lucie River, and FB950 traveled with 3 companions during the early morning 16 km into a headwater creek of the North Fork of the St. Lucie River. FB435 in CNJ, assumed to be a coastal migrant, made an overnight trip into the back-barrier estuary through the inlet at Atlantic City, despite local reports that dolphins rarely venture into the bays (Toth *et al*. 2011). Overall, 8 of the 27 dolphins (30%) spent some portion of their day within inlets, although not all made excursions into coastal waters. These observations suggest that the daily movements of estuarine dolphins can include a variety of habitat patches, each of which presumably present different foraging opportunities and prey densities. The findings of the present fine-scale study may benefit future research with the suggestion that daily movement patterns have been underestimated in the past.

Sarasota Bay resident dolphins are known to venture out to the nearshore Gulf waters, varying their frequency of oceanic habitat use during different seasons (Irvine *et al*. 1981, Scott *et al*. 1990, Wells 1991, Waples 1995, Wells *et al*. 2003, McHugh *et al*. 2011). SAR dolphins are suspected to move into coastal waters following prey fish assemblages during spawning migrations (Waples 1995, Barros and Wells 1998, McHugh *et al*. 2011). In contrast, there is little evidence to show that resident IRL dolphins make frequent excursions outside the inlets into coastal Atlantic waters (Mazzoil *et al*. 2005, Noke Durden *et al*. 2011); however, there have been sightings of oceanic dolphins entering briefly into the IRL estuary (Odell and Asper 1990, Mazzoil *et al*. 2011). Abundance estimates vary widely between winter and summer in the IRL, suggesting that some influx/efflux likely occurs between coastal waters and adjacent estuarine regions (Stolen and Barlow 2003, Noke Durden *et al*. 2011).

SAR dolphins frequent the lower portion of the Manatee River as well as around creek outfalls (Irvine *et al*. 1981, Wells *et al*. 1998a, Urian *et al*. 2009). Likewise, dolphins in the southern IRL are known to frequent the St. Lucie River (Mazzoil *et al*. 2008a, Bechdel *et al*. 2009), inhabiting an area with frequent boat encounters, high fresh water influx and periodic pollutant discharges that might be related to pathological findings in the resident dolphins (Reif *et al*. 2006). In North Carolina, Read *et al*. (2003a) reported the distribution of dolphins throughout the bays, sounds, rivers and nearshore waters surrounding Beaufort, and showed that dolphins occupied each of the available habitats and displayed seasonal residency. Surveys near Cape May, New Jersey (Toth *et al*. 2011) revealed summer residency of the nearshore coastal habitat by northern coastal migratory dolphins. Although few (n=8) sightings were made of animals inside the back-barrier estuary, the majority of dolphin encounters occurred along the New Jersey coastal waters within 2 km of the beach. This raises many questions about the importance of near-beach versus inshore habitats, and how human and natural events influence habitat selection by these coastal migrants at the northern extent of their range (Toth *et al*. 2011).

Despite the known range of dolphins at each study site from previous studies, tagged dolphins in the present study made extensive movements venturing more than 10 km into fresh water habitats at the Manatee River in Sarasota and the St. Lucie North Fork in the southern IRL, as well as a presumed coastal migrant dolphin which entered the back-barrier lagoon in New Jersey overnight. Across study sites, the number of tagged dolphins that exhibited habitat choices outside their expected range (estuarine or coastal) was high. Two of the five Beaufort dolphins left the estuary for the Atlantic shoreline. It was not surprising that Beaufort animals occupied riverine habitats since they are commonly found there. Likewise, in the southern IRL, three of the tagged dolphins made excursions into the St. Lucie River where they are known to range, however, the travels of FB950 far into the upper reach of the North Fork was unexpected (M. Mazzoil, pers. comm. 2004). During this focal follow into a narrow blind cove, two of the conspecifics were observed chasing fish onto shallow sand flats, suggesting this upstream foray was a familiar foraging tactic for these animals. During 2005-2006, the Sarasota Bay region experienced a bloom of the red-tide algae *Karenia brevis*, which may have contributed to dolphins periodically leaving the bay for coastal waters in search of prey (McHugh *et al*. 2011). Three tagged Sarasota dolphins traveled out to the Gulf shoreline, yet none of the 12 tagged IRL dolphins made excursions through inlets to the ocean, albeit two did spend a portion of time milling at Sebastian Inlet before resuming travel inside the lagoon. The New Jersey dolphin entered the back-barrier estuary comprised of shallow salt marsh mudflats but darkness prevented direct observations, and malfunction of the FST recorder precluded collection of archival data to determine if this was a foraging foray.

Stomach temperature changes revealed foraging activity was often correlated with abrupt water temperature changes associated with specific geographic features. Sudden FST drops coincided with changes in water temperature on 17 of the 31 presumed foraging episodes; the tagged dolphins were diving through thermoclines at the edge of channels, swimming through creek outfalls, foraging in inlets during tidal flushing, or making forays into warm shallow areas.

FB189 was the most interesting case. This dolphin spent several hours traveling around Venice Inlet at the southern end of Little Sarasota Bay during an incoming tide on the first night of tracking (Figure 25). Prior to sunset, the dolphin left the inlet and swam into the Gulf, then returned to the inlet and foraged inside the bay and the ICW for the sunset +2 h interval. Later between 22:00 - 24:00, her activity involved continual patrolling along the rock jetty at the mouth of the inlet, where she would swim outward toward the Gulf, then turn and dive for periods of 30-60 s. Her subsequent resurfacings were in a line moving along the margin of the jetty toward the estuary until reaching the harbor where the currents were reduced. The pattern repeated over a one hour period, during which at least five such forays occurred. This foraging activity took place during the peak of the incoming tide and underwater recordings revealed loud soniferous fish making rapid drumming sounds consistent with silver perch, *Bairdiella chrysoura* (D. Gannon and D. Mann, pers. comm. 2005). FB189’s foraging appeared to employ an ambush tactic, most likely approaching prey in a head-on direction with the incoming tide flow as the fish oriented against the current. During the second evening of tracking just after sunset, FB189 engaged in dive bouts with a cohort in Blackburn Bay. Acoustic recordings made at this location also suggested that silver perch were very abundant, as well as Gulf toadfish (*Opsanus beta*), another preferred dolphin prey fish in the Sarasota Bay region (Berens McCabe *et al*. 2010).

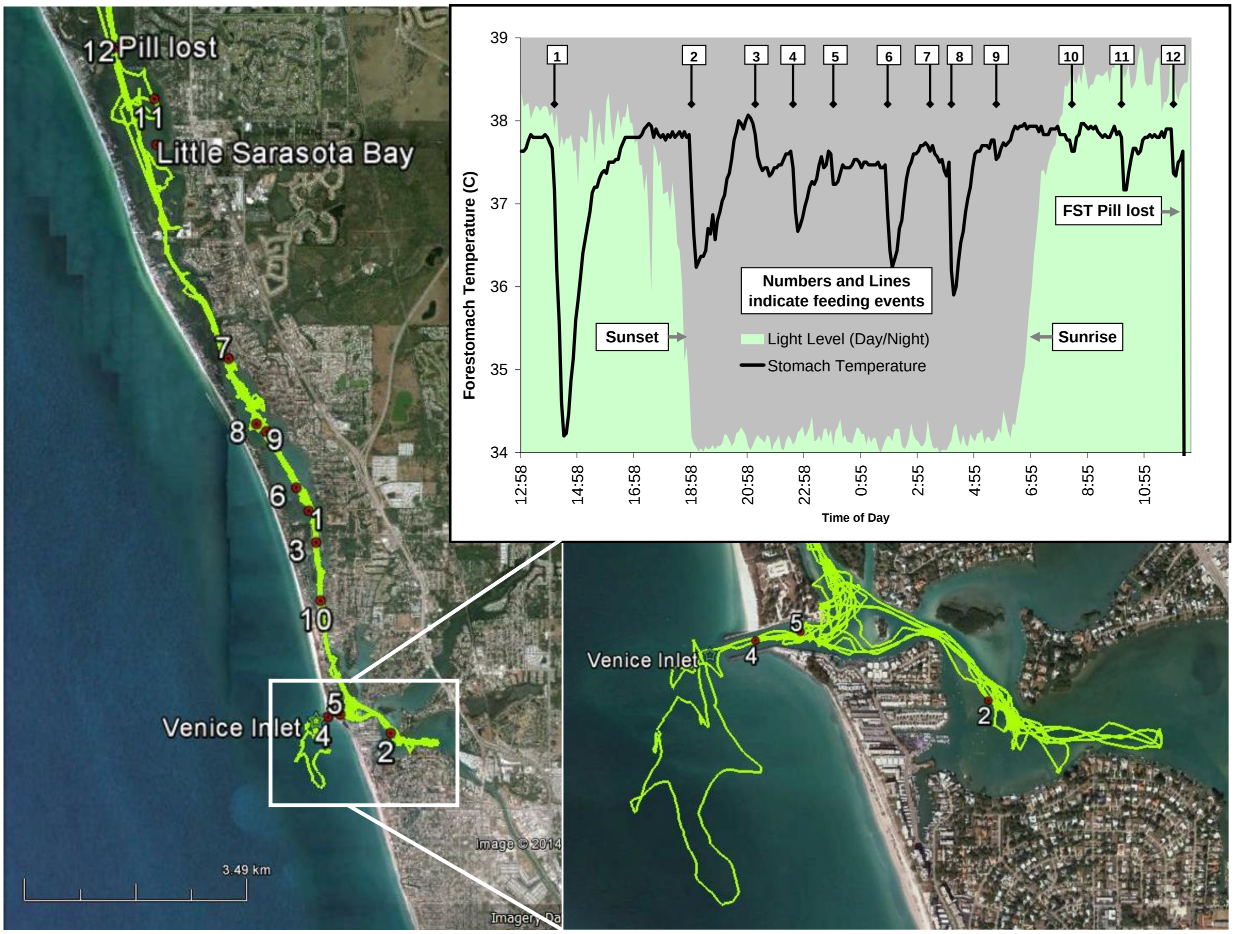


Figure 25. FB189 track and foraging activity in the Little Sarasota Bay and Venice Inlet.

Numbers on map refer to FST changes in chart indicating locations where feeding occurred. Inset shows dolphin foraging activity along rock jetty and in Gulf.

Activity budgets: All dolphins that were tracked in the present study remained active throughout day and night; none were ever observed motionless for any length of time. Eight dolphin tracks with nocturnal components were analyzed to determine activity budgets. SAR and IRL dolphins' activity were roughly similar; SAR dolphins spent more time foraging and socializing, however, a bias exists since long periods of FST data were collected from Sarasota dolphins that allowed a better analysis of their nocturnal activity. Since the SAR and IRL dolphins were known estuarine residents, their daily activities were expected to be comparable. In contrast, FB435 in CNJ displayed a different activity pattern, although this coastal migrant traveled through a more open and dynamic habitat. Regardless, the relative frequency of daily activity spent traveling, foraging, and resting remained consistent with those reported in other studies (Waples 1995, Clelland 2008, McHugh *et al*. 2011).

There was not a noticeable difference between transit swimming, resting, and foraging activity between daytime and nighttime. The use of forestomach temperature monitoring provided strong evidence that foraging occurred in both periods and appeared to have an increased component just after sunset (see Chapter 2), in concert with the increase of soniferous fish calls that were detected on underwater recordings. Three animals with long nocturnal tracks had FST records that indicated foraging took place during the entire night, which suggests that estuarine dolphins continue to feed opportunistically throughout their daily travels.

In general, resting is a low activity state with little energetic cost, which therefore infers that restful transit swimming must be at a pace with a minimum COT to achieve optimal travel speeds. Clelland (2008) suggested that estuarine dolphins optimize travel speeds to conserve energy across time (which therefore includes rest-swimming) while maximizing foraging potential during their progress through a habitat with widely and evenly distributed prey. Since free-ranging dolphins maintain constant awareness of their surroundings and each other (Ridgway *et al*. 2009), they likely also are vigilant of foraging opportunities as well as predators and disturbances while engaged in rest-swimming. Indeed, there were periods in the focal follows of some of the tagged dolphins where they quickly switched from tranquil transit swimming to circling and diving activity consistent with foraging.

In each study referenced above describing activity budgets in dolphins, travel was the most common activity, and this incurs the greatest energetic expense (Williams *et al*. 1996). Resting has been described in other studies as slow quiescent activity or remaining motionless at the surface (Waples 1995); display of slow, quiescent activity in absence of other identifiable activities (McHugh *et al*. 2011); moving very slowly or drifting in one direction (Miller *et al*. 2010); and as rest-swimming where individuals move slowly in strong synchrony (Gnone *et al*. 2001). In the present study resting was defined only as an identifiable behavior during transit swimming as described by Sekiguchi and Yoshima (2003), thus combining resting and transit swimming into one activity of "travel" would involve over 60% of a dolphin's daily budget. This may explain the slightly lower mean travel speed observed in the tagged dolphins in this study compared to predictions for optimal range speed by Williams *et al*. (1993) and Yazdi *et al*. (1999). The results presented here for dolphin mean travel speeds included the time spent engaged in resting behavior and foraging-socializing, activity states that have slower swim speeds. It is reasonable that the observed mean speeds were roughly 30% lower than the predicted optimal speeds for minimal COT (*e.g.*, $1.64 + 0.49 = 2.1\ \mathrm{ms}^{-1}$). Travel that is punctuated by periodic foraging and rest is therefore still accounted for within minimal COT while allowing daily movement distances of 100 km as seen in this study.

To maintain daily energetic balance, dolphins should maximize foraging opportunities while moving at optimal speeds between foraging patches. Mean daily swim speeds include slow-speed rest intervals, which can occur both in the daytime and at night. Activity budgets of the tagged dolphins in the present study compared with those reported elsewhere, although observations are included here showing that nocturnal movements were similar to diurnal periods, and that foraging occurred both during day and night. The constant activity and foraging patterns of free ranging dolphins has been suggested as providing potential protective factors against metabolic syndrome and insulin resistance (Wells *et al*. 2013), as compared to some managed dolphin populations in human care that exhibit hyperglycemia and hyperinsulinemia (Venn-Watson *et al*. 2011).

The findings presented here provide evidence that the tagged dolphins' energetic demands for travel within and between various habitat types, from riverine to inlet, may not be greatly increased by short-term anthropogenic disturbances caused by exposure to passing boats, construction, and other human activity. Impacts to habitat quality and prey resources could nonetheless result in dolphins making temporary movements away from locations where they typically reside and this could ultimately impose additional energetic costs over a longer time scale. These findings at four different study sites demonstrate both the common characteristic of dolphins using energetically efficient travel speeds while displaying plasticity in choice of habitat and foraging opportunities both during day and night.

CHAPTER FOUR:
BOTTLENOSE DOLPHIN ABUNDANCE AND STRANDING MORTALITY IN THE CHOCTAWHATCHEE BAY ESTUARY

Introduction

Bottlenose dolphin stocks in the western Florida panhandle have been severely impacted by unusual mortality events (UMEs) since 1990 (Figure 26). Harmful algal blooms (HABs) were implicated in two UMEs during 1999-2006 (NMFS 2004, Flewelling *et al*. 2005, Gaydos 2006, Twiner *et al*. 2012). In response, the National Marine Fisheries Service (NMFS) initiated a multi-year project to assess population status, genetics, and toxin burdens of dolphins in coastal bays along the northern Gulf of Mexico, giving regions with UMEs special attention (Schwacke *et al*. 2004, Gaydos 2006, Mullen *et al*. 2007).

Choctawhatchee Bay (CB) in Northwest Florida was an estuary of particular concern since it had a resident bottlenose dolphin stock that was not well studied (Schwacke *et al*. 2010, Twiner *et al*. 2012). UMEs associated with red tide HABs resulted in high mortalities of dolphins in the area (Figure 27): over 100 stranded during 1999-2000, and 50 died during 2005-06 within CB and the adjacent Gulf shoreline (Gaydos 2006, Twiner *et al*. 2012). Given the historical mortality rate of 17.9 (± 2.3 SE) dolphins per year since 1990 in the CB region, these UMEs likely resulted in a significant reduction of resident dolphins in this bay. A longitudinal study investigating dolphin abundance, residency, and mortality was warranted to address the data gap for the CB region and evaluate the population status.

Choctawhatchee Bay is one of many estuaries in the Florida Panhandle with resident dolphins belonging to the bay, sound, and estuarine (BSE) stock. NMFS currently lists these as strategic stocks because available information is insufficient for assessment (Waring *et al.* 2012).

The Marine Mammal Protection Act (MMPA) defines a strategic stock as one where: the level of direct human-caused mortality exceeds the potential biological removal level; which is declining and likely to be eventually listed as a threatened species; or which is listed as a threatened or endangered species, or is designated as depleted under the MMPA. Numerous variables may impact a stock's status, including disease prevalence, biotoxins, and incidences of harmful human interactions (HI) or fishery interactions (FI) (Mullen *et al*. 2007). Understanding the frequency of movement of animals between bays was identified as one of several priority research needs for determining bottlenose dolphin stock status and whether disturbance events such as red tides have long-term deleterious impacts on their populations (Gaydos 2006).

Some information on bottlenose dolphin abundance and residency in CB existed prior to the 2005-06 UME. A photo-identification (photo-id) study conducted in 1989-92 catalogued 71 individual animals in western CB and the adjacent Gulf (M. Townsend, unpublished). An aerial survey in 1993 yielded an estimate of 242 animals for CB (Blaylock and Hoggard 1994). I had begun a project in CB after the 2005-06 UME to gather data on dolphin residency, resulting in a photo-id catalog of 125 individuals. NMFS then conducted a comprehensive mark-recapture study in CB during July - August 2007 that estimated a summer resident population of 176 dolphins (Conn *et al.* 2011), and created an expanded photo catalog with 226 marked individuals (A. Gorgone, pers. comm. 2008).

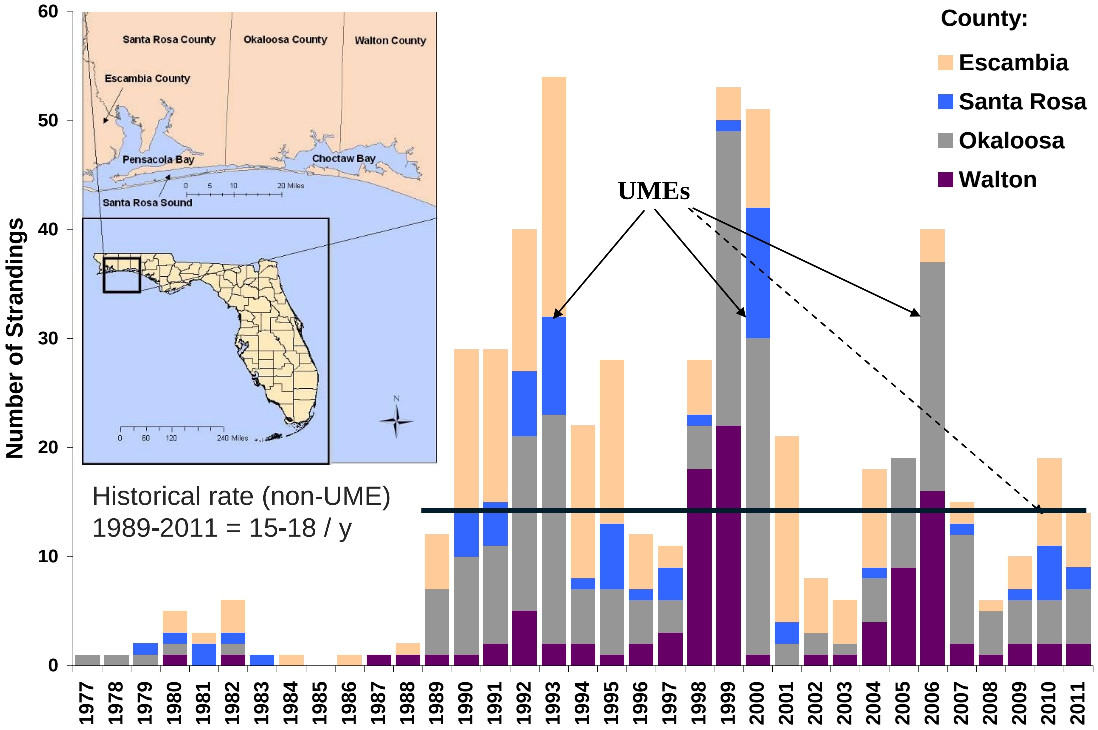


Figure 26. Historical marine mammal strandings in the western Florida panhandle 1977-2011.

Four unusual mortality events (UMEs) occurred in Choctawhatchee Bay since 1990; the first was not defined; 1999-2000 and 2005-06 linked to harmful algal blooms; and a large area UME declared in 2010 included the Florida panhandle with unknown etiology (dashed line).

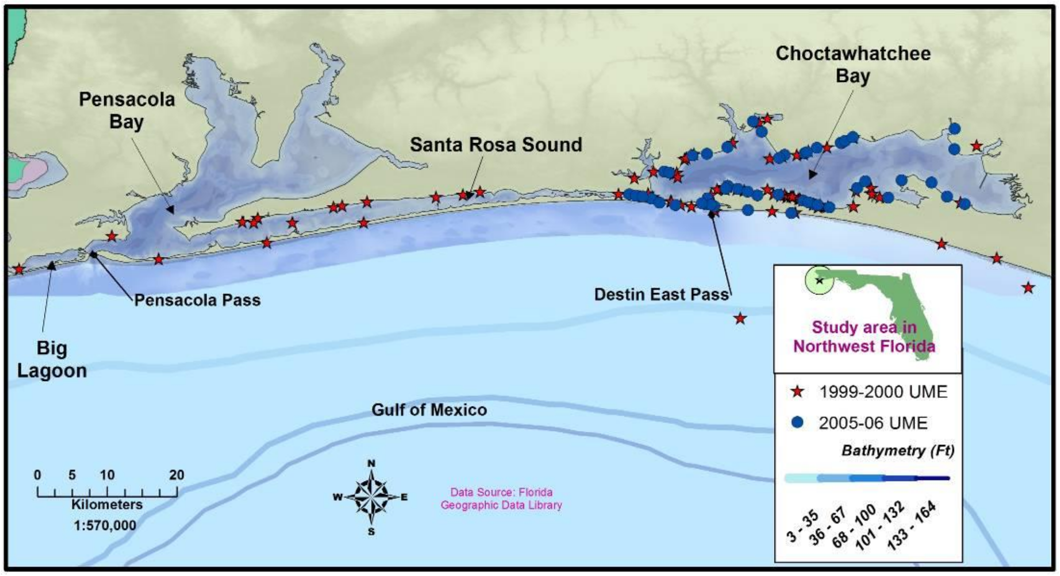


Figure 27. Bottlenose dolphin strandings during 1999-2000 and 2005-06 UMEs.

CB dolphins were again threatened by a HAB during fall of 2007. Although relatively few dolphin mortalities were reported, massive fish kills occurred in CB and Santa Rosa Sound (research.myfwc.com/fishkill). HABs produced by the ‘red tide’ dinoflagellate *Karenia brevis* typically include high mortality of putative dolphin prey fish (Flewelling *et al*. 2005, Landsberg *et al*. 2009). These algal blooms are linked to degraded inshore water quality caused by high nutrient loads and low dissolved oxygen levels (Van Dolah 2000, Flewelling *et al.* 2005, Magana and Villareal 2006, Heisler *et al*. 2008). Man-made sources of nutrients and natural weather events, such as tropical storms and increased seasonal rainfall, contribute to degradation of estuarine habitats that may accelerate HAB formation (Van Dolah 2000, Landsberg *et al*. 2009). Degraded water quality can indirectly lead to decreased fertility and reduced juvenile survival of aquatic species, and compromised foraging success in apex predators (Pattillo *et al*. 1997, Gillanders *et al*. 2003, Paperno *et al*. 2006). The impacts are decade-long in terms of population recovery and in resolving the changes in estuarine fish assemblages and prey availability (Gannon *et al*. 2009, Landsberg *et al*. 2009).

Declines in prey abundance might cause dolphins to shift to alternative but high-risk foraging strategies such as depredation of fisheries and dependency on human provisioning (Berens McCabe *et al*. 2010). Increasing urbanization is gradually changing CB, which may affect dolphin distribution due to frequent human interactions and from changes in habitat resource availability. Both commercial and sport fishermen in this region report an increase of FI with dolphins since 1990 (Thoms 2006). At the same time, dolphin-watch tourism has become prolific, raising concerns that illegal provisioning of the animals can lead to increased mortality (*e.g.*, Samuels and Bejder 2004, Cunningham-Smith *et al*. 2006, NOAA 2007). HABs are linked to eutrophication and have been shown to alter predator-prey relationships in impacted estuaries

(Naar *et al*. 2007, Fire *et al.* 2008, Gannon *et al.* 2009, Landsberg *et al*. 2009). Coastal land development poses the additional threat of habitat destruction and pollution, further exacerbating the potential for HI and FI. This may result in changes to dolphin foraging patterns, movements in/out of the estuaries, reproductive fitness, and juvenile dispersal.

To better define the variables that impact the resident dolphins in CB and nearby Gulf shorelines, I undertook a multi-year project to assess their habitat use, site affiliations and movements, stranding rates, and observed frequency of HI and FI. I used photo-id surveys to extend sighting histories developed during the 2007 NMFS summer stock assessment. I initially focused my efforts around Destin East Pass and Santa Rosa Sound, both of which are the main corridors for movement of dolphins in and out of the bay, and subsequently expanded surveys after 2007 across the entire bay. Dolphin's site fidelity and broad-scale movements might be associated with environmental factors that trigger their selection of habitat, thus, I gathered data on water chemistry, phytoplankton trends, and habitat conditions. I used commercial fishery landings as a proxy for assessing dolphin prey availability in CB. Information on dolphin strandings and mortality were acquired by coordinating with the regional marine mammal stranding networks.

Methods

Study Site

CB is bordered by the Destin peninsula to the south, Fort Walton Beach to the west, Eglin AFB property to the north, and the less developed shorelines of Freeport and Santa Rosa Beach to the east. A single jetty-maintained inlet to the Gulf of Mexico is at Destin East Pass where a sheltered harbor is situated. The bay spans 334 km^2 and narrows to Santa Rosa Sound to the west, a natural 60 km inshore waterway connecting with Pensacola Bay that is bounded on the south by a barrier island. At the eastern extent of CB, the Intracoastal Waterway connects via a 31 km dredged barge canal with West Bay in Panama City, FL. Freshwater flows into eastern CB from the 13,856 km^2 watershed encompassing the Choctawhatchee River basin. CB has an annual salinity range of 15-28‰ increasing from east to west, a max depth of 10.9 m (mean = 5.0 m) with extensive shallows, a yearly temperature range of 10˚-30˚C and once-daily tides of 0.25-0.80 m (Livingston 1986, Hoyer *et al*. 2013). Undeveloped coastlines are typically fringed by *Spartina* salt marshes. Strong tidal flows through Destin Pass result in variable salinity changes that limit seagrass mostly to the central and western portions of CB (Ruth and Handley 2006, Yarbro and Carlson 2011). Based on eutrophication parameters and water chemistry profiles, CB consists of three habitat zones from the river-influenced region on the east to the Gulf tidal dominated area to the west (Ruth and Handley 2006, Hoyer *et al*. 2013).

Dolphin Surveys

I conducted surveys from an outboard boat navigated through specific areas of the estuary. When dolphins were sighted, the boat was maneuvered to within 50 m to make observations. Dolphin sighting data were collected on location, group size, number of adults and juveniles, environmental conditions, and habitat characteristics. A YSI-85 probe was used to measure salinity, temperature, dissolved oxygen, and conductivity at all sightings, and Secchi disk measurements gave water clarity. Tracks and waypoints were recorded on a Garmin GPSMAP device and later were downloaded for analysis using Garmin Mapsource software ver. 6.15 (Garmin International, Olathe, KS). Survey data were recorded in an Excel spreadsheet grouped by study site for analyses of searched distance (effort), group sizes, and encounter frequencies. Location and sighting data were imported into a GIS database (ArcGIS 10.1, ESRI) to map sighting distributions. Surveys were conducted in accordance with NOAA Scientific Research Permit No. 522-1785 (issued to R. Wells), and under UCF - IACUC protocol 08-21W.

CB was divided into four zones (Figure 28): 1) Santa Rosa Sound waterway and western CB (SRS/WCB) including bayous at Fort Walton Beach; 2) the inshore area surrounding the Destin peninsula and nearby Gulf extending 2.5 km seaward of Destin inlet (DST); 3) middle CB; and 4) easternmost CB. To detect dolphin movements in and out of the bay, survey effort was greatest in DST and SRS/ECB (Sites 2 & 1) as those connect with the Gulf and Pensacola Bay, respectively. Site 3 contained open water expanses bordering extensive shallow zones along both north and south shores with limited boat access; choppy waters often caused poor sighting conditions in the mid-bay. Site 4 had shallow zones at the eastern end near the river delta that limited boat access, although these areas were likewise prohibitive to dolphins. Since sites 3 and 4 proved difficult to survey as separate units, data were combined (hereafter termed ECB) to create a useful sample size for analysis consistent with zones described in Hoyer *et al*. (2013).

During 2006 - spring 2007, surveys were made randomly in Site 1 and 2 from Santa Rosa Sound to Destin inlet. Beginning mid-2007 in conjunction with the NMFS summer abundance assessment (Conn *et al*. 2011), survey effort was expanded into ECB. I participated on 5 trips during Jul-Aug on the 2007 NMFS surveys, and conducted other surveys independently. After summer 2007, trips were conducted approximately 3 times monthly through Nov 2009. Random surveys typically followed shoreline contours within marked channels, and usually included shallow areas and bayous where dolphins were frequently noted. Systematic transits across the open bay were impractical due to limited resources and the frequently poor sighting conditions caused by wind driven chop and whitecaps.

Photo-Identification

High resolution digital photography was used to identify individual dolphins by approaching within 50m proximity of dolphin groups. Images were acquired using digital Nikon SLR cameras equipped with 70-300 VR telephoto lenses. Highest quality photos of dolphin dorsal fins and flanks were edited and cataloged using ACDSee Pro imaging database software (ACDSee Systems International). Dolphins were categorized into four levels of distinctiveness of markings: high, medium, low, and non-distinct (following Conn *et al*. 2011). Standardized protocols were followed to catalog individuals (Scott *et al.* 1990, Wells 2009a). Dolphin images were compared with the 2007 NMFS catalog compiled for CB (A. Gorgone and L. Hansen, pers. comm. 2008) and cataloged followed the same naming convention. The 2007 NMFS survey effort and sighting data were compiled from the Finbase database developed for CB (pers. comm., J. Adams, NMFS Charleston Lab, June 2013).

Dolphin Stranding and Mortality Analysis

I began coordinating marine mammal stranding response for the Emerald Coast Wildlife Refuge in 2008, working under letter of authorization with the Southeast Region of NOAA's Marine Mammal Health and Stranding Response Program (MMHSRP). Stranding records for the CB region since 2005 were reviewed, and increased data collection from new strandings began in 2008. Bottlenose dolphin strandings were evaluated and defined by location, age class, and type of mortality (*i.e*., disease, human interaction, predation, or 'could not be determined'). Historic marine mammal (all cetacean species) stranding rates for the Choctawhatchee-Pensacola Bay region were determined using stranding data since 1982 compiled via the MMHSRP database. In addition, I reviewed the CB dolphin photo-id catalog for visible signs of injury on free ranging dolphins indicative of HI / FI or natural predation. Visible injuries were determined using standard methods in Pugliares *et al*. (2007) as:

1) Laceration indicative of line entanglement
2) Dorsal fin amputations (partial or complete)
3) Predation wounds
4) Boat strike/propeller marks

Habitat Characterization, Water Chemistry Monitoring, and Fisheries

The Choctawhatchee Basin Alliance (CBA) has conducted semi-monthly water sampling at 77 sites in CB since 2001 (Hoyer *et al*. 2013); I regularly sampled 7 stations for the CBA long term database. A Hydrolab Quanta probe (Hydrolab Corp., Austin, TX) was used to measure parameters at two depths per station (surface and bottom) for salinity, temperature, pH, dissolved oxygen, and turbidity. Secchi depth, vanishing point, wind, tide stage, and current data were taken. Total phosphorus, nitrogen, and chlorophyll concentrations were analyzed by the Florida LAKEWATCH Program (lakewatch.ifas.ufl.edu), determined from 500 ml samples collected at each station. CB and Gulf water samples were collected monthly using 50 ml bottles containing Lugol’s solution for analyzing phytoplankton constituents by the Florida Red Tide Offshore Monitoring Program (RTOMP) (www.myfwc.com/research/redtide/statewide). Water quality data were compiled from CBA, LAKEWATCH, and STORET (www.epa.gov/storet/dbtop.html). Commercial fisheries landings were queried from Florida Fish and Wildlife Conservation Commission (www.myfwc.com/research/saltwater/fishstats) selecting Okaloosa and Walton Counties to represent CB. Rainfall data were compiled from almanac records selecting airports in the CB watershed region at Valpariso, Crestview, and Defuniak Springs, and from Eglin Air Force Base in Niceville (S. Pizzolato, pers. comm. Feb 2010).

Results

Survey effort varied across years as this study evolved (Table 11). In 2006, trips were limited to the SRS/WCB and DST sites. Beginning in summer 2007 through November 2009, surveys were made in all three CB zones spaced roughly equally across each season of each year (Figure 28). Search distances increased in both the DST and ECB sites each year but remained approximately equal to 2006 in the SRS/WCB site. Search times increased per survey, but surveys in ECB were logistically difficult, thus it was not possible to produce sufficient coverage of all the available bay habitats for mark-recapture abundance analysis from my data.

Table 11. Survey Effort at Three Sites in Choctawhatchee Bay.

	# Surveys			Search distance (km)			Search time (h)		
Year	SRS/WCB	DST	ECB	SRS/WCB	DST	ECB	SRS/WCB	DST	ECB
2006	23	4		1,086	190		77.67	13.54	
2007	30	12	6	844	386	189	56.40	27.17	11.65
2008	26	21	4	888	636	246	69.31	46.19	14.45
2009	31	24	3	949	1,117	264	49.67	86.63	14.68

SRS/WCB = Survey area in Santa Rosa Sound and Western Choctawhatchee Bay; DST = Destin East Pass area; ECB = Eastern Choctawhatchee Bay.

Dolphin Sightings and Photo-id Catalogs

Encounters with dolphins were recorded as individual sightings (Table 12). Field estimates of the number of dolphins in each sighting provided a comparative reference for encounter frequencies and dolphin relative abundance per km (D/km) searched (per Fazioli *et al*. 2006). Surveys during 2006 resulted in identification of 125 individuals with 54 dolphins resighted; 22% were seen on three or more days. The NMFS 2007 study identified 226 dolphins; my sightings through the end of 2009 increased the catalog to 311 animals, of which 64% were resighted multiple times. Mark distinctiveness ranged 72% high, 23% medium, and 6% low. Completed results of photo-id effort for 2008-09 were not available at the time of this analysis.

Table 12. Dolphin Encounters and Sightings

	# Sightings			# Dolphins *			Dolphins/km		
Year	SRS/WCB	DST	ECB	SRS/WCB	DST	ECB	SRS/WCB	DST	ECB
2006	34	8		216	76		0.54	0.47	
2007	29	28	21	180	279	158	1.32	0.80	0.75
2008	31	44	20	183	316	116	0.53	1.07	0.49
2009	25	48	12	131	311	55	0.60	0.40	0.21

Includes re-sightings of individuals on subsequent surveys, therefore the same animals may have been counted several times. SRS/WCB = Survey area in Santa Rosa Sound and Western Choctawhatchee Bay; DST = Destin East Pass area; ECB = Eastern Choctawhatchee Bay.

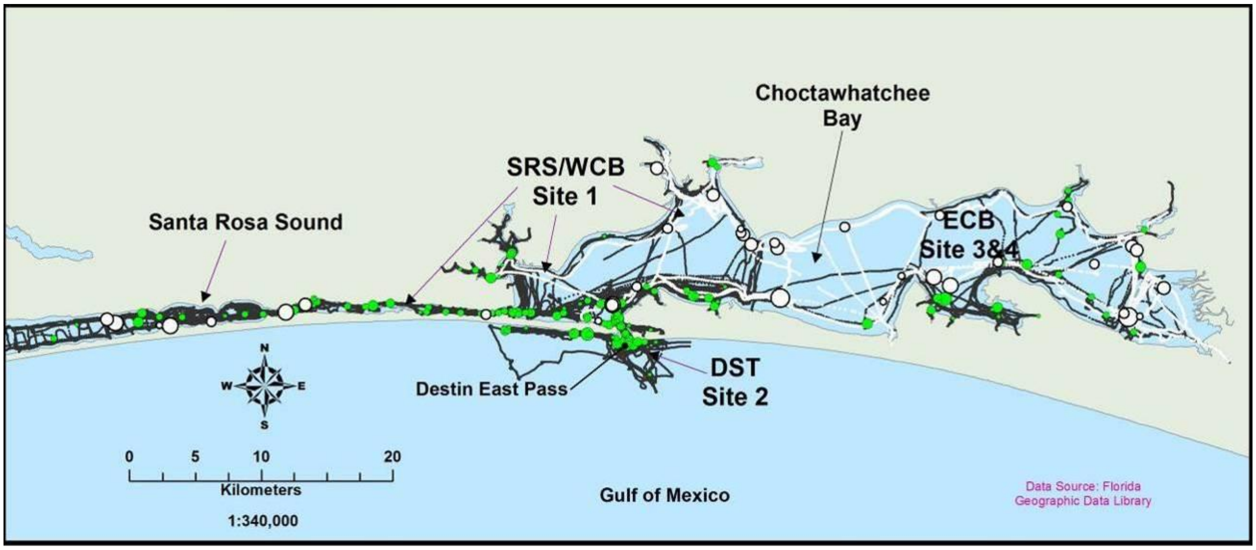


Figure 28. Survey effort and dolphin sightings in Choctawhatchee Bay.

White lines and circles denote my 2007 survey tracks and sightings; Black lines and yellow circles denote 2008-09 survey tracks and sights. Circle size indicates relative dolphin group size. SRS/WCB = Survey area in Santa Rosa Sound and Western Choctawhatchee Bay; DST = Destin East Pass area; ECB = Eastern Choctawhatchee Bay.

Relative dolphin abundance (dolphins sighted per km searched or D/km) compared by study site during 2007-09 showed variations in the frequency of encounters and number of animals sighted (Figure 29). D/km was approximately constant in SRS/WCB, but decreased at DST and ECB during 2009. Total number of sightings increased at DST in 2008-09 versus 2007, attributed to more intensive survey effort those years. Despite increased surveys in 2009 verses prior years, there was a significant overall decrease in the observed D/km in CB per distance searched (Figure 30). Group sizes were not significantly different between years (*p*= 0.08), but generally decreased at each study site from 2007 to 2009 (Table 13).

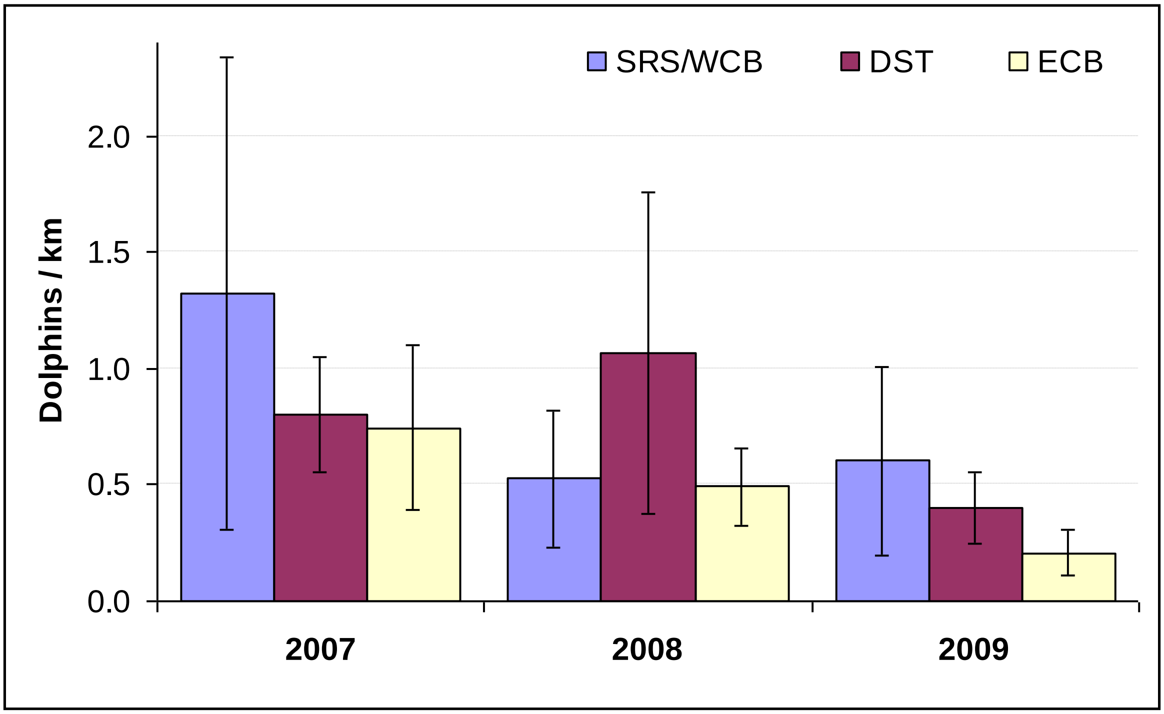


Figure 29. Relative abundance of dolphins per km of survey track per site during 2007-09.

SRS/WCB= Santa Rosa Sound and West Choctawhatchee Bay; DST=Destin inlet; ECB=East Choctawhatchee Bay. No significant differences between years per site were detected ($p > 0.05$). Error bars denote 95% confidence intervals.

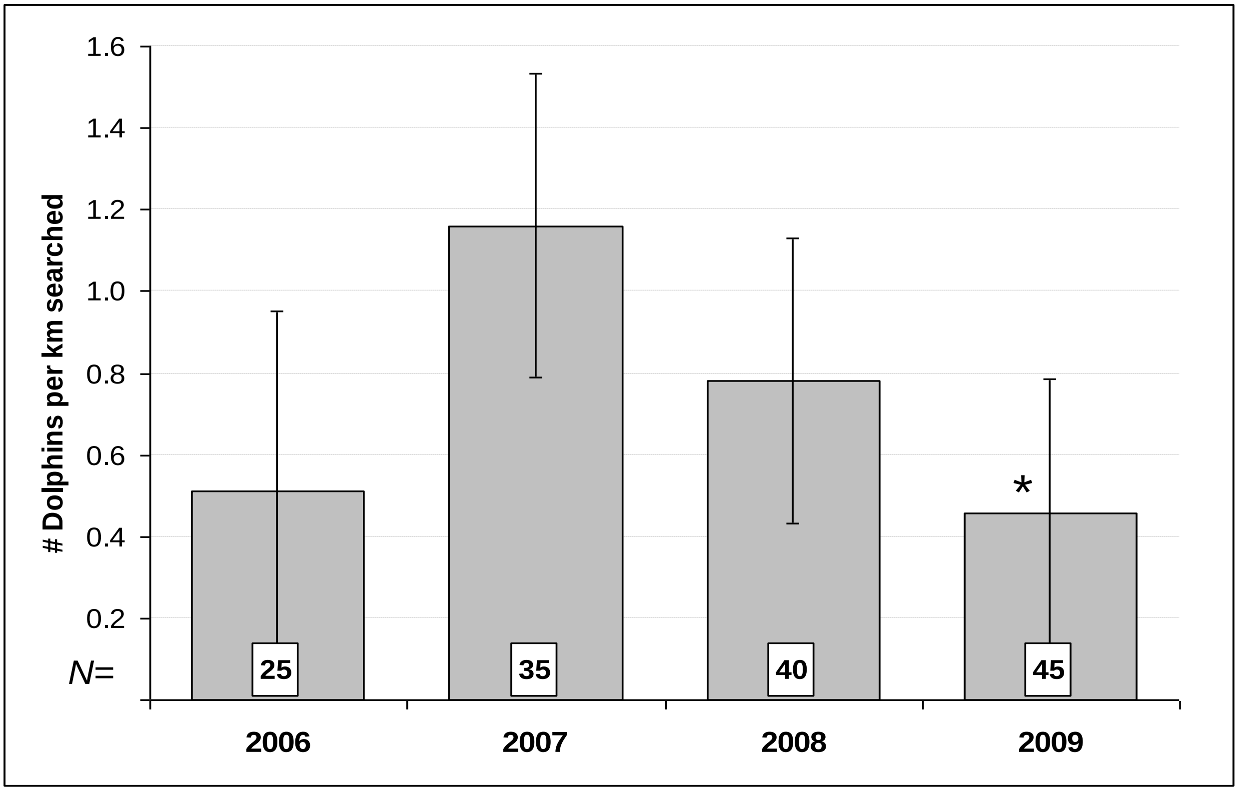


Figure 30. Overall mean number of dolphins per km of searched distance.

Bars represent Gabriel comparison intervals (Gabriel 1978); pairs of means whose intervals do not overlap (2007 and 2009) are significantly different ($p < 0.05$). N indicates number of surveys.

Table 13. Mean Group Size (Number of Dolphins/Sighting) during 2006-09.

Year	SRS/WCB	DST	ECB
2006	6.4	9.5	n/a
2007	6.2	10.0	7.5
2008	5.9	7.2	5.8
2009	5.2	6.5	4.6

SRS/WCB = Survey area in Santa Rosa Sound and Western Choctawhatchee Bay; DST = Destin East Pass area; ECB = Eastern Choctawhatchee Bay.

Dolphin Distribution and Movements in 2007

I analyzed the NMFS 2007 photo-id sightings, placing each unique individual into the study site location(s) where seen. Distribution of dolphins across study sites demonstrated animals were present in all regions of the bay. Of 226 individuals, 24% were sighted more than three times during the summer of 2007. Dolphins had varying degrees of movement around CB (Table 14): the subset of unambiguously marked animals (199 individuals of medium and high distinctness) showed 28% were seen only in a single site; 62% were seen in two different sites; and 10% were seen in all three sites.

Table 14. Individual Dolphin Sightings by Location during July - August 2007.

Dolphin resighting counts					Unique individuals by sites		
# times sighted	WCB Site 1	DST Site 2	ECB Site 3&4	Total	Locations where seen	# unique dolphins	% of total
1	82	59	91	150	WCB	5	3%
2	43	15	30	45	DST	11	6%
3	20	5	29	34	ECB	39	20%
4	3	1	24	25			
5	1	1	19	20	WCB – DST	19	10%
6	0	0	13	13	WCB – ECB	85	43%
7	0	0	10	10	DST – ECB	20	10%
8	0	0	4	4			
9	0	0	1	1	WCB – DST – ECB	20	10%
Total	149	81	221	302	Total # dolphins:	199	

In 2008-09, a concurrent project investigated dolphin interactions with fishing activity at two Gulf fishing piers, one near Destin and the other at Pensacola (see Chapter 6). Movements of dolphins in and out of the Destin East Pass were commonly observed, and at least 18 resident DST dolphins were also seen on various days at the nearby Gulf fishing pier. Three dolphins were positively identified in CB and at the Pensacola fishing pier. Two other dolphins were sighted in Pensacola Pass in 2009 that previously had been seen at DST, a distance of over 65 km away. In addition, two known CB dolphins from 2006-08 were found dead-stranded in Pensacola Bay during 2009.

Dolphin Mortality and Injuries

Tursiops stranding records for Escambia to Walton counties were evaluated from 2005 to 2009 and classified by age class and type of mortality (Table 15 and Figure 31). During 2007-09, 35 strandings were evaluated: 50% were scored as disease related without sign of HI; 19% involved clear signs of HI; and 25% were scored as 'could not be determined.' A fish kill event associated with elevated *Karenia brevis* cell counts peaked in November 2007 in CB and SRS, which coincided with 18 dolphin strandings during October 2007 – February 2008. Biotoxin analysis of samples collected from 12 of the dolphins confirmed that six were positive for brevetoxin congeners (pers. comm., S. Fire, 2014). Following spring 2008 throughout 2009, stranding rates declined to below the historical average of 17-20 for the panhandle region (Twiner *et al.* 2012). Young-of-year (either perinatal or within the first year of life) accounted for 38% of confirmed strandings in 2007 and 83% of strandings in 2009.

Table 15. Strandings in the Emerald Coast Wildlife Refuge Response Area.

Year	Disease	HI	CBD	Predation	Total
2007	8	3	4	1	16
2008	8	2	3	0	13
2009	5	0	1	0	6

Data collected from ECWR and MMHSRP records for Walton, Okaloosa, Santa Rosa, and Escambia counties in northwest Florida. HI = stranding involved Human Interaction; CBD = could not be determined if stranding involved HI.

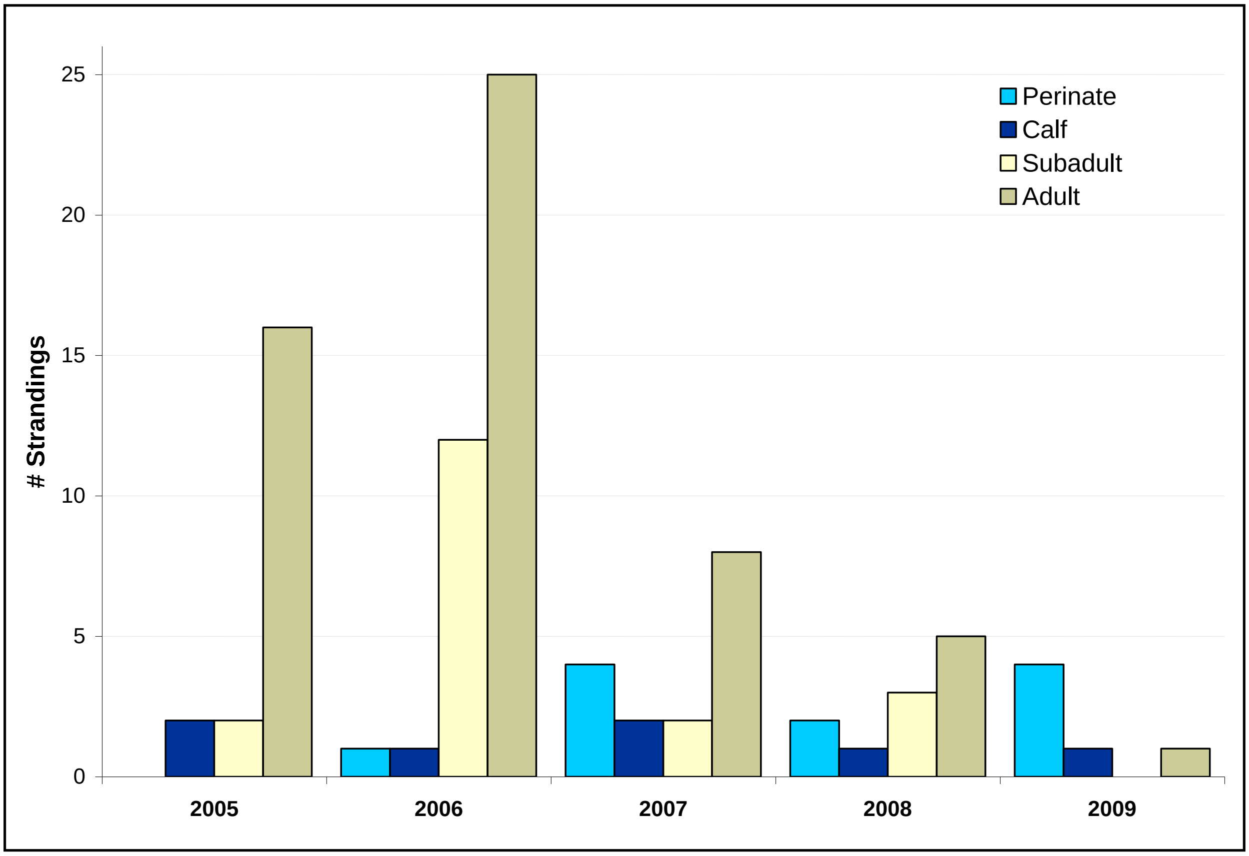


Figure 31. Strandings in 2005-09 grouped by age class.

Perinate defined as infant near time of birth (one month before to one month after normal time of birth), measuring less than 115 cm total length. Calf refers to young of year between 115 and 160 cm length. Subadult refers to juveniles less than 200 cm total length.

Photo-id Visible Injury Analysis

I used a highly conservative approach to evaluate wounds on free ranging dolphins photographed in CB, SRS, and DST (Figure 32). Only fresh wounds or healed injuries that could not be attributed to conspecific interactions were scored. This analysis resulted in identification of 85 individuals with visible marks or lesions suggestive of HI / FI or predation by sharks (Table 16). The most prevalent lesion type involved linear cuts into the dorsal fin margins or on the body in front of the fin, which are indicative of entanglement with fishing line or twine (Barco *et al*. 2010, Pugliares *et al*. 2007, Lukensburg 2014). Predation wounds were not easily scored since marks left by predators can be confused with other types of trauma, such as propeller cuts, impact, or aggressive interactions with conspecifics. Nine individuals had easily recognized circular transverse impressions around the torso or peduncle that were consistent with wounds caused by line entanglement. No animals had visible signs of skin disease complications such as lacaziosis fungal infections (*Lacazia loboi*) as described elsewhere on *Tursiops* (Bossart *et al*. 2003, Noke Durden *et al*. 2009), although one frequently sighted individual had light colored mottled skin lesions (*e.g*., Hart *et al*. 2012).

Table 16. Analysis of Photo-id Catalog for Visible Sign of Injury and Lesions.

Type of injury	*N*
Laceration / line entanglement	52
Fin amputations	25
Predation wounds	6
Boat strike/propeller marks	2

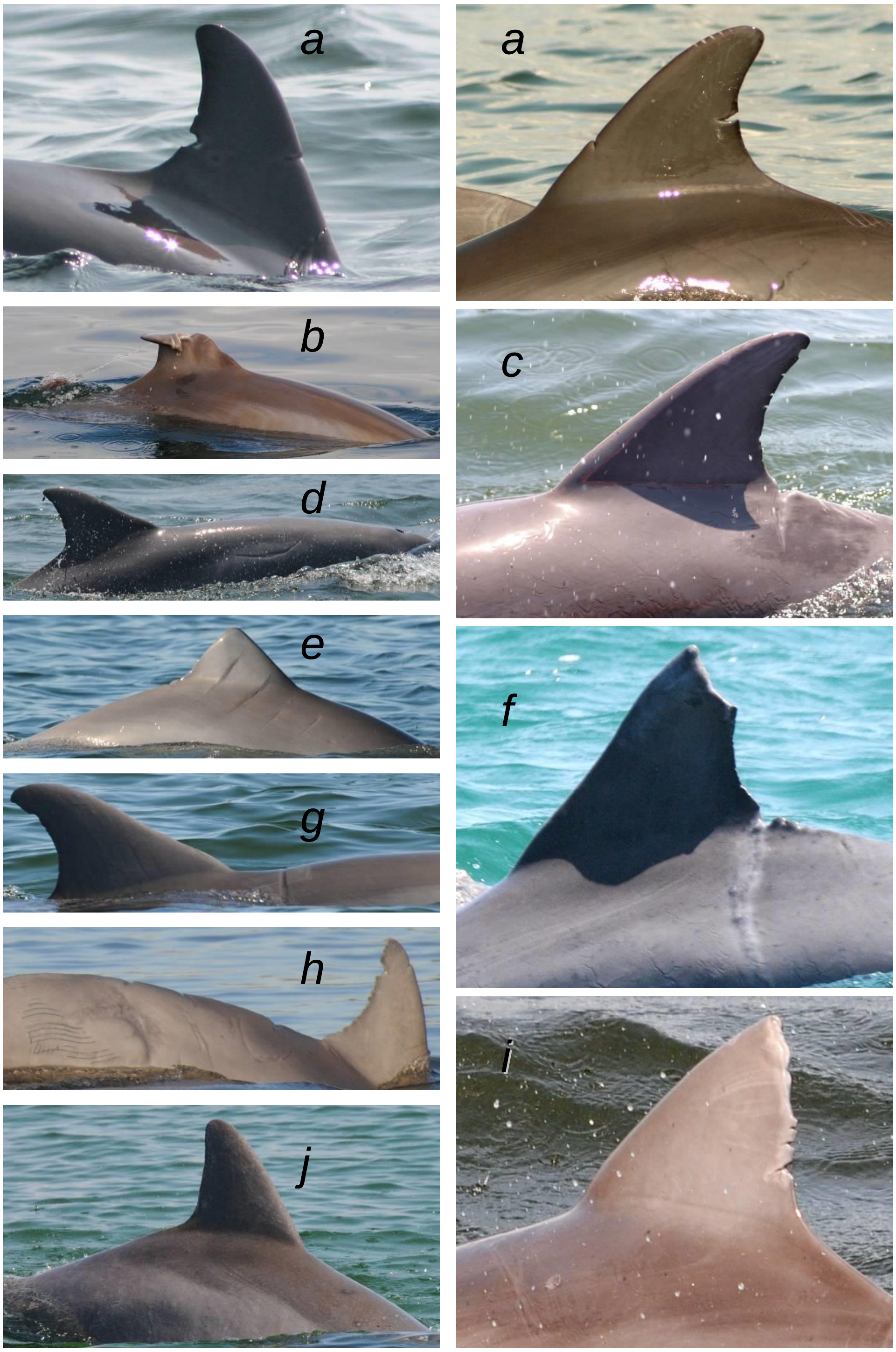


Figure 32. Examples of lesions observed on photographed dolphins.

Linear cuts into fin margins, b. fin amputation by line, c. post-dorsal laceration, d. flank laceration, e. propeller impact, f. probable predation wound, h. impact trauma, i. shark bite, j. mottled/ spotted skin lesion.

HAB Monitoring, Weather Events, and Changes in Habitat Characteristics

Results from RTOMP did not indicate increased concentrations of HAB-causing organisms above background levels in Florida panhandle waters during 2008-09, and only detected a short lived increase in *Psuedo-Nitzchia* off the coast of Alabama (Liefer *et al*. 2009). Since wind and weather conditions can drive offshore plankton blooms toward estuarine waters (Van Dolah 2000, Landsberg *et al*. 2009), tropical weather events were taken into consideration. During 2006-09, no major hurricanes impacted this coast; three tropical storms affected the region (two in 2008 and one in 2009), which contributed to increased rainfall but did not result in severe coastal erosion. In winter, spring and summer of 2009, rainfall was significantly greater compared to 2006-08 (Figure 33), which resulted in flood stage conditions in rivers feeding Panhandle estuaries. Standardized precipitation index (SPI) values for Mississippi, Alabama, Georgia, and Florida during March-August 2007 were all 'much below normal' while in 2009 were all 'above normal' (Table 17). 2006 and 2007 were characterized as drought years, and 2009 changed to a wet year. (S. Pizzalato, pers. comm. Feb 2010). CBA data showed significant downward salinity changes throughout CB in 2009 (Anova ($F_{(2,105)} = 5.02$, $p < 0.001$), that persisted throughout the summer in ECB but began to rebound during summer in WCB (Figure 34). Salinity in Santa Rosa Sound in 2006-07 was typically 21-25 ppt, but averaged 18.5 (±4.7) ppt during 2009. Dissolved oxygen levels and pH did not show significant changes at CBA sampling sites throughout CB in 2009. Water chemistry results (total nitrogen, phosphorus, chlorophyll, and water clarity levels) from LAKEWATCH analysis varied during 2007-09 showing some significant changes in total nitrogen and phosphorus in 2009 versus 2007 (Figure 35). Hoyer *et al.* (2013) also noted correlation of increased nutrients (nitrogen and phosphorus levels) correlated with low salinities in 2009.

Brown shrimp (*Farfantepenaeus aztecus*) and striped mullet (*Mugil cephalus*) landings were chosen as proxies for fishery resources within CB (Table 18); harvests were lower in 2009 compared to prior years. Shrimp fishing effort was reduced by 75%. White shrimp (*Litopenaeus setiferus,* a fresh-water associated species) was more abundant in 2009, but most commercial shrimpers moved to other bays to harvest brown shrimp (Capt. Walter Hicks, pers. comm. 2009).

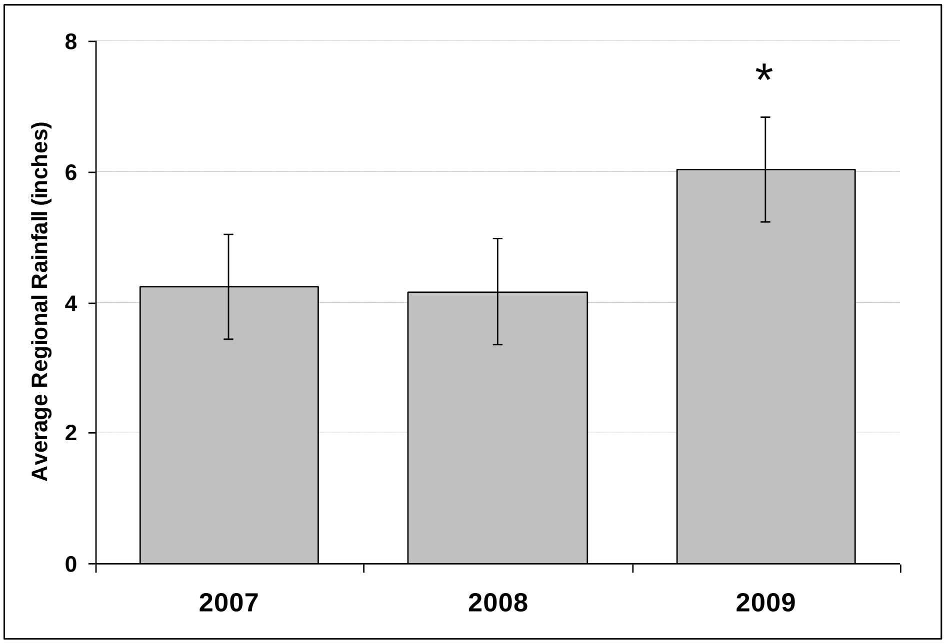


Figure 33. Annual mean rainfall in CB region in 2007-09.

Bars show Gabriel comparison intervals (Gabriel 1978); *2009 is significantly different from 2007-08 (p <0.05).

Table 17. Standardized Precipitation Index (SPI) Values for Southern States 2008-09.

Year	MS	AL	GA	FL	Average	Score
2007	5	2	3	2	3.0	Drought
2008	76	72	36	95	69.8	Normal
2009	84	95	86	82	86.8	Wet

Data from National Climatic Data Center/NESDIS/NOAA National Temperature and Precipitation Maps. Time intervals selected for each year were March-August. Range: 1 = driest; 112 = wettest.

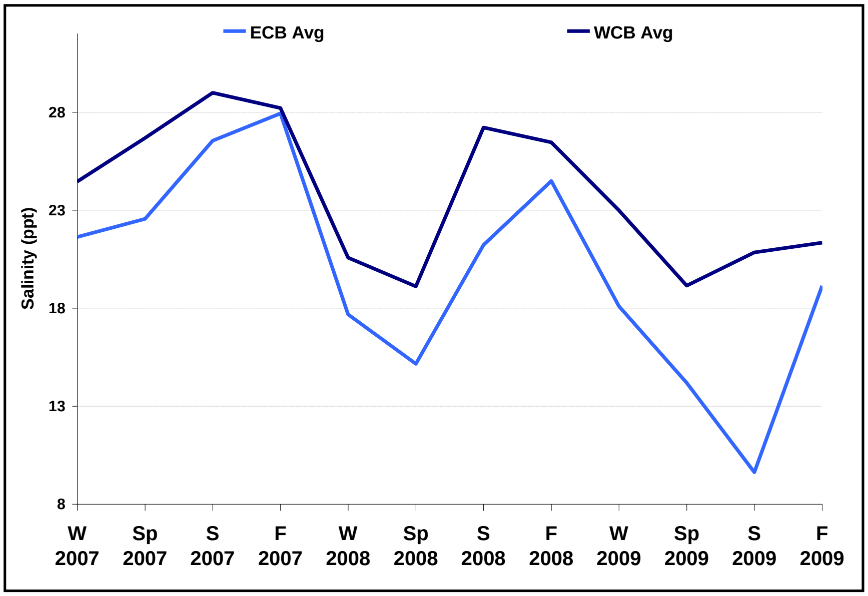


Figure 34. Mean salinity in eastern (ECB) and western (WCB) Choctawhatchee Bay.

W=Winter; Sp=Spring; S=Summer; F=Fall..Data derived from Choctawhatchee Basin Alliance

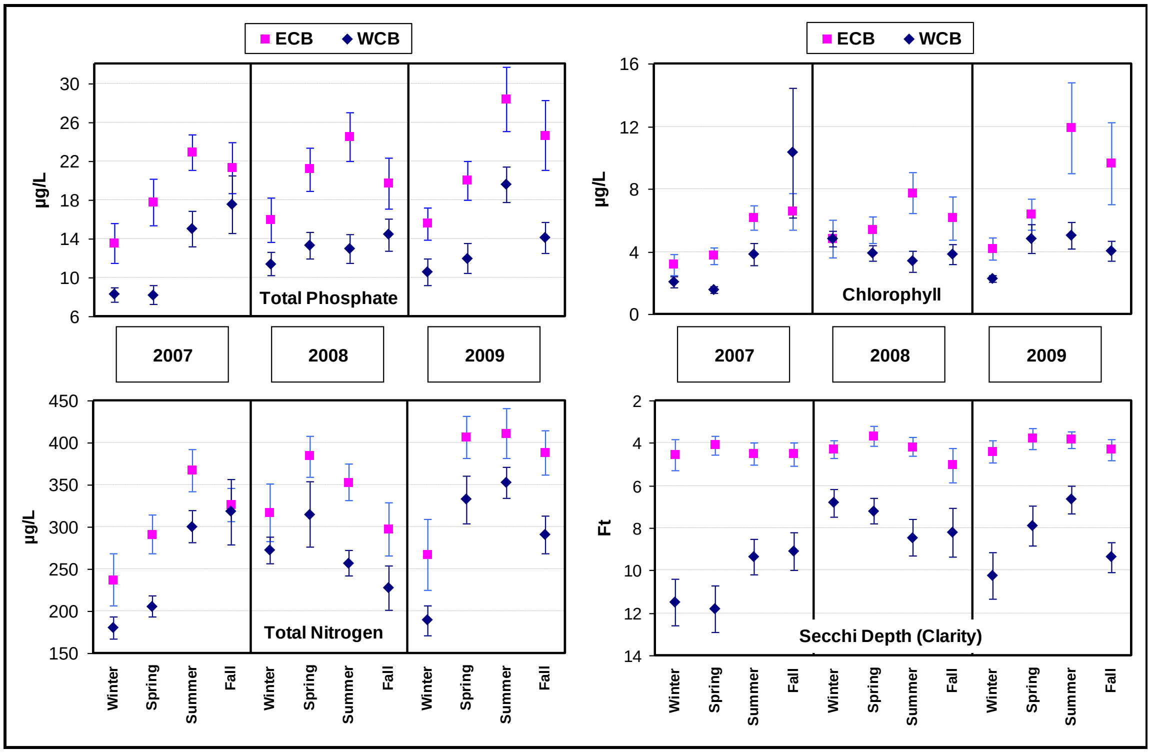


Figure 35. Water chemistry in eastern and western Choctawhatchee Bay, 2007-09.

Light blue = eastern (ECB) and dark blue = western (WCB) Choctawhatchee Bay. Vertical bars denote 95% confidence intervals. Data source: Choctawhatchee Basin Alliance and Florida LAKEWATCH.

Table 18. Commercial Harvests of Brown Shrimp and Striped Mullet in Choctawhatchee Bay.

	Shrimp						Striped Mullet					
Year	Total Harvest (kg)	Δ Harvest	Shrimp trips	Δ Trips	kg/trip	Δ kg/trip	Total Harvest (kg)	Δ Harvest	Mullet trips	Δ Trips	kg/trip	Δ kg/trip
2003	23,937	-55%	280	-28%	86	-40%	24,308	-23%	359	-5%	68	-24%
2004	73,884	40%	388	0%	190	33%	40,313	28%	467	23%	86	-3%
2005	26,845	-49%	209	-46%	128	-10%	52,821	68%	325	-14%	163	83%
2006	50,677	-4%	254	-35%	200	40%	43,317	38%	341	-10%	127	43%
2007	34,320	-35%	284	-27%	121	-15%	34,694	10%	316	-17%	110	23%
2008	48,616	-8%	233	-40%	209	46%	32,535	4%	236	-38%	138	55%
2009	13,303	-75%	171	-56%	78	-45%	6667	-79%	82	-78%	81	-9%
10 y mean (1999-2008)	52,841		389		143		31,401		379		89	

Δ values show change from 10 y mean values for total harvest, trips, and kg/trip. Data derived from Florida Fish and Wildlife Commission commercial fisheries landing database (myfwc.com/research/saltwater/fishstats/commercial-fisheries/landings-in-florida).

Discussion

Resightings and photo-identifications during 2006-2009 showed that a resident community of dolphins is located in CB, composed of 179 to 311 individuals, varying across seasons (per Conn *et al*. 2011 and from extended photo-id data). Prior to 2007, dolphins were cataloged in WCB, SRS and DST. Subsequent surveys of ECB revealed dolphins were also abundant in that river-influenced region. Photo-id results show CB dolphins have long term residency and varying degrees of site fidelity, as has been described in other locations (Barco *et al*. 1999, Gubbins *et* al. 2003, Hubard *et al.* 2004, Urian *et al*. 2009, Toth *et al.* 2011). 24% of individuals were sighted four or more times during summer 2007 most often in ECB, although that likely was due to greater search effort in ECB and because surveys did not occur in SRS or on the Gulf (Conn *et al*. 2011). By comparison, my independent surveys from 2006 through 2009 found dolphin abundance in SRS and DST was similar to ECB, and animals were regularly seen traveling between the inshore and Gulf shoreline year-round at DST.

Sightings of CB dolphins in different, well-separated sites in excess of 20 km apart on different days or seasons suggest some animals had larger ranges than others. For example, in 2008 a known individual seen in ECB was sighted in the Gulf outside DST on the next day (>30 km apart). Surveys into the west end of Santa Rosa Sound in 2006 and 2008 produced sightings of known CB dolphins, and in 2009, three dolphins known from WCB were seen over 65 km away during a scouting survey in Pensacola Bay. In addition, three animals known from inside CB were sighted at both Gulf fishing piers (located >53 km apart). Two stranded animals found in Pensacola Bay during 2008-09 were included in the 2007 CB photo-id catalog. Balmer *et al*. (2008) described similar movement of dolphins between St. Joseph Bay and Crooked Island

Sound, located 120 km to the east of DST. On the other hand, movements of dolphins further east and west of those specific sites may have been limited based on findings from stable isotope signature analysis of dolphin tissues in the adjacent St. George Sound region, which showed animals foraged primarily within constrained zones in the sound and were not feeding at coastal reefs (Wilson *et al*. 2013). In the present study, CB dolphins were observed along the Gulf shoreline, but none were detected farther than 2 km from shore (see also Chapter 6), suggesting they likewise do not forage at offshore reef areas.

Dolphin relative abundance in CB was significantly lower in 2009 compared to 2007. Despite increased search effort, dolphins were seen less frequently in the same areas where they were commonly found in prior years. This suggests animals either dispersed more widely about the estuary or moved to adjacent habitats outside the surveyed areas.

Persistent rainfall in 2009 caused flood conditions in rivers feeding Panhandle estuaries that dramatically altered salinity and nutrient characteristics. Diminished water clarity due to flooding (Hoyer *et al*. 2013) reduced phytoplankton abundance in WCB compared to 2007 (a drought year) signaled by lower chlorophyll concentrations. Such a change would affect primary producer trophic levels, and change conditions necessary for larval development and growth (Pattillo *et al*. 1997). It was reasonable to expect diminished fisheries landings due to low salinity in CB, as was evidenced in the 2009 commercial shrimp and mullet harvests.

Prolonged low-salinity exposure (below 20 ‰) in ECB could have presented an osmotic challenge to resident dolphins in 2009. Husbandry standards for marine mammals in human care recommend salinity levels above 24 ‰ (Whaley and Gage 2008). Ridgway and Venn-Watson (2010) found that mean sodium and chloride plasma levels declined below reference ranges in dolphins given 2-4 L fresh water, leading to potential diuresis that could cause a state of clinical hypochloremia and hyponatremia. Low salinity can negatively affect dolphin health (Colbert *et al*. 1999, Barry *et al*. 2008) as well as their prey availability, although the latter is probably the greatest determining factor in dolphin's selection of habitat (*e.g*., Mazzoil *et al*. 2008a).

Mullet and shrimp landings may serve as a proxy for the prey base resource that dolphins pursue (Gunter 1951, Barros and Odell 1990), and could mirror abundance of higher trophic level fish. Bowen (2011) analyzed stomach contents of dolphins in northwest Florida and found that mullet were present in 22% of stomachs comprising 5% of the prey mass, and penaeid shrimp were found in 32% of stomachs. Shrimp boat captains report that dolphins have become an increasing nuisance around their boats since 2005 (Capt. W. Hicks, pers. comm. 2010), which is of concern and warrants further study.

Fewer bottlenose dolphin strandings occurred during 2009 in the Destin to Pensacola region compared to previous years, but perinates represented a proportionally greater share of those strandings, suggesting either higher monitoring vigilance by responders, or that a stressor was acting on females resulting in loss of newborns (Mann *et al*. 2000, Wells *et al*. 2008). If rainfall related habitat changes in 2009 reduced availability of preferred prey fish, this may have contributed to pregnancy complications, and caused dolphins to range farther in search of more suitable foraging habitat.

Aside from indirect impacts of HABs and weather on foraging resources, dolphins in CB face direct threats from human interactions. Review of the photo-id catalog showed that nearly 20% of sighted animals in the region bore signs of injury that probably resulted from contact with fishing line, entangling debris, or boats. Similar observations have been made in other locations where resident populations of dolphins have been studied (Gorzelany 1998, Samuels and Bejder 2004, Wells *et al*. 2008, Lukensburg 2014) and this escalating threat represents one of the greatest challenges to conservation of these animals (Thoms 2006, Mullen *et al*. 2007, Wells *et al*. 2008). The incidence of HI / FI reported in the MMHSRP database for the Florida panhandle and eastern Alabama coast indicates a steady increase occurred in region since 1990 (Figure 36). An alarming aspect of this problem is that the majority of cases involved juvenile animals. The rising trend of FI related stranding events raises concern for the long-term status of bottlenose dolphins in coastal estuaries such as CB where limited data have been available for stock assessments. Considering the relatively high mortality rates of adults and young of year in 2007 (a non-UME year), and the disproportional perinatal mortality rates in 2009 and during the recent 2010 Gulf UME (Carmicheal *et al*. 2012, Colegrove *et al*. 2013), it is imperative to gain a better understanding of dolphin distribution and reproductive capacity in the Florida panhandle, and the genetic connectivity between adjacent dolphin communities.

It was apparent that some animals traveled in excess of 60 km between CB and Pensacola Bay during 2006-09. Previous work using radio tracking methods (see Chapter 3) showed movements of 60-100 km in a single day were common for some dolphins at other sites. Climate variations (such as drought vs. wet seasons as seen in 2007-09), anthropogenic disturbances, and fisheries interactions may influence BSE dolphin abundance and movement between bays along the northern Gulf coast (*e.g*., Hubard *et al*. 2004, Mullen *et al*. 2007, Miller *et al*. 2010). This highlights the potential benefit of establishing a Gulf-wide photo-id catalog of dolphin sightings and identifications shared through collaboration between regions, leading to better delineation of BSE stocks and filling current data gaps on how HABs, climate changes, and human interactions are impacting this species.

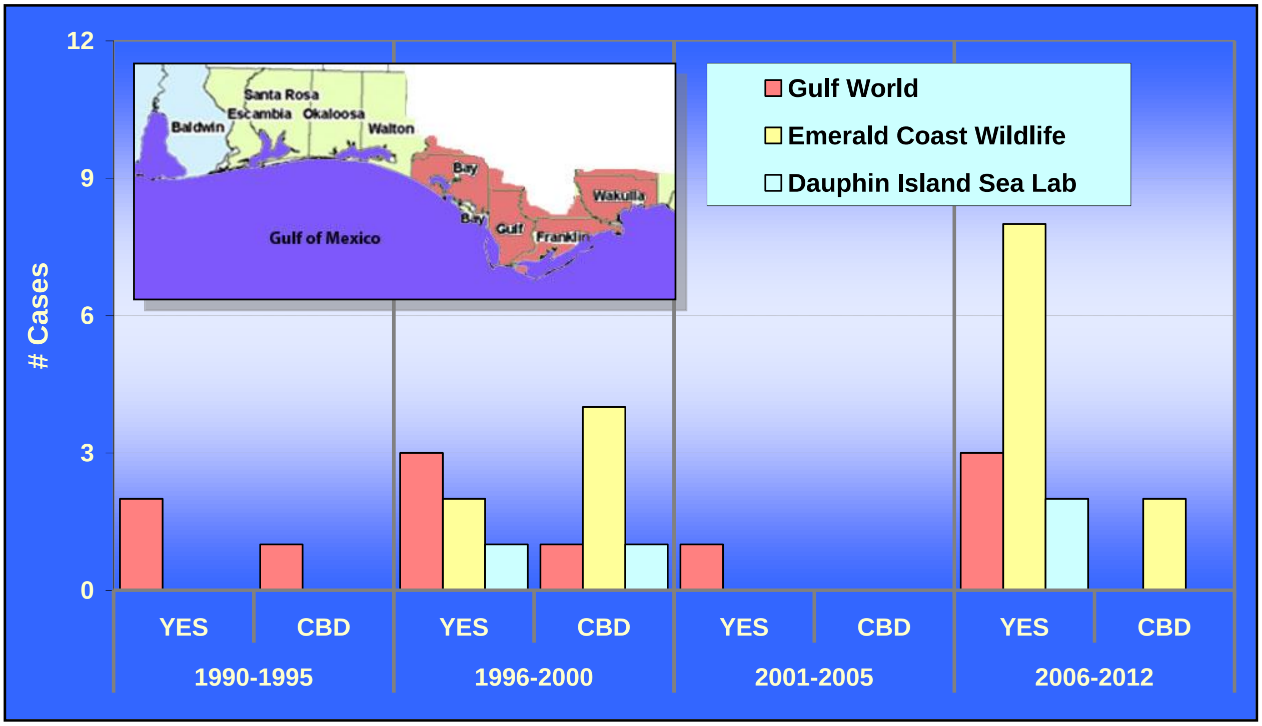


Figure 36. Strandings reporting fishery interactions in the Florida panhandle and Alabama

From Shippee *et al*.[1] Data provided from the MMHSRP, queried by stranding network organization. "Yes" = stranding showed fishery interactions, "CBD" = could not be determined if stranded animal had injuries from fishery interaction.

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[1] Shippee, S.F., A. Wilkerson, S. Kadletz, and S. Leveille. 2012. A review of fishing line entanglement cases involving bottlenose dolphins in northwest Florida. Southeast Region Marine Mammal Health and Stranding Response Biennial meeting, Charleston, SC, 15-17 Feb 2012.

CHAPTER FIVE:
BOTTLENOSE DOLPHIN MOVEMENTS AND COMMUNITY STRUCTURE AT CHOCTAWHATCHEE AND PENSACOLA BAYS

Introduction

A marine mammal unusual mortality event (UME) began in the northern Gulf of Mexico (nGOM) in February 2010, two months prior to the catastrophic Deepwater Horizon Oil Spill (DHOS). Declaration of the UME was made retroactively in December 2010 due to delays caused by the DHOS response effort (Litz *et al.* 2011). To prepare for a UME investigation, NOAA advised stranding network members to conduct enhanced data collection protocols and necropsy procedures for deceased animals early in 2010 (Geraci and Lounsbury 1993, Galloway and Ahlquist 1997, Rowles *et al.* 2001, Johnson and Zaccardi 2006). By the end of the spill response phase in November 2010, 236 stranded marine mammals had been collected in the nGOM region from Louisiana to northwest Florida, 86% of which were bottlenose dolphins (*Tursiops truncatus*). Continued mortalities over the following two years reached unprecedented numbers compared to previous UMEs along the Gulf coast (Litz *et al.* 2011, Colegrove *et al*. 2013). The lack of sufficient baseline information about dolphin populations, ranging and residency in the estuaries of northwest Florida prompted a rapid response project to collect data on abundance, mortality, and morbidity of dolphins in this region (Worthy *et al*. 2013).

Over 1000 km of Gulf coast shorelines were contaminated during the DHOS event, of which about 20% were deemed moderately to heavily oiled (National Commission 2011). Dense slicks landed in the Louisiana delta and on the Mississippi barrier islands, with lesser impacts to shorelines eastward in Alabama and northwest Florida (FDEP 2011, Hayworth *et al*. 2011). All four states were consequently included in the DHOS response zone (National Commission 2011, NRDA 2012). Wildlife mortalities were reported wherever spill products landed, especially of avian, sea turtle, and marine mammal species (NOAA 2010). Given the potential that the oil spill affected organisms at lower trophic levels (Mitra *et al.* 2012) and the likelihood that upper trophic level consumers in the coastal regions directly encountered slicks of oil and dispersants, it was expected that measureable changes would occur in apex predator feeding ecology, habitat utilization, abundance and survival over time (*e.g.*, Loughlin 1994, Matkin *et al*. 2008, Gannon *et al*. 2009, NMFS 2010a, Mitra *et al.* 2012, SEDAR 2012).

Dolphins in Louisiana and Mississippi coastal waters were observed swimming in direct contact with oil (Schwacke *et al*. 2013), however, dolphin occurrence with oil further east at the margin of the spill impact zones were not well described (NMFS 2010a). Weathered oil first washed onto northwest Florida shorelines in June and slicks were detected entering Perdido and Pensacola Bays during incoming tides (National Commission 2011). Sporadic tar deposits accumulated on estuarine shores inside Perdido Bay, Pensacola Bay, and western Santa Rosa Sound near Gulf Breeze and Pensacola Beach, FL (Griggs 2010). By December 2011, over 1.27 million kg of oiled material had been collected on beaches in Northwest Florida, 99% of which was on Perdido Key and Santa Rosa Island in the counties encompassing the interconnected Perdido-Pensacola-Choctawhatchee Bay estuaries (FDEP 2011).

Evidence of potential indirect interactions of the spill with abiotic factors began to emerge during the post-response phase (Colegrove *et al*. 2013). NOAA health assessments of 32 live dolphins in Barataria Bay during summer 2011 found animals were underweight, anemic, had low blood sugar and/or some symptoms of liver and lung disease, and nearly half had abnormally low levels of hormones responsible for stress response, metabolism, and immune function (Schwacke *et al*. 2013). In early 2011 there was a marked increase in perinatal (near term to neonatal) bottlenose dolphin mortalities in the nGOM. Between 1 January and 30 April 2011, 184 bottlenose dolphins, including 84 perinatal calves (< 115 cm), washed ashore from Louisiana to northwestern Florida (NMFS 2010b, Colegrove *et al*. 2013). While the majority of stranded dolphins were discovered on Louisiana and Mississippi coasts, the highest proportion of perinatal dolphins were found on the Mississippi-Alabama barrier islands (Carmichael *et al.* 2012). The timing of this event early in the first peak calving season after the oil spill raised concerns that these mortalities were connected with exposure to oil or dispersant-derived contaminants (Gutman 2011, Semansky 2011, Colegrove *et al*.2013). Alternatively, Carmichael *et al.* (2012) suggested that nGOM dolphins were in poor condition as a result of potentially compromised food resources related to freshets from the extended duration of cold weather over two winters (2010 – 2011), which compounded the effects of the DHOS event.

Bottlenose dolphin stocks in the westernmost Florida panhandle were not well defined prior to DHOS, and their status was largely unknown (Waring *et al.* 2012). Previous UMEs connected with algal bloom toxins significantly impacted dolphins in the Pensacola-Choctawhatchee Bay area during 1999-2000, and 2005 (Gaydos 2006, Schwacke *et al*. 2010, Twiner *et al*. 2012). In response, NOAA began a coordinated research and response plan to better define the Florida panhandle dolphin stocks, their biotoxin exposure, and ranging patterns (Schwacke *et al.* 2004, Gaydos 2006). An intensive mark-recapture study of dolphins in Choctawhatchee bay in 2007 estimated a summer resident population of 176 dolphins and a superpopulation, accounting for transients, of 232 dolphins (Conn *et al.* 2011). In 2008, a photo-identification catalog of 88 distinct dolphins was created for the Perdido Bay estuary (Pabody 2008). Abundance estimates for bottlenose dolphins in Pensacola Bay, Big Lagoon, and Santa

Rosa Sound were lacking with the exception of a single aerial count in 1993 that gave a ‘best’ number of 33 animals in Pensacola and East Bays (Blaylock and Hoggard 1994).

Surveys of estuarine and near-shore regions from small boats are a commonly used technique to monitor bottlenose dolphin populations and estimate abundance levels (Wells and Scott, 1990, Zolman 2002, Read *et al*. 2003a, Fazioli *et al*. 2006, Mazzoil *et al.* 2005, Sellas *et al.* 2005, Adams *et al.* 2008, Balmer *et al.* 2011, Conn *et al.* 2011). Low-level surveys are conducted to determine the dolphin communities and identify individuals to derive resident population size, distribution, and habitat selection. Continuation of long-term studies in multiple seasons allows evaluating shifts in dolphin habitat use, movement patterns, and home range expansion and contraction (Odell and Asper 1990, Scott *et al.* 1990, Mazzoil *et al.* 2005, Balmer *et al.* 2008, O’Shea and Odell 2008). Acquisition of epidermis and blubber tissue via remote-dart biopsy is a commonly used technique to evaluate free swimming bottlenose dolphins’ health status, foraging ecology, and stock structure (Hansen *et al.* 2004, Mullin *et al*. 2007, Balmer *et al.* 2011). Combining dolphin identifications with remote-dart biopsy sampling for genetic, stable isotope and contaminant analysis allows assessment of distribution, community structure, and foraging patterns (Sellas *et al*. 2005, Knoff *et al*. 2008, Balmer *et al*. 2011; 2012, Wilson *et al*. 2012; 2013).

I had begun a long-term photo-id project in 2006 for the Choctawhatchee to Perdido Bay region that provided baseline catalogs of individual dolphins present before and during the DHOS event (see Chapter 4) that could be used to compare future population changes in the region. An intensive study investigating dolphin movements within and between these connected estuaries immediately after the spill was warranted to assess dolphins’ potential contaminant exposure and aid in predicting long-term toxicity or reproductive decline. Therefore, I expanded my original focus area within Choctawhatchee Bay to include the entirety of Santa Rosa Sound through the lower portion of Pensacola Bay, and Big Lagoon, which was suspected to be an important habitat for dolphins owing to large expanses of seagrass (Ruth and Handley 2006). The project was intended to identify dolphin habitat use and foraging patterns, assess their site fidelity, and derive data for estimating abundance and population status. Photo-id surveys were made concurrent with efforts to acquire tissue samples via remote-dart biopsy of free ranging dolphins, prey fish sampling, and assessment of deceased animals found on local shorelines (Worthy *et al*. 2013). Further, collection of tissues acquired from free ranging and stranded dolphins in partnership with the Marine Mammal Health and Stranding Response Program (MMHSRP) were made to monitor changes in diet composition and nutritional status (Worthy 2001, Gannon and Waples 2004, Gaydos 2006, Colegrove *et al*. 2013). Combined, this sampling supported ongoing investigations on genetic structure, epizootics, biotoxin and contaminant burdens, and foraging ecology (*e.g*., Loughlin 1994, Mullen *et al*. 2007, Vollmer and Rosel 2013).

Specifically, I investigated dolphin movements between the interconnected bays and assess their ranging patterns to determine the likelihood of whether estuarine dolphins had exposure to oil contaminants in the bays and nearshore Gulf. By identifying individual animals and assigning residency patterns to defined regions in the estuaries, it would be possible to estimate abundance, community structure, and foraging dynamics detected by discernable differences in stable isotope signatures acquired through tissue sampling. Sighting histories created for these dolphins are available for future population modeling (Rosel *et al*. 2011), with the potential to inform NOAA management on the status of bottlenose dolphin stocks that inhabited the Perdido-Pensacola-Choctawhatchee estuaries.

Methods

Study Area

This study encompassed the northwest Florida estuaries of Choctwahatchee Bay (CB), Santa Rosa Sound (SRS), Lower Pensacola Bay (LPB), Big Lagoon (BL), and the nearshore Gulf coastal zone associated with the inlets at Destin and Pensacola. CB is bordered by the Destin peninsula to the south, Fort Walton Beach to the west, Eglin Air Force Base property to the north, and the less developed shorelines of Freeport and Santa Rosa Beach to the east. A single jetty-maintained inlet to the Gulf of Mexico is at Destin East Pass where a sheltered harbor is situated. The bay spans 334 km^2 and narrows into SRS to the west, a natural 60 km inshore waterway connecting with Pensacola Bay that is bounded on the south by a barrier island. At the eastern extreme of the bay, the Intracoastal Waterway connects via a 31 km dredged barge canal with West Bay in Panama City, FL. Freshwater flows into eastern CB from the 13,856 km^2 watershed encompassing the Choctawhatchee River system. CB has a salinity of 15-28‰ increasing from east to west, a max depth of 10.9 m (mean = 5.0 m) with extensive shallows, a yearly temperature range of 10 - 30 ˚C and once-daily tides of 0.25-0.80 m (Livingston 1986, Hoyer *et al*. 2013). Undeveloped coastlines are typically fringed by *Spartina* salt marshes. Strong tidal flows at Destin Inlet result in variable salinity changes that limit seagrasses mostly to the central and western portions of CB (Ruth and Handley 2006, Lazzarino 2010, Yarbro and Carlson 2011). CB consists of three habitat zones based on eutrophication parameters and water chemistry profiles, from the river-influenced region on the east to the Gulf tidal dominated area to the west (Ruth and Handley 2006, Hoyer *et al*. 2013).

Pensacola Bay is an extensive estuary consisting of open surface waters of 373 km^2 divided into five subareas: LPB, BL, SRS, Escambia Bay and East Bay. Four rivers drain into the bay system and the watershed covers nearly 18,130 km^2. All bay subareas eventually drain into LPB which has a natural deep water opening to the Gulf of Mexico between the western end of Santa Rosa Island and Perdido Key. The upper reaches of the estuary are primarily river dominated; the lower portion is tidally influenced by the strong daily ebb and flow of salt water from the Gulf. Regions of the bay surrounding the port of Pensacola and the Naval Air Station have been heavily dredged and affected by pollutant discharges since 1945, resulting in loss of over 90% of the historical seagrass beds that once dominated the system (Ruth and Handley 2006). Seagrass losses are less severe in the SRS and BL subareas of the bay which are fringed by marsh and retain natural depths except for navigation channels.

The Intracoastal Waterway (ICW) through SRS has a depth maintained to 4.5 m. The average water depth outside of the ICW is typically 1-2 m and shallows along the southern side of SRS to less than 0.5 m within 100 m of shore. Seagrass beds line the south shore primarily at the western end of the sound, but can also be found along stretches of shallow waters behind spoil islands near the eastern regions. *Spartina* salt marshes border SRS along much of its length although development on the northern shore limits this habitat feature. Numerous small tributaries and drainages empty into SRS, but there are no major fresh water inputs. The flow of water is tidally driven from the bays at each end, although the middle sound has relatively low salinity (10-22‰) during the winter and spring due to localized freshwater runoff. At the western extent of LPB, the ICW continues through a similar habitat zone in BL, which connects via a short narrows with Perdido Bay. Summer water temperatures in SRS and BL can reach 35 °C; salinity rarely exceeds 25‰ and can fall below 10‰ after heavy rains (EPA Storet Station

320100A5). Isotopic studies suggest that such mesohaline waterways are vital to estuarine food webs, and prey from these habitats is found in the stomach contents of many transient marine fishes (Gillanders *et al*. 2003).

Subarea Selection

The study area was divided into six subareas of the estuarine and near-shore Gulf waters between east CB and BL (Figure 37). GIS shapefiles of the surrounding shorelines were acquired from the Florida Geographic Data Library (FGDL.com), processed, and subareas were drawn using ArcMap 10 (Environmental Systems Research Inst., Redlands CA).

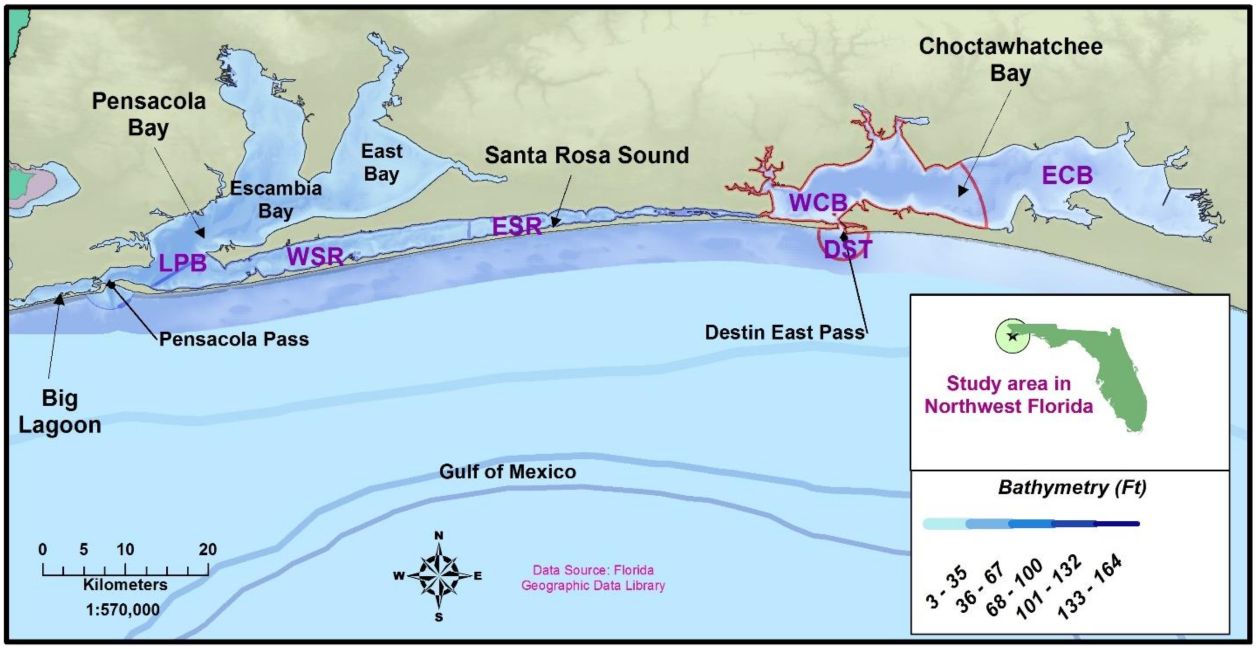


Figure 37. Choctawhatchee and Pensacola Bay region of NW Florida.

LPB = Lower Pensacola Bay; WSR and ESR = Western and Eastern Santa Rosa Sound; DST = Destin inlet area; WCB and ECB = Western and Eastern Choctawhatchee Bay.

Due to the expansiveness of upper Escambia and East Bays, only the LPB portion of the bay was selected for surveying since it is directly continuous with SRS and BL. LPB was bounded by a N-S line just eastward of the Three-Mile Bridge, extending west across the bay including each bayou, Pensacola Pass, and BL. SRS was divided into two subareas with eastern (ESR) and western (WSR) portions divided by a N-S line near Navarre Beach. CB was divided into three subareas: the west portion of the bay (WCB) from Fort Walton Beach and including all bayous extending eastward to a N-S line drawn near mid-bay; all eastern portions of the bay (ECB) including bayous from that line to the Choctawhatchee River Delta; and the area surrounding Destin East Pass (DST) demarked to the north by an arc spanning 1 km inward to CB. Both the LPB and DST subareas included the areas on the outside of the inlets extending approximately 2 km southward by 10 km E-W along the nearby Gulf shoreline.

Each subarea was sized to allow completion of boat-based surveys in one to two day's effort (Table 19); ESR could be easily searched in less than one day. ECB constituted the largest area at ≈200 km^2, but the open water mid-bay portion was difficult to survey due to wind fetch and thus was excluded from most search days. Survey routes were drawn using GPS software (Mapsource ver 6.15, Garmin International, Inc, Olathe, KS) and downloaded to the GPS unit used on the vessel. Track lines served as navigation guides for each subarea (Figure 38), which varied in separation distance and heading to best conform with the search areas: LPB transects were spaced at 2.0 km intervals heading NW-SE; zigzag lines were used to navigate through WSR; contour lines guided surveys through ESR, all narrows, bayous, and BL; N-S lines with 2 km spacing guided surveys in all of WCB and ECB. The DST and LPB inlet surveys followed the channels and coastline contours. The Gulf shoreline surveys at Destin Pass spanned up to

8 km west because of the predictable movement of dolphins in that region. Navigation of the survey subareas was adjusted each trip to optimize sighting probabilities for weather conditions.

Table 19. Survey Subareas and Search Track Line Characteristics.

Subarea	Area (km^2)	Search track length (km)	Survey effort per track (d)
LPB	100	145	2.0
WSR	75	103	1.5
ESR	35	95	1.5
WCB	125	148	2.0
DST	50	57	1.0
ECB	200	155	2.0

LPB = Lower Pensacola Bay; WSR and ESR = Western and Eastern Santa Rosa Sound; DST = Destin inlet area; WCB and ECB = Western and Eastern Choctawhatchee Bay.

Photo-Id Surveys

Quarterly surveys were planned to occur in as few days as possible for visual capture of individuals present in each subarea while minimizing effects of immigration, emigration, births, and mortality (Rosel *et al*. 2011). Surveys of all planned track lines could be completed within a 10-day interval under normal seasonal weather conditions. Partial surveys during inclement weather were conducted as long as a reasonable assumption of detection was maintained; these usually were in sheltered waters such as bayous and the narrow waterways of ESR.

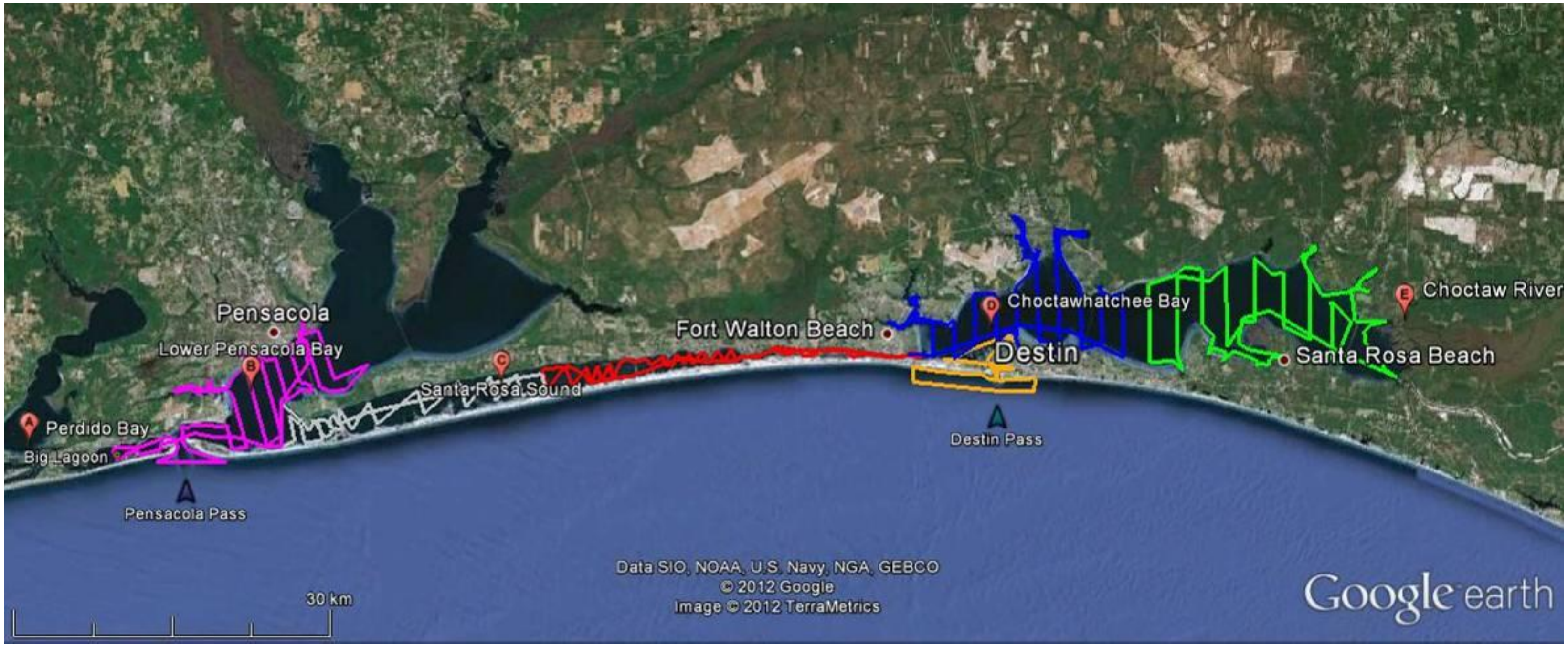


Figure 38. Survey tracklines in each of the six estuarine subareas.

Colors denote different subarea survey routes.

Since dolphin birthing season is typically in late winter through spring in this region (Urian *et al.* 1996), encounters in the study area during spring 2010 were included in the analyses to assign identified juveniles born prior to the DHOS event with respective mothers. Focused surveys were conducted from January-September 2010 at DST, WCB, ESR, with random trips in WSR and LPB. Comprehensive surveys began in August 2010 and were conducted each season defined as: winter = December-February; spring = March-May; summer = June-August; fall = September-November.

Observers worked from a 5.5 m outboard boat. Standardized photo-id survey protocols were followed to approach dolphin groups (Wells 2009a). Survey tracks and sighting locations were recorded with a GPS device, and water depths were measured with a hull-mount bottom sounder. Water parameters (clarity, salinity, temperature, and dissolved oxygen) were measured at each sighting and periodically during the course of daily surveys along with environmental data. All small boat surveys were conducted in accordance with NOAA Scientific Research Permit No. 522-1785 to R.S. Wells and UCF-IACUC protocol 08-21W.

Surveys usually followed the pre-plotted tracklines in each subarea although deviations were allowed to explore off-track sightings or avoid open-water routes in poor environmental conditions. Boat speed was usually maintained at 28-35 km/h while two observers watched ahead for dolphins. Effort differentiated between searching open water transects, searching sheltered waters, conducting observations, and during conditions of low sighting probability. Effort type, search time, and sighting conditions were recorded for each survey segment. Surveys stopped when conditions reduced sighting probability below reasonable likelihood of detection within 150 m of either side of the bow. Under normal conditions, probability of detection exceeded 250 m to either side. Surveys were discontinued in Beaufort Sea States >3 due to low sighting probability, although chance encounters en route were included in analyses.

The boat was maneuvered to within 50 m of dolphin groups when sighted to acquire photographs. Group size, estimated numbers of adults, juveniles and young-of-the-year, travel direction, behavioral activity, occurrence of *Xenobalanus* (a cetacean-specific stalked barnacle), and visual injuries or scars were noted. After sufficient photos were acquired for identification and related observational data were completed, the boat resumed the survey course. A typical sighting took 15 to 45 min depending on group size. Each encounter was recorded as a distinct sighting, even if groups were re-sighted later that day.

Photo-Identification and Development of Catalogs of Individuals

As possible, all dolphin dorsal fins and other identifying features were photographed during sightings. Photos were taken using digital SLR cameras (Nikon D300 or D70 with 70-300 mm VR-II zoom lenses; Nikon Inc, Melville, NY). Cameras were date and time-synched with the on-board GPS device before each use. Digital images were downloaded and archived in original format after each day of observations. Photo analysis was made on MS Windows computers with ACDSee software (ACD Systems, Saanichton, BC, Canada). Photo-id catalogs were created by visually matching images on computer monitors. Best quality photos from each day were sorted and selected for analysis. Dolphins were categorized in four levels of marking distinctness: high, medium, low, and non-distinct. Calves were defined as animals visually distinguishable in size from the adults (less than 65% adult body length), especially when seen with the presumed mother dolphin. Very young animals that could be assigned to a mother were cataloged if they had consistent markings that could be seen over subsequent sightings. Dolphins with low distinctness were included in daily edited photos if they were distinguishable from others in the sighting, even if not identifiable and were counted only as present in a sighting.

Standardized methods were used to catalog individuals (Urian *et al*. 1999, Wells 2009a, Rosel *et al*. 2011). To confirm matches, images were overlaid in transparent layers using Adobe Photoshop 7.0 (Adobe Systems Incorporated, San Jose, CA). ACDSee software was used to organize a searchable database of edited images. Complementary field metadata were combined with the photo-id catalog information in MS Excel and Access database applications. Catalog names for every distinctly marked dolphin consisted of an alphanumeric ID that was entered into the database and could be queried by date, sighting, location, and season. Newly photographed dolphins were compared with existing catalogs previously compiled for CB during 2006-09 (A. Gorgone and L. Hansen, pers. comm. 2008; Chapter 4); offshore Gulf of Mexico near Destin and Orange Beach; and Perdido Bay (Shippee *et al.* 2011).

Remote-Dart Biopsy Sampling

A collaborative effort to acquire epidermal samples from free-ranging dolphins using remote-dart biopsy methods was conducted with J. Allen and A. Barleycorn from Sarasota Dolphin Research Program (SDRP) utilizing equipment and procedures that adhered to standard biopsy sampling protocols (Hanson *et al.* 2004, Wenzel *et al.* 2010, Balmer *et al.* 2011). Biopsy surveys were conducted in accordance with NOAA Scientific Research Permit No. 522-1785 issued to R.S. Wells.

Two vessel-based biopsy sampling sessions were planned to follow initial mark surveys, and again after a 5-6 month interval. Biopsy sampling trips were designed to maximize dolphin encounters, but were conducted in each subarea to acquire samples representative of the spatial distribution of animals across the CB-SRS-LPB region. Surveys were made for one or two days per subarea aboard the 5.5 m boat used in the low-level surveys. The boat moved at survey speed until dolphins were sighted, at which point the animals were approached. Slow traveling dolphin groups surfacing sequentially were sought out. Those with distinct fins or identifying marks were preferred; females with dependent calves, very young animals, and animals previously sampled were avoided. Focal dolphins were selected based on ease of approach, size, recognizable marks, independence from offspring/mothers, and visual appearance of good health. Once a dolphin was selected, the boat was maneuvered to within 5 m to position for firing a dart.

The sampling team consisted of a four person crew, with the sampler (rifleman or arbalester) positioned on the bow when approaching dolphins. A cameraman worked in concert with the darter to acquire identification images of the target dolphin. Darts were fired only when dolphins were within 2-10 m of the boat and the target animal was predictably surfacing alone. The dart consisted of a 0.3 m carbon-fiber bolt holding a 25 mm x 10 mm stainless cutter head with a beveled, leading edge and rear facing prongs. Two methods were used to propel the dart at the target dolphins: a blank charge fired from a modified 0.22 caliber rifle; or a recurve crossbow with a draw weight of 68 kg (Barnett Outdoors LLC, Tarpon Springs FL). Biopsy darts were always directed away from the vessel at no more than a 90 degree angle off the bow when the target dolphin was in range. Sampling location was typically just under or anterior to the dorsal fin on the body flank and penetrated through the epidermis to a depth of 15-20 mm. Darts were designed to rebound off the flank after penetration, holding the epidermis/blubber sample afloat in the water column for easy retrieval by the boat crew. Records were kept for each sampling condition, shot distance, body sampling site, if sample was collected, length of sample, and dolphin reaction. Following recovery of a dart, the crew continued to track the target dolphin for

10-30 min to observe post-biopsy behavior and acquire additional photos. Further biopsy attempts within the same dolphin group occurred only if the previously sampled individual could be identified and the group was not reacting adversely to vessel approaches.

In contrast to systematic photo-id surveys in which all dolphins in a sighting were observed and photographed, remote biopsy surveys were more selective. During the focal follows, cohort dolphins were photographed along with those that were sampled for inclusion in the photo-id catalogs. Remote-dart biopsy sampling typically required 15-30 min of observation and close following, although some attempts lasted for up to 60 min. After sampling in a sighting concluded, the boat resumed the planned survey track at search speed. Biopsy surveys ended each day when either sufficient samples were acquired, or the maximum day length was reached.

Samples were recovered and processed immediately on board using sterile techniques. Epidermis and blubber was sectioned into four longitudinal quarters using a sterile blade and forceps and then placed into vials for preservation: 1) one epidermis section in 20% buffered DMSO for genetics; 2) one epidermis section for stable isotope (SI) analysis; 3) one blubber section for fatty acid signature analysis; and 4) one blubber section for PAH/toxin contaminant analysis. DMSO vials were stored at ambient temperature; all other sample containers were immediately frozen at -80^{o}C in a liquid N_2 Dewer flask onboard the boat. All samples were transferred to storage containers (dry box or in liquid N_2) at the completion of each day, and subsequently express shipped to labs for analysis at session’s end.

Stranded Animal Investigation and Sampling

I coordinated with NOAA Marine Mammal Health and Stranding Response Program (MMHSRP) as the local stranding network representative to record and evaluate dolphin and whale mortalities under letter of authorization through Emerald Coast Wildlife Refuge (ECWR) in Fort Walton Beach, FL. The ECWR stranding response area includes the entire region from ECB through middle Perdido Bay, spanning 140 km of linear Gulf shoreline. All stranded animals discovered in the area during 2010-13 that could be accessed were examined for cause of stranding, and were handled following protocols disseminated by MMHSRP. Trained ECWR personnel made field observations and examined deceased dolphins as soon as possible. Photos were taken of dorsal fins and any distinct markings that would allow matching stranded dolphins to the CB and LPB photo-id catalogs. Other information gathered during exams included signs of human interaction, wounds, morphometrics, and general body condition. Select tissues were routinely collected for life history, to include epidermis for genetics and stable isotope analysis. Enhanced necropsy exams collected organ samples for nutritional, chemical, viral, bacterial, and biotoxin analysis, as directed by the NOAA MMHSRP regional coordinator, and transferred under chain of custody procedures for analysis by the NOAA UME investigative team.

Abundance Estimates and Photo-Identification Analyses

Relative abundance indices of dolphins in each subarea were determined from average number of dolphins sighted per km of trackline searched (D/km) (Fazioli *et al*. 2006). This potentially includes repeated encounters with individuals on multiple days and thus does not give a measure of population size but rather reflects the presence of dolphins spatially and temporally.

Population abundance estimates were derived from the photo-identification results by applying the Chapman modified Lincoln-Peterson (LP) model for closed populations (Chapman 1951, Williams *et al*. 1993a). Each season represented a capture-recapture period, with an initial mark session followed by a recapture session within that season. Surveys during each session covered areas where dolphins were expected to be abundant and representative of the bay population (per Conn *et al*. 2011).

To meet mark-recapture assumptions of equal catchability and independence, non-distinct animals and young-of-year calves were removed from sighting data used in the abundance estimates. Sightings that were used for analysis were restricted to estuarine dolphins only, animals seen only along the Gulf shoreline were excluded. A dolphin was counted once per session regardless of multiple resightings during surveys in that session. Statistics were derived for the number of unique dolphins photographed in each session (n_1 and n_2), and the number of marked animals seen during both sessions (m_2). Abundance estimates (N_c) were calculated as:

$$N_C = \frac{(n_1+1)(n_2+1)}{(m_2+1)} - 1 \tag{1}$$

Variance (var N_c) and standard error (SE) were calculated as:

$$\operatorname{var} N_C = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \tag{2}$$

$$SE = \sqrt{\operatorname{var} N_C} \tag{3}$$

Models for evaluating emigration, immigration and survival are based on the proportion of distinctive to non-distinctive animals that are sighted in a survey period (Williams *et al*. 1993a). To derive distinctness ratios, the number of individuals with high and medium mark distinctness was determined for the total number of animals sighted in each survey (Read *et al*. 2003a). This gave a second estimate for total population size for each survey period (season) as:

$$\tilde{N}_{\text{total}} = \tilde{N} / \leq \Theta \qquad (4)$$

where $\tilde{N}_{\text{total}}$ = estimated total population, Ñ = estimated number of individuals in a survey period, and Θ = estimate of distinctiveness ratio in a survey period. Since dolphins were known to range between subareas, survey data in ECB-DST-WCB-ESR were combined to represent CB, and LPB-WSR to represent LPB/SRS. Survey periods were divided into seasons from summer 2010 to summer 2011, selecting all trips in each combined bay area as a single seasonal capture-recapture occasion.

Sightings of each individual dolphin during this study, along with prior sighting histories since 2006, were used to establish if animals were resident or transient, and to define their site fidelity affiliations. An estimate of number of resident dolphins was derived from photo-id data, defined by number of individual dolphins seen on more than one day (Conn *et al*. 2011). Dolphins that were only seen a single occasion during 2010-11 were coded as 'transient' unless they had a sighting history prior to 2010. Animals seen multiple times but in more than one subarea were coded as 'travelers.' Subarea affiliation for each subarea of dolphins seen three or more times during 2010-11 was calculated using a relative sighting proportion (SPi):

$$SP_i = \frac{n_i}{\sum_{j=1}^{N} n_j} \quad \text{(Adams } et\ al.\text{ 2008)} \qquad (5)$$

where n_i = number of times an individual dolphin was sighted in subarea i, and N = number of subareas. Sightings in all six subareas were used for this calculation. Dolphins with SP ≥ 0.5 for a specific subarea were classified as having a higher affinity for that subarea, unless sighted an equal number of times in two or more subareas.

Analyses and summary datasets were done in MS Excel to produce abundance estimates, SPi values, timeline and discovery curves, sighting frequency tables, distribution pattern tables, and catalog composition.

Stable Isotope Analyses

Dolphin epidermis samples collected by remote-dart biopsy sampling were submitted to Michigan State University (MSU) for stable isotope (SI) analysis using methods described in Worthy *et al*. (2013). Briefly, mass spectrometry was used to measure naturally occurring stable carbon and nitrogen isotope concentrations, expressed as a ratio of heavy to light forms ($\delta^{15}N/^{14}N$ and $\delta\,^{13}C/^{12}C$). Results from the analysis are used here for spatial evaluation of dolphin ranging in the subareas.

Results

Dolphin Photo-Identification Survey Efforts and Sightings

In total, 179 subarea surveys were conducted over 93 separate days during January 2010 - August 2011, covering 6179 km searched during 375 hours of effort (Table 20). An additional 127.5 h was spent observing and photographing dolphins over a combined distance of 727 km during sightings. Multiple subareas were often transited per day. Dolphins were sighted on 90 of the 93 survey days. Although LPB surveys comprised only 8% of the total number of trips, the search distance was comparable with ECB and DST. The greatest effort occurred in WCB and

ESR since most boat trips in CB originated at launch ramps in those subareas. Survey effort was concentrated in only CB during winter-spring 2010; after September 2010, effort was more uniformly distributed across all seasons. The entire search effort was highest in spring, and lowest in winter when weather was often less favorable.

Table 20. Search Effort and Dolphin Relative Abundance by Period and Subarea.

Subarea	# Surveys	# Sightings	# Dolphins sighted	Search Distance (km)	Search time (h)	Search time %	# Dolphins / km	km searched /sighting
Overall Survey Effort								
ECB	11	63	339	840	41.2	11%	0.40	13.3
DST	45	98	770	784	79.1	21%	0.98	8.0
WCB	50	68	440	1820	104.7	28%	0.24	26.8
ESR	49	36	248	1301	81.1	22%	0.19	36.1
WSR	10	28	270	584	22.9	6%	0.46	20.9
LPB	14	34	290	851	45.4	12%	0.34	25.0
TOTAL:	179	327	2357	6179	374.4		0.38	18.9
Routine Surveys (January-August 2010)								
ECB				Not surveyed				
DST	18	30	203	313	33.0	40%	0.65	10.4
WCB	16	12	66	367	24.5	30%	0.18	30.6
ESR	17	7	56	311	19.6	24%	0.18	44.5
WSR	1	2	5	10	0.8	1%	0.51	5.0
LPB	2	4	15	76	4.6	6%	0.20	19.1
TOTAL:	54	55	345	1078	82.6		0.32	19.6
Intensive Surveys (September 2010 - August 2011)								
ECB	11	63	339	840	41.2	14%	0.40	13.3
DST	27	68	567	471	46.1	16%	1.21	6.9
WCB	34	56	374	1453	80.1	27%	0.26	25.9
ESR	32	29	192	989	61.4	21%	0.19	34.1
WSR	9	26	265	574	22.1	8%	0.46	22.1
LPB	12	30	275	774	40.8	14%	0.36	25.8
TOTAL:	125	272	2012	5101	291.8		0.40	18.8

Prior to DHOS, I had been conducting periodic surveys in CB and Perdido Bay to identify inlet-associated dolphins in those regions (see Chapter 5). During January-August 2010, 54 surveys involving 82.5 hours of search effort were made in CB primarily around DST and in WCB; there were no trips made in ECB and only one survey into WSR. Two brief trips were made in LPB near Pensacola Pass. The resulting baseline dolphin catalog, including young-of-the-year existing in spring 2010, provided a reference for the months immediately prior to DHOS, in addition to the long-term CB photo-id catalog created during 2006-09 containing 311 identified dolphins.

Post-DHOS effort encompassed 125 surveys completed across the six subareas. Eight limited searches were made in WCB and DST during September 2010. Intensive surveys began in October across all subareas with subsequent surveys each season. Intermittent trips at DST, WCB, and ESR were made in spring to identify new born calves.

Overall, 327 sightings of dolphin groups occurred and an estimated 2,362 dolphins were sighted, which includes individuals that were repeatedly encountered and therefore counted multiple times. During January 2010 – August 2011, a mean of 25.4 (± 18.7) dolphins were sighted per day and over 52,000 identification photos were taken. Dolphin relative abundance (D/km) was consistently highest in DST and lowest in ESR (Figure 39). Overall D/km was lowest in spring months. Population estimates derived from Lincoln-Peterson analysis were made for CB/ESR and LPB/WSR (Table 21 and Figure 40). Direct comparisons of the pre-DHOS and intensive survey phases cannot be made due to the limited range and effort of the former, however, D/km was approximately equal in both winters. Abundance estimates for summer of 2010 in both CB and SRS/LPB were not feasible from the limited sighting data since it did not include uniform survey coverage of all subareas.

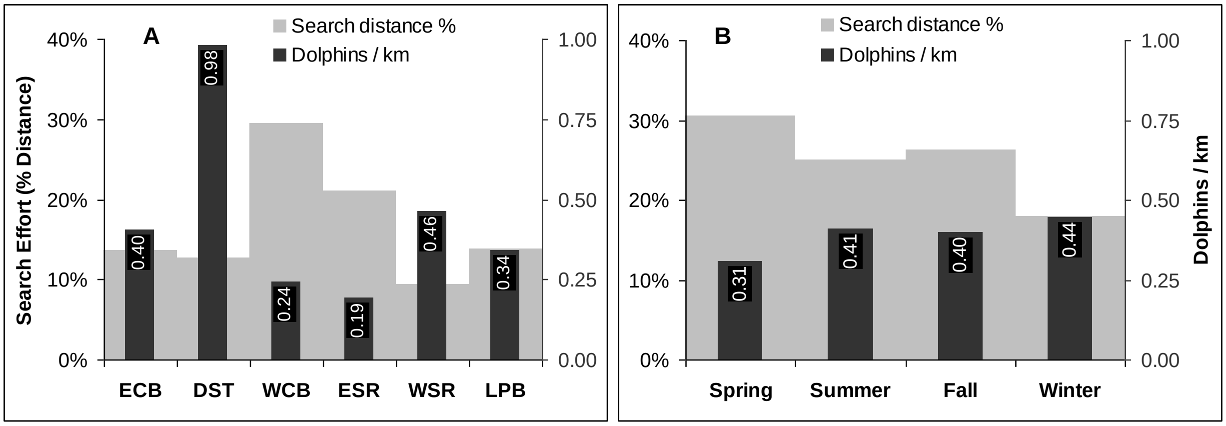


Figure 39. Pooled relative dolphin abundance between January 2010 and August 2011.

Search effort and observed dolphins/km based on encounter frequencies during surveys, A) by survey subarea, B) by seasons defined as: Winter = December-February; Spring = March-May; Summer = June-August; Fall = September-November.

Table 21. Abundance Estimates for Choctawhatchee and Pensacola Bays.

	Choctawhatchee Bay/ East Santa Rosa Sound				Lower Pensacola Bay/ West Santa Rosa Sound			
Season	Fall 2010	Winter 2011	Spring 2011	Summer 2011	Fall 2010	Winter 2011	Spring 2011	Summer 2011
No. of Surveys	17	9	16	12	6	3	4	3
No. Unique Dolphins	199	162	204	172	182	79	128	81
Mark Distinctness Ratio	0.72	0.77	0.74	0.73	0.72	0.77	0.70	0.66
Est. of Total Marked + Unmarked	278	210	274	234	254	102	183	123
N_c (Lincoln-Peterson)	265	199	285	233	347	338	226	217
SE	14.9	10.4	21.3	15.1	36.3	90.1	25.2	48.8
95% CI	235-294	178-219	243-327	204-263	276-418	161-514	176-275	121-312

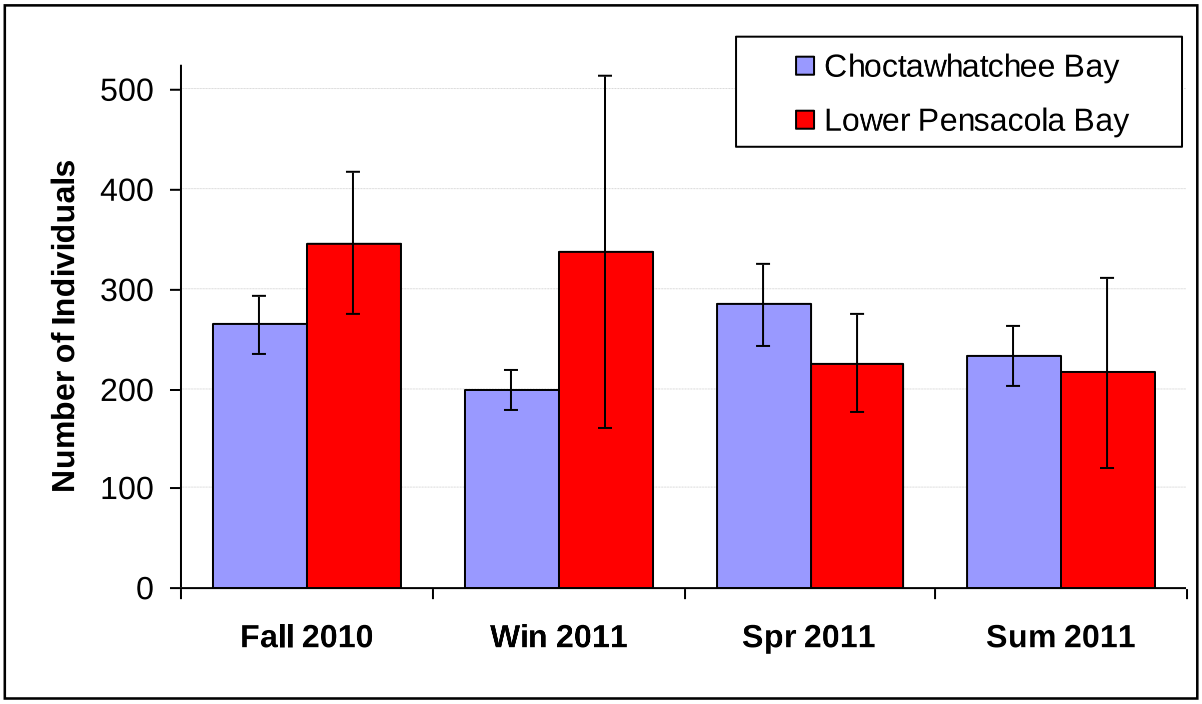


Figure 40. Abundance estimates (Chapman modification of Lincoln-Peterson Model). Error bars denote 95% confidence intervals.

Sightings occurred over shorter average search distances in DST (8 km) and ECB (13 km) than other areas. ESR had the longest average search distance between sightings (36 km). By season for the total area, dolphin encounters varied from one sighting per 16 km searched in the fall, to one sighting per 22 km in the spring. Dolphin group size (average number of animals per sighting) varied widely across locations, with larger groups commonly seen in summer and winter (mean = 7.3 ± 7.8/sighting). Encounters of large groups of dolphins occurred often at DST and WSR/LPB, with the greatest of 48 animals dispersed over 1 km^2 at Destin inlet in Nov 2010.

Remote-Dart Biopsy Sampling and Stranded Animal Tissue Collection

Biopsy sessions occurred during 8-13 Nov 2010, and again five months later during 18-22 April 2011 (Figure 41). Remote-darting occurred in all six subareas in both sessions. Biopsy samples were acquired from 32 dolphins in the fall and 34 in the spring, for a total of 66 samples, with one dolphin being sampled in both sessions. 58% of November samples were acquired near DST and WSR, while half of the April samples were taken in DST and WCB. There were no samples taken in ESR during November; three dolphins sampled in ESR during April continued to travel westward and therefore were counted with those in WSR as a single group. Sex was known or presumed for 34 of the animals; males represented 36% of samples and females 15%, while 47% were of unknown sex (genetic analyses incomplete, P. Rosel, pers. comm., 2012). Samples were shipped to analytic labs within 5 days of each session. Genetic samples were sent to NOAA Fisheries Science Center in Lafayette, LA; Stable isotope vials were shipped on dry ice to MSU; frozen PAH/toxin samples were sent in a liquid N_2 shipping Dewer to National Institute of Science and Technology, Charleston, SC for archiving.

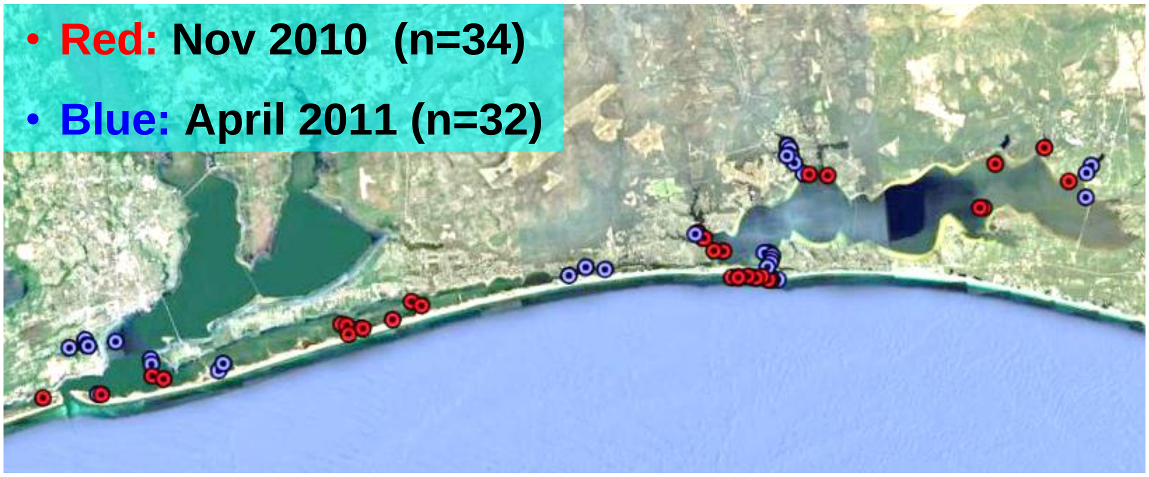


Figure 41. Locations of remote-dart biopsy sampling.

Tissue samples for contaminants and life history were collected from all stranded dolphins during 2010-2011 by ECWR. Stranded dolphin samples were archived under chain of custody requirements in the MMHSRP UME investigation and were not available for analysis in support of the present study, but were added to the MMHSRP tissue bank for future evaluation.

Strandings and Mortalities

ECWR stranding response efforts during 2010 resulted in the recovery of 12 bottlenose dolphins (5 adults, 2 subadults, 2 yearlings, and 3 perinates). Thirteen stranded *Tursiops* were recovered during 2011 in the response area (2 adults, 3 subadults, and 8 perinates), and 10 were found in 2012 (2 adults, 3 subadults, and 5 perinates). A total of 23 necropsies were performed to collect tissues for investigation of the UME. Four non-perinate dolphins were positively identified from the photo-id catalogs for the region, while the others were either non-distinct, presumed coastal/ offshore stock, or too decomposed to identify. Three mortalities involved evidence of direct human interactions (entanglement or acute trauma); one animal exhibited severe pneumonia and nutritional distress. Determination of stranding and mortality for dolphins in the Florida panhandle remained under investigation and none had been directly linked to the DHOS event as of February 2014.

Photo-Identification Catalogs

Analyses of photos collected during January 2010 - August 2011 resulted in identification of 655 individual dolphins with distinct marks on their dorsal fin or body, or calves of low distinctness consistently seen with recognizable adults. 176 dolphins sighted on different days were not identified either due to non-distinctness or low image quality, therefore many may have been sighted repeatedly. Of the total number of dolphins cataloged, 5% were not distinct, 23% had low distinctness, and 73% had medium and high distinctness.

Rate of discovery of new fins decreased consistently over time, approaching asymptote by June 2011 (Figure 42 and Figure 43). Separate catalogs for all identified animals during 2010-11 were created for three locations: CB contained 403 dolphins; LPB contained 174 dolphins (29 shared with CB catalog); and alongshore Gulf of Mexico contained 78 dolphins. The latter were separately defined since they were seen in the Gulf between Destin and Pensacola but never sighted inside the estuaries. Dolphins seen in SRS were placed in either of the estuarine catalogs depending on location where first seen: ESR dolphins added to CB and WSR dolphins to LPB.

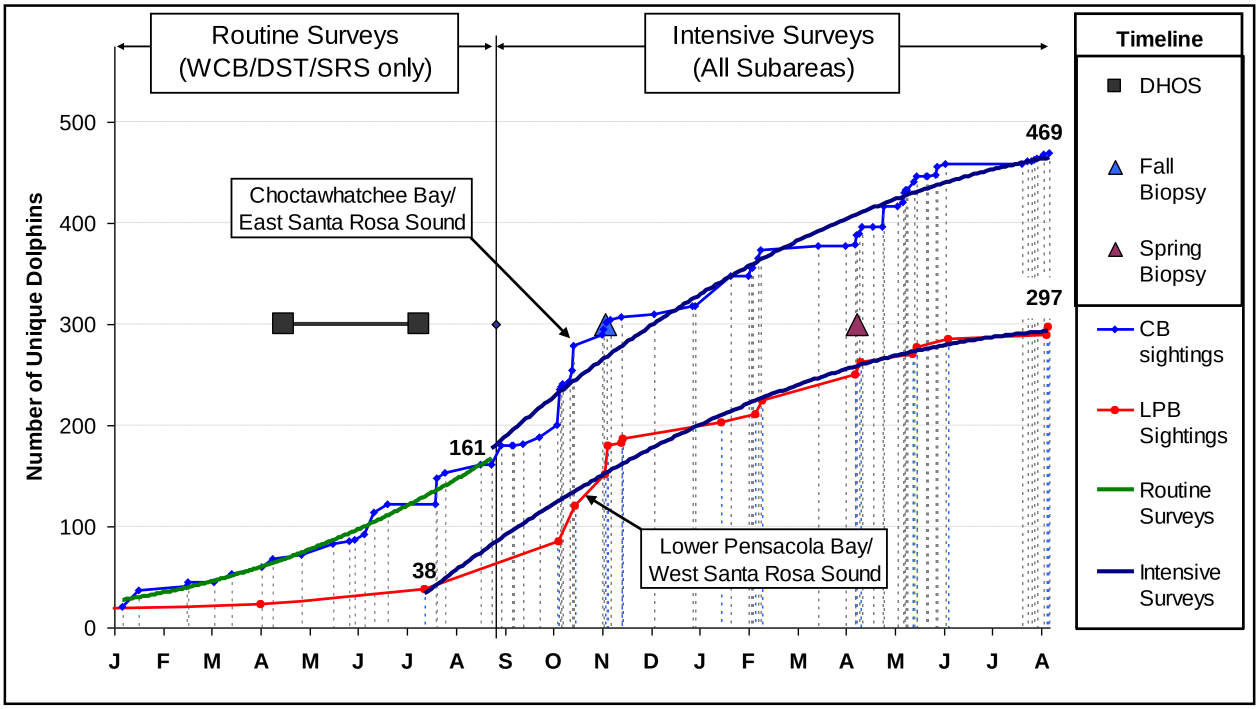


Figure 42. Timeline for discovery of new fins over 18 months.

Vertical Bars represent survey days. 111 dolphins were seen in both bays by the end of August 2011.

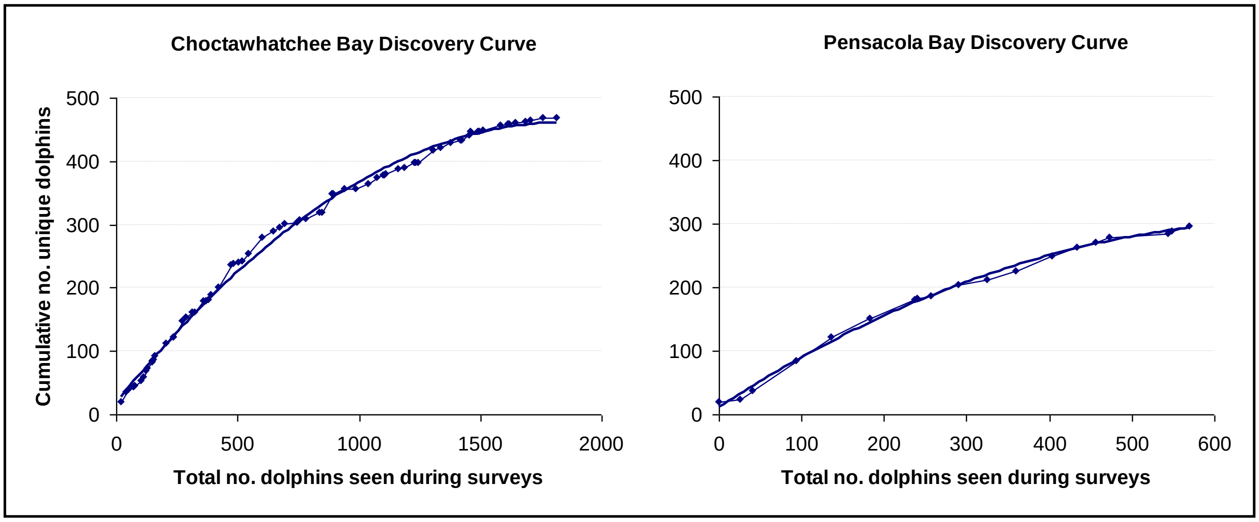


Figure 43. Discovery curves for Choctawhatchee and Pensacola Bays.

Plots the trend between identifications of newly identified marked individuals versus the cumulative total of dolphins seen during 2010-11 (Williams *et al*. 1993a).

Dolphin Resighting and Distribution

Overall, 427 dolphins (65.2%) were resighted during January 2010 - August 2011 (Figure 44): 307 dolphins (47%) were seen three or more days, and 36 (5.5%) were sighted ten or more days, with one dolphin resighted 17 different days (median = 2, mean = 3.3, SD = 2.97). In addition, 77 animals that were only sighted once during 2010-11 were known from prior years or suspected to be yearling calves (58 adults in CB and LPB/WSR; one deceased adult in SRS; and 18 semi-distinct calves seen with known resident individuals). Of 311 previously cataloged fins during 2006-09 in CB, 68.5% were resighted. 117 calves (including yearlings) were identified and assigned to presumed mothers (mean number of individual calf sightings = 3.3 ± 3.2 SD, median = 2, max = 16).

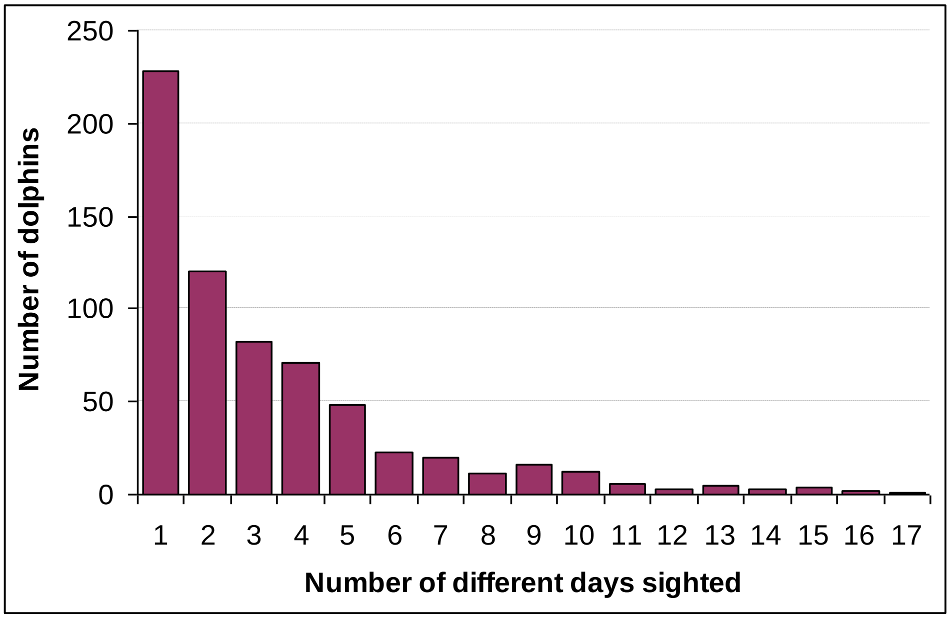


Figure 44. Resighting frequency of photo-identified dolphins during 2010-11 surveys.

Prior to beginning intensive surveys, 181 animals were identified (89% in CB and 11% in LPB-WSR), of which 55% were matched to the existing 2009 CB catalog. Of these, 89.5% were resighted after September 2010; many others were not identifiable due to low distinctness. Thirty young dependent calves or yearlings born since 2009 were identified and assigned to presumed mothers, 90% of which were seen again at least once during September 2010 - August 2011.

Sightings of dolphins occurred in all subareas during all seasons, with the exception of ESR in winter 2010. Dolphins at DST were followed on bay-Gulf excursions during surveys year round. The topography and expanse of Pensacola inlet is much different than Destin (max depth 18 m at Pensacola Pass compared to 6 m at Destin East Pass), therefore it was difficult to closely follow dolphins in that region due to increased dive times and unpredictable surfacings. As a result, dolphin movements from LPB to the Gulf were rarely documented.

Resightings of individual dolphins were scored by subarea (Figure 45). Each was placed one time in a distribution matrix: either in a single subarea; or in a combined category defined by the subareas where sighted. Of those, 32.2% were sighted multiple times only in a single subarea; 22.9% were seen only one time and labeled as ‘transient’; and the remaining 44.9% traveled between multiple subareas. In total, 225 dolphins were sighted only around the inlets at DST and LPB, of which 78 were sighted exclusively in the Gulf. The remaining 430 dolphins (70% of identified animals) were seen inside the estuaries, some of which were also sighted in the nearshore Gulf. Many dolphins were seen ranging extensively across the study area, 54 of which were sighted at locations more than 65 km apart. Twenty four were seen at both Destin inlet and Pensacola Bay; most of these were never seen in SRS, WCB, or ECB, and they all periodically had multiple clusters of *Xenobalanus* on their fins.

Site affiliations for 307 dolphins that were sighted at least three times were calculated for each subarea (Table 22). ECB had the highest mean affinity index, slightly above DST where the greatest number of resightings occurred; lowest mean affinity was at ESR, followed by WCB. Ten dolphins were seen more than five times only in DST, six of which were seen ≥10 times there. The most often sighted dolphin was seen with calf 16 times in DST and once in WCB. The most frequently seen traveling dolphin (15 sightings) had higher site affinity to ESR (SPi=0.6) but was also seen in 4 other subareas.

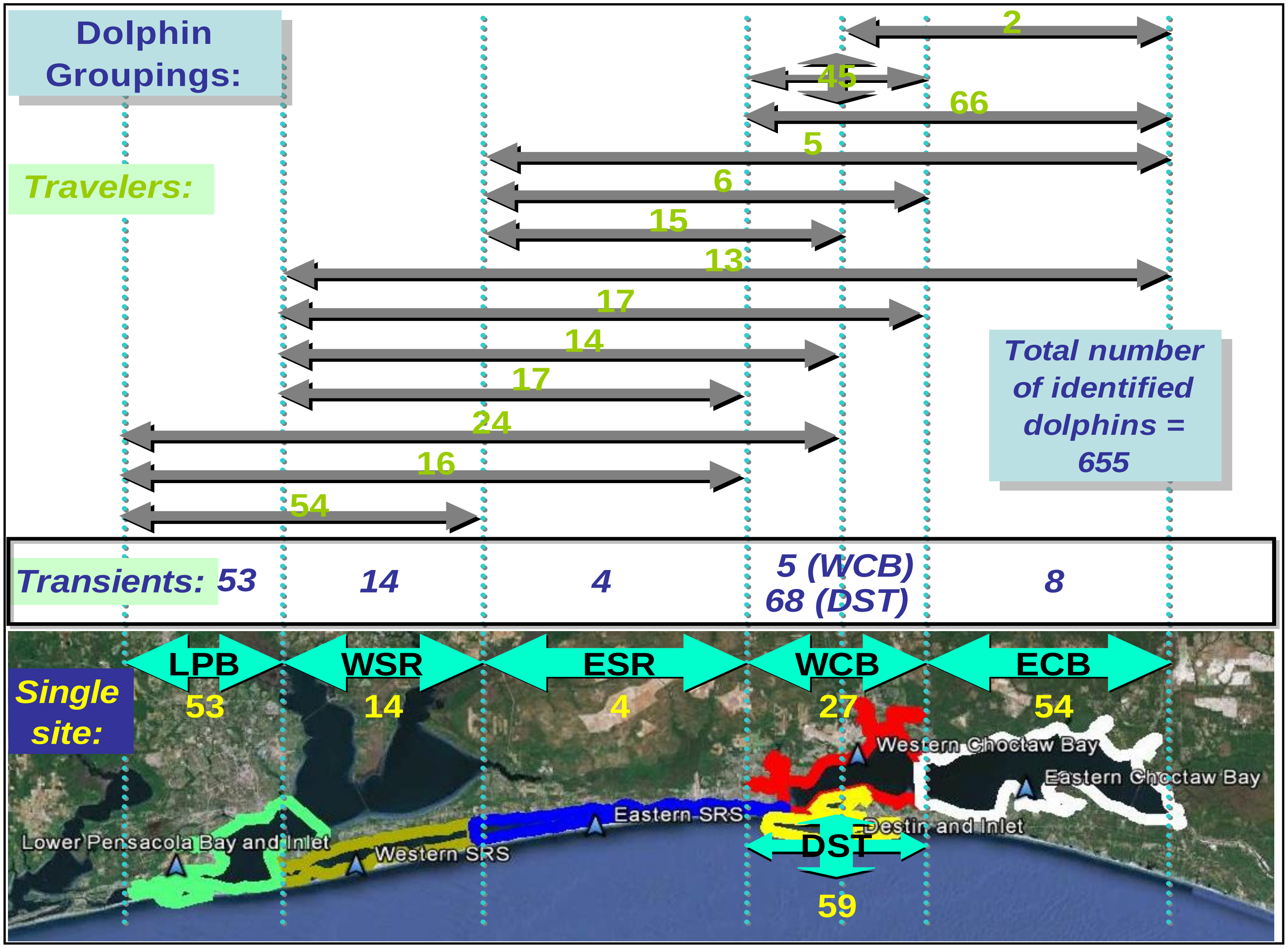


Figure 45. Dolphin distributions.

Numbers indicate count of dolphins in each subarea; Single site animals were seen multiple times always in one subarea; Transients were animals that were only seen one occasion; Travelers were seen in multiple subareas throughout the study period.

Table 22. Sighting Proportion Index (SPi) and Site Affiliations.

Affinity	ECB	DST	WCB	ESR	WSR	LPB
Dolphins with SPi ≥ 0.5	38	83	52	30	20	30
Mean SPi	0.89	0.87	0.74	0.68	0.77	0.84
# Seen only in this site	20	32	5	1	1	7
# Seen equally in 2 sites	2	5	6	0	3	4
# seen > three times in site	40	88	58	30	23	34
Maximum # individual sightings in subarea	7	17	9	15	6	6

Biopsied dolphins were sighted 1-15 times during 2010-11 (mean = 4.0 ± 2.91). Distinctness of marks varied, making some animals difficult to identify in the photo-id catalog (high and medium = 57; low = 11; nondistinct = 1). Sighting histories from before or after sampling existed for 55 of the biopsied dolphins; 10 were unconfirmed as ever sighted other than on day of sampling. Site affiliations for biopsied dolphins were determined based on either their SPi values for specific subareas, or by assumption that they remained for a majority of time in the subarea where sampling took place.

Analysis of residency of dolphins during 2010-11 showed a high proportion were present for most the year (Table 23). 56% of animals were seen in two seasons, and 32% were seen during 3 or more seasons. Of 125 dolphins first sighted in CB and SRS during 2006, 60% (n=75) were matched to the 2010-11 photo-id catalog.

Table 23. Seasonal Residency of Dolphins during 2010-11.

Seasons	# Unique Dolphins	Proportion
Winter + Spring	12	3%
Winter + Summer	16	4%
Winter + Fall	26	7%
Spring + Summer	39	11%
Spring + Fall	35	9%
Summer + Fall	32	9%
Winter + Spring + Summer	16	4%
Winter + Spring + Fall	33	9%
Winter + Summer + Fall	37	10%
Spring + Summer + Fall	43	12%
All Seasons	80	22%

Seasonal distribution of dolphins across the study area was calculated by pooling all sighting data during January 2010 - August 2011 (Figure 46). The highest number of uniquely identified animals was in the fall (470); followed by spring (406), summer (384) and winter (358). The greatest concentration of dolphins was near Destin, which includes transients and Gulf shoreline dolphins as well as those from the estuary that periodically ventured out the inlet. Surveys of LPB and WSR produced seasonally variable number of sightings and dolphins per trip, with large group encounters in the fall and lower frequency of encounters in winter and spring. Overall, lowest relative encounter rates per survey were at ECB in winter and spring. Occurrence of individual dolphins was significantly different in fall versus summer (Figure 47).

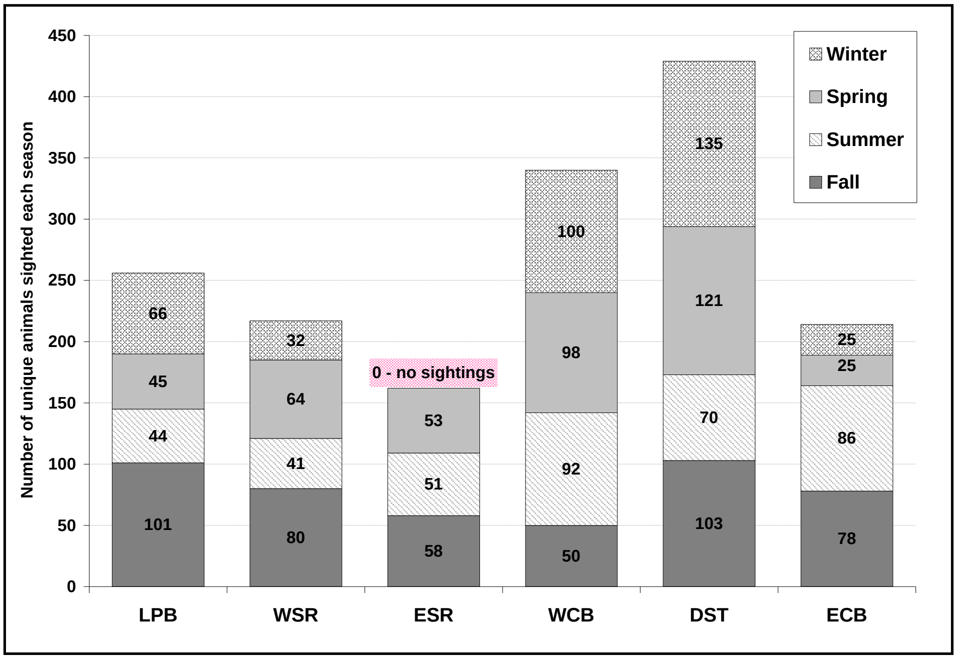


Figure 46. Seasonal occurrence of identified dolphins in each subarea.

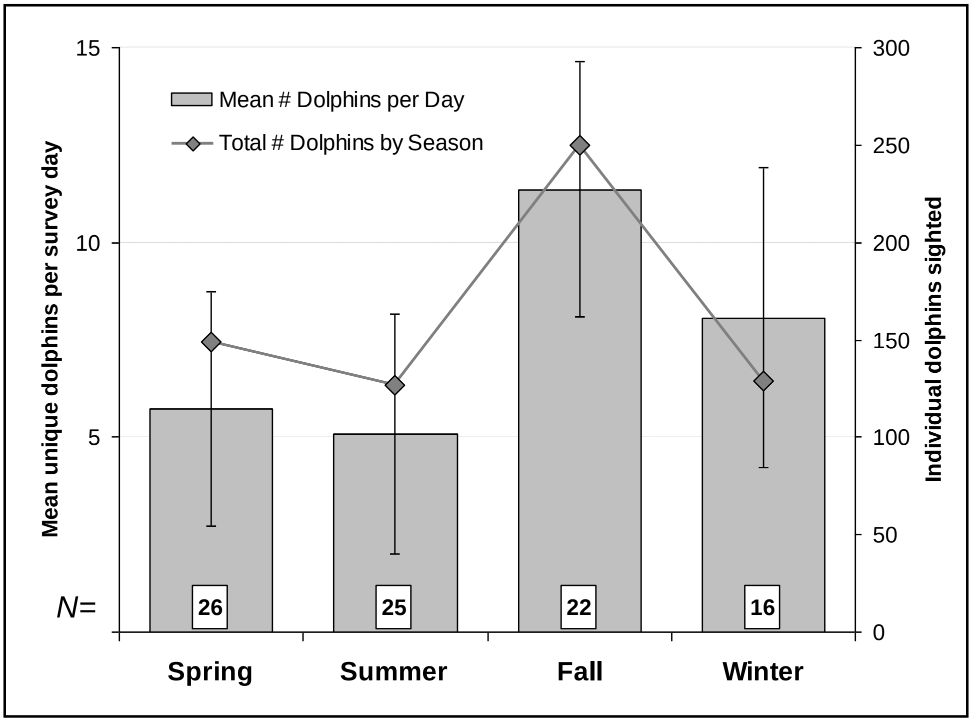


Figure 47. Uniquely identified dolphins each season.

Means are shown with Gabriel comparison intervals (Gabriel 1978); pairs of means whose intervals do not overlap (Fall and Summer) are significantly different (P<0.05). N indicates number of survey days.

Stable Isotopes

Epidermal samples from 66 remote-dart biopsies were submitted to MSU for carbon and nitrogen stable isotope analysis. Animals were grouped into five subarea affiliations determined by sighting history or location where the sample was collected (*e.g.*, subarea where biopsied). Since ESR was the least occupied subarea during winter (no sightings), it was removed from the analysis. Three of the biopsied dolphins had higher site affiliation with ESR but were also seen in other areas; thus two of them were grouped in WSR and the third in LPB.

The five dolphin groups varied in terms of their average location in isotopic niche space as a result of differences in $\delta^{15}N$ and/or $\delta^{13}C$. Isotopic values were compared by subarea and by season (Figure 48). Significant differences were found between subarea groups within seasons (November: $\delta^{15}N = F_{(28,32)}=18.93$, $p < 0.001$, $\delta^{13}C = F_{(28,32)}=5.95$, $p < 0.002$; and April: $\delta^{15}N = F_{(28,32)}=7.18$, $p < 0.001$, $\delta^{13}C = F_{(28,32)}=31.22$, $p < 0.001$. Tukey-Kramer post hoc tests showed for November $\delta^{15}N$ samples: WCB dolphins differed significantly from all other subareas; DST dolphins differed from WCB and WSR dolphins; and WSR differed from LPB dolphins. For November $\delta^{13}C$ samples: ECB dolphins were significantly different from DST, WCB, and WSR groups, but not from LPB dolphins. For April, $\delta^{15}N$ values differed significantly between both DST and LPB groups from WCB and WSR groups; there were no differences between DST, LPB, and ECB dolphins. For April $\delta^{13}C$ values, ECB group was significantly different from all other subareas, but there were no differences between DST, WCB, WSR, and LPB dolphins.

Comparing values for each subarea group between seasons (Figure 49) revealed significant differences existed for both $\delta^{15}N$ and $\delta^{13}C$ in ECB dolphins ($p < 0.05$ and $p < 0.001$ respectively), and for $\delta^{15}N$ in WCB dolphins ($p < 0.003$). The other subarea groups were not significantly different for both $\delta^{15}N$ and $\delta^{13}C$ when compared seasonally.

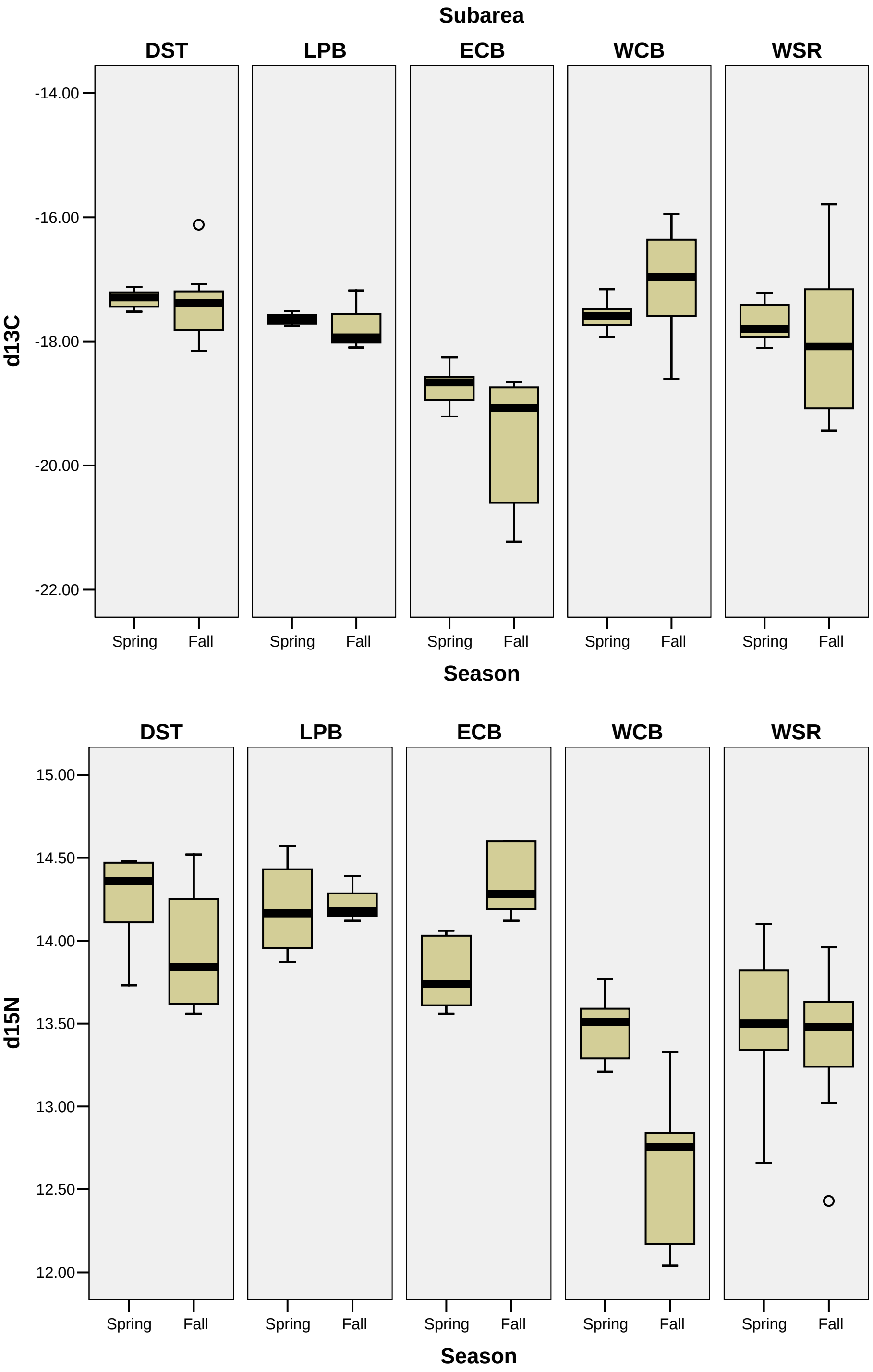


Figure 48. Boxplots of isotope values for sampled dolphins.

Upper panel = δ13C; Lower = δ15N. Subareas: DST=Destin Inlet; LPB=Lower Pensacola Bay; ECB=East Choctawhatchee Bay; WCB=West Choctawhatchee Bay; WSR=West Santa Rosa Sound.

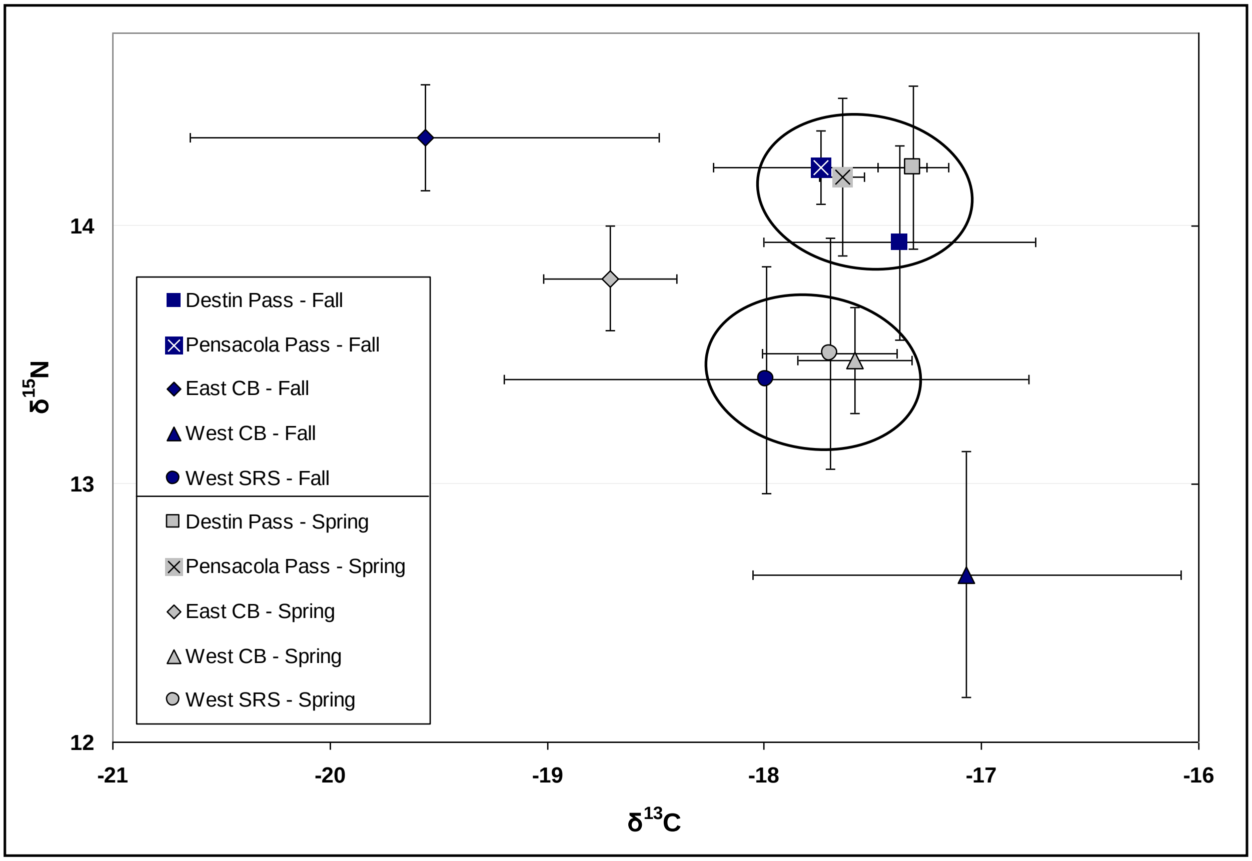


Figure 49. Seasonal mean isotopic signatures (‰) of biopsied dolphins grouped by subarea.

November 2010 samples = dark blue; April 2011 samples = light gray. All values are mean ± SD. Circled points are not significantly different

Discussion

Photo-id catalogs created during the present study contained over 650 individual dolphins that occupied the connected Choctawhatchee and Pensacola Bay estuaries during the four months immediately before and one year after DHOS. Of those, 88% were residents for at least part of that time, and all others were classified as transients since they were seen only once and did not match any fins in the long-term photo-id catalog spanning 2006-11. Relative abundance varied seasonally, being highest during fall in both bays. The period of lowest abundance differed between bays, with CB having fewer dolphins in summer, and LPB/SRS having fewer in winter.

I derived an abundance estimate of 233 (± 30) dolphins present in CB during summer 2011, which is comparable with the estimated superpopulation of 232 dolphins during summer 2007 (Conn *et al.* 2011). The earlier study created a catalog of 226 unique dolphins, 55% of which matched to my CB catalogs during summer 2011. Overall, I resighted 73% of the animals in the 2007 CB catalog during 2010-11. Of 311 CB dolphins that were identified during 2006-2009, 77% were sighted during summer 2011 in CB, and 18% in LPB/WSR, indicating some resident animals moved between bays.

The present study provides the first photo-id based dataset of bottlenose dolphin abundance and distribution in the Pensacola estuaries. Surveys of LPB and WSR had highly variable dolphin encounter rates, yet the relative abundance of dolphins per km searched was similar to ECB and WCB, especially during the fall. Despite the encounter variability in LPB, my estimates of total abundance derived from distinctness ratios per season (102 to 254) are considerably different from the 1993 'best' estimate of 33 dolphins cited in NOAA stock assessments (Blaylock and Hoggard 1994, Waring *et al.* 2012). LP abundance estimates for LPB/WSR resulted in high variance due to few numbers of surveys that could be conducted there, thus the results are speculative. However, they do suggest a potential population size equal to or greater than that in CB. I did not survey upper Pensacola Bay regions and it is probable that dolphins made excursions into those areas, putting them just outside my search routes. Likewise, movements of dolphins in and out of the Pensacola Pass to the Gulf shoreline were observed on occasion, suggesting that this broad and deep inlet is equally important habitat for dolphin foraging and social aggregation as was observed at Destin East Pass.

It is clear that a sizeable resident population of dolphins was present at both the Destin and Pensacola inlets during the spill event. Pensacola Pass was not well surveyed during the present study; therefore, many more dolphins may have occupied the inlet than is reported here. Dolphin groups were commonly followed between the bay and Gulf during surveys in DST, sometimes making back and forth excursions several times in a day. Numerous dolphins with site affiliations within CB were also seen at times along the Gulf shoreline. Some animals were seen in both CB and LPB in the same week, traveling distances in excess of 65 km. At least 24 dolphins seen in DST were also sighted in LPB, many of which bore multiple clusters of *Xenobalanus* on their fins indicating their affinity to Gulf shoreline habitat (Orams and Schuetze 1998, Toth Brown and Hohn 2007). This observation is consistent with sightings of DST dolphins transiting along the shoreline past fishing piers between Destin and Pensacola, as well as with findings of stranded dolphins in Pensacola Bay that were previously known in CB (see Chapter 4). Observed movements of inlet-associated dolphins along the Gulf shoreline suggests these animals were potentially exposed to higher levels of DHOS contaminants than full-time estuarine residents of CB and LPB/SRS. Likewise, inlet associated dolphins would potentially have been indirectly impacted by changes in prey base that may have resulted from low trophic level disruptions. In addition, estuarine resident dolphins in that region could also have experienced impacts from exposure to DHOS residuals since there was floating oil inside LPB during the peak of the spill event, and submerged tar mat deposits were found at numerous sites through the spring of 2011, especially at Pensacola Pass, Perdido Key, and in Big Lagoon (Griggs 2010, FDEP 2011, National Commission 2011, Samarco *et al*. 2013).

Many dolphins showed varying degrees of site fidelity to one or two subareas, while others ranged widely within the bays. Dolphins were sighted in all subareas of the connected estuaries during each season, with the exception of ESR during winter months. The 505 resident dolphins I identified were split between those that had site fidelity to only one estuary subarea

(42%) and those seen traveling between subareas (58%), over a third of which transited between CB and LPB/WSR. While ESR had the lowest number of dolphin sightings per survey in general, it was where the highest number of resightings of individuals occurred. Of 99 dolphins seen there, 92% were also sighted in other subareas suggesting that ESR is an important conduit between habitat patches. This lagoon passageway may once have had greater ecological significance since CB was not historically a high salinity estuary; the current maintained inlet at Destin East Pass was established in 1929 and prior to that was an intermittent channel (Ruth and Handley 2006), thus SRS was a primary route of water flow from the Choctawhatchee watershed to the Gulf via LPB and Pensacola Pass.

Except for LPB/WSR, other subareas all had high dolphin abundance in the summer months, and variable numbers of dolphins during spring calving season. Encounters with dolphins inside CB during fall and winter months increased closer to the inlet and decreased in SRS and ECB, yet roughly 10% of the inshore population affiliated strongly with ECB near the Choctawhatchee River delta and maintained seasonal residency. ECB dolphins had the highest SPi scores, and ranked second in number of individuals consistently seen in one subarea. These river-associated dolphins likely had the lowest exposure to contaminants from the DHOS event; however, their ranging patterns appeared to vary seasonally as they tended to be in the deeper middle portion of the bay in late fall/winter where there is more tidal exchange. Worthy *et al*. (2013) reported results of fish sampling indicating dolphin putative prey species also moved toward deeper water during this time of year. Numerous fish species (Mugilidae, Clupeidae) head toward Gulf waters in fall and winter months to spawn. For example, striped mullet migrate in large schools from the bay to the Gulf during the fall (Hoese and Moore 1998), and dolphins were frequently observed pursuing these fish during fall and winter along the Gulf shorelines.

ECB dolphins had stable isotope values that were consistently different from other dolphins, reflecting their site fidelity to the riverine influenced region. The Choctawhatchee River delta area has very distinct habitat characteristics compared to the tidally influenced regions, primarily the lack of seagrass communities and presence of stenohaline fish assemblages that migrate from the river tributaries during low salinity conditions (Lazzarino 2010, Ruth and Handley 2006, Yarbro and Carlson 2011, Hoyer *et al*. 2013). Dolphins feeding in open waters have lower δ^{13}C values than those feeding on seagrass-associated prey (Wilson *et al*. 2013), which agrees with the pattern observed in ECB dolphins. Likewise, stable isotope values for sampled putative prey fish in ECB reported in Worthy *et al*. (2013) were similar to published δ^{13}C ratios for Suwanee River fish (Gu *et al.* 2001) and confirm that ECB dolphins consume a significant fraction of prey maturing from a freshwater origin (*e.g*., Browning *et al.* 2014).

Based on stable isotope signatures for the sampled dolphins, there is a probable overlap of foraging patterns during spring for the WCB/WSR dolphins and the inlet associated dolphins at DST and LPB. However, WCB dolphins were significantly depleted in δ^{15}N during fall compared to all others, suggesting they were foraging on lower trophic level species. WCB and ESR are spatially continuous and there are numerous developed bayous in the region, which may play an important role as foraging habitat for these estuarine resident dolphins during fall and winter. ESR had very low dolphin relative abundance in winter, and dolphins seem to avoid this shallow subarea at that time of year perhaps due to low fish abundance in preference of better foraging habitat in the deeper zones of WCB, including the bayous.

Inlet-associated dolphins at DST and LPB had similar isotopic signatures during both seasons. Four of the sampled dolphins were sighted at both inlets during 2010-11, one of which was also sighted frequently in WCB. In general, the inlet dolphins did not go far into the bays and were found near the passes and the Gulf beachfront, which is consistent with their observed isotopic values that differed from bay residents.

Worthy *et al*. (2013) reported corrected standard ellipse area (SEA_c) results as a measure of the mean core population isotopic niche, which corrects for small sample size (Jackson *et al.* 2011). SEA_c can be used to represent bivariate data similar to how standard deviation represents univariate data, and also allows visualizing niche overlap between groups and seasons. SEA_c results reported in Worthy *et al*. (2013) showed clear separation of ECB dolphins from the other groups during November and April. Although there appears to be overlap between inlet animals with the WCB and WSR groups during spring, they are clearly different isotopically in the fall. Despite presumed seasonal similarities and overlap in feeding habits, dolphin groupings were distinguishable using stable isotopes and confirmed with photo-id analysis.

Isotopic signatures can be used to place dolphins in the region into at least three general communities: 1) riverine, 2) inshore estuarine, and 3) inlet associated. A possible fourth group of dolphins was identified along the nearshore Gulf between the Destin and Pensacola Inlets, consisting of at least 75 individuals that were never sighted inside the estuaries, 35% of which were sighted more than once. These dolphins were within 2 km of the beachfront and often were seen in association with individuals that were known to travel into the inlets, however, they were distinctly different spatially from a separate cataloged group of reef-associated dolphins found further offshore (see Chapter 5). No offshore dolphin was ever sighted in the nearshore zone.

Recent studies have used stable isotopes to describe the distributions of dolphins across habitat zones. Gibbs *et al.* (2011) found distinct differences in $\delta^{13}C$ and $\delta^{15}N$ between bottlenose dolphins living in coastal and offshore habitats in Australia, which was corroborated by stomach content analysis. Barros *et al.* (2010) used isotopic signatures to distinguish dolphins off west-central Florida into offshore, coastal, and bay resident populations. In the nGOM, dolphins inhabiting St. Josephs Bay, St. George Sound, and St. Andrews Bay were delineated into different communities based on stable isotope ratios and priority organic pollutants, which was consistent with sighting and satellite tracking data that indicated limited movements of dolphins between those regions (Balmer *et al.* 2008, Wilson *et al.* 2012; 2013). DST and LPB dolphin isotopic signatures in the present study compared to these other nGOM dolphins (Figure 50) suggests a separation of foraging specialization exists for different bays moving towards the west (Worthy *et al*. 2013).

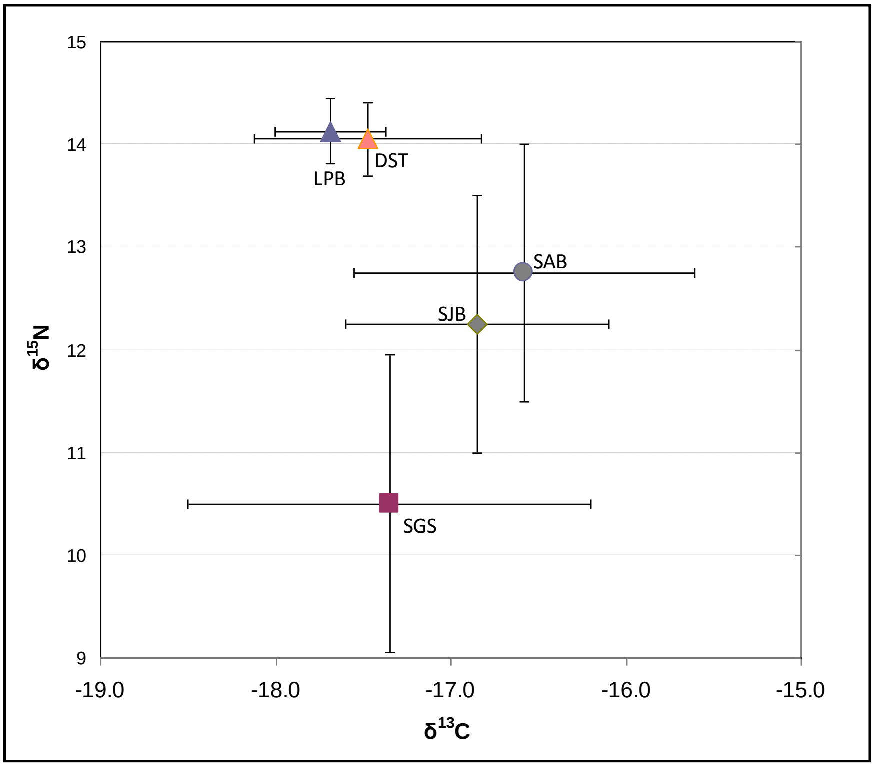


Figure 50. Comparison of stable isotope signatures of dolphins in five west Florida bays.

Destin (DST) and Pensacola Inlet (LPB) dolphins compared to St Andrew Bay (SAB), St Josephs Bay (SJB) and St Georges Sound (SGS) (data derived from Wilson et al. 2012).

Although the nGOM UME involved large numbers of *Tursiops* during the three years post-DHOS, the stranding rate in northwest Florida remained close to the historical average throughout the event. This suggests that the immediate health consequences to estuarine dolphin communities at the margin of the oil spill impact zone were far less dramatic than at the spill centrum and that long term effects, if any, would be a more likely outcome. Many species of the estuarine dolphins' prey spawn in the Gulf and therefore were potential reservoirs of incidental contaminants from DHOS derived from oceanic waters. The nutritional value or availability of these fish populations could have been impacted by changes in ecosystem dynamics in regions far distant from where the dolphins reside. Over time, changes in the quality and/or quantity of the prey base exploited by apex predators could lead to direct changes in their foraging habits and nutritional condition (Patterson *et al*. 2012) or to indirect changes in their health status. Even year-round resident dolphins of coastal bays and estuaries that rarely venture into Gulf waters could eventually be affected. Indeed, ECWR recovered several dolphins from northwest Florida beaches in 2010-12 that had signs of nutritional disorder and respiratory ailments, along with a higher than normal number of near-term perinates. Carmichael et al. (2012) suggested that the results of indirect ecosystem level effects may have been involved in the die-off of neonates in the northern Gulf in 2011.

Numerous studies published since the DHOS event discussed various documented impacts of the oil spill ranging from effects on coastal marshes, to observations of diseased fish and the infiltration of the planktonic food web (*e.g*., Whitehead *et al.* 2011, Hicken *et al.* 2011, Chanton *et al.* 2012, Mitra *et al.* 2012, Patterson *et al*. 2012, Samarco *et al*. 2013). Others concluded that immediate, catastrophic losses of 2010 cohorts were largely avoided and that no acute shifts in species composition occurred following the spill (*e.g*., Fodrie and Heck 2011).

Despite the range of findings, all studies made the same recommendation – potential long-term impacts facing these species as a result of chronic exposure and potential delayed indirect effects require continued monitoring with focus specifically directed to near-shore areas. The present study demonstrates both the overlap of the dolphin communities seasonally and spatially, and indicates that the Choctawhatchee and Pensacola Bays may contain sympatric rather than independent stocks of dolphins, as is currently defined in the NOAA stock assessment (Waring *et al.* 2012). Adverse impacts on the distinct dolphin communities in either of the estuaries could have a deleterious effect on the overall stock structure. This highlights the need to conduct follow-up monitoring in future years to compare long-term changes in community composition, habitat use, and foraging patterns to determine the potential effects resulting from the DHOS event in the Northwest Florida region. Continuing studies using stable isotope signature analysis over a wider range will aid in defining the population structure of nGOM dolphins, and ultimately will lead to better understanding of their foraging dynamics and more effective management as it relates to human interactions. Genetics data derived from the biopsy-sampled dolphins in the present study will further elucidate the fine-scale stock structure of the dolphins in the Choctawhatchee-Pensacola Bays, especially when combined with archived contaminant samples collected both via the biopsy sampling and from stranded animals that provide a baseline reference of potential oil-spill exposure of these dolphins.

CHAPTER SIX:
ASSESSING BOTTLENOSE DOLPHIN INTERACTIONS WITH THE NORTHWEST FLORIDA AND ALABAMA SPORT FISHERY

Introduction

Incidences of harmful interactions between recreational (sport) fisheries and bottlenose dolphins (*Tursiops truncatus*) have become common along the US Gulf coast. Fishery interactions (FI) with dolphins involving commercially valuable fish are known worldwide and have received much attention (*e.g.*, Nitta and Henderson 1993, Kobayashi and Kawamoto 1995, Nieri *et al*. 1999, Cox *et al*. 2003, Zollett and Read 2006, Gazo *et al*. 2008, Gönener and Özdemir 2012), but have not been well studied at the Gulf of Mexico. Illegal provisioning of wild dolphins at several Gulf coast ports was suggested as a reason that dolphins routinely approached boats for food (NMFS 1994). Since the 1980s there has been increasing public demand for close encounters with free ranging dolphins, leading some to offer feed to the animals (Mann *et al*. 2000, Samuels and Bedjar 2004). The National Marine Fisheries Service (NMFS) determined that provisioning wild dolphins causes health impacts and behavioral changes leading to improper nutrition, long-term fitness reduction, and decreased reproductive potential due to altered parental behavior and migration patterns (NMFS 1994). As dolphins habituate to provisioning as a means of opportunistic feeding, they could pass along these behaviors to offspring resulting in increased numbers of animals participating in the activity over time (Finn *et al*. 2008, Powell and Wells 2011). The Marine Mammal Protection Act (MMPA) defines such outcomes as a form of take and bans provisioning of marine mammals in the wild.

Incidental feeding of dolphins interacting with sport fishing is likely detrimental to their health for the same reasons as intentional provisioning. Aside from direct injury and mortality due to entanglement or gear ingestion, long-term fitness consequences can result as dolphins depredate fisheries for species that are not normally part of their diet, such as in Gulf fisheries targeting Snapper and Grouper (Nieland *et al*. 2007). Dolphins may potentially become exposed to offshore compounds not found in their typical prey, such as red tide toxins from *Karenia brevis* (Flewelling *et al.* 2005, Naar *et al.* 2007, Fire *et al.* 2008, Gannon *et al*. 2009) and petrochemical contaminants (Houde *et al*. 2006, Gulland and Hall 2007).

Conflict between anglers and dolphins along the Gulf coast has resulted in heightened media attention (Reeves 2009) and frequent testimony by charter boat captains at fisheries management meetings (GOMFMC 2007). Anglers state that regulations on fish size limits and season lengths resulting in high discard rates encourage dolphins to scavenge on released fish. In addition, charter operators report a high incidence of dolphins' depredating hooked fish and bait. Frustration with dolphins has led anglers to occasionally resort to retaliation, which resulted in criminal prosecutions of Gulf coast fishing boat captains in 2007 and 2009 for illegal activities under the MMPA that were intended to cause harm to dolphins (SERO 2009).

To gather background on this issue, I interviewed Gulf coast charter operators (Capts. R. Boggs, E. Dykes, R. Hardy, M. Eller, T. Frady, B. Miller, S. Robson, B. Walters, J. Westgate, J. Westbrook, pers. comm. 2004-08). Their primary concerns involved dolphin FI while bottom fishing for offshore reef fish. Dolphins were said to reduce fishing success by depredation of catch and depressing fish availability by "killing the bite." Captains routinely stopped fishing and moved off fishing spots once dolphins appeared, but reported dolphins would often follow behind their boats for long distances. Some captains reported that rather than consuming fish, dolphins would toy with them at the surface. Many felt that young dolphins were being recruited into the activity by adults (GOMFMC 2007). Frequent dolphin interactions were also reported at fishing piers along the Gulf Coast. Dolphins would occasionally get hooked while depredating catch from fishing lines at the Okaloosa Island Pier in Fort Walton Beach, FL (E. Gentry and D. Debar, pers. comm. 2012).

Charter captains often voice concern that dolphin interactions pose a potential economic harm to their livelihood. Dolphins scavenging discarded reef fish may also represent a significant share of fish mortality (GOMFMC 2007, SEDAR 2012). The impact of dolphin FI on reef fish stocks, as well as the sport fishing industry, was historically unknown (Burns and Restrepo 2002, Burns *et al.* 2004, Rummer and Bennett 2005, Nieland *et al*. 2007, Loftus and Radonski 2012). Very few empirical data existed for the Gulf coast prior to 2006 until the Alabama Department of Conservation and Natural Resources conducted two types of surveys with for-hire recreational charter and head boats designed to collect data on by-catch and regulatory discards of species of concern, which provided information on fate of released fish and take by dolphins (K. Anson, pers. comm. 2008). Data collected during fish stock abundance sampling trips in 2006-07 at Dauphin Island Sea Lab showed dolphins were observed near the boat during 10% of time spent on fishing reef spots (J. Lee, pers. comm. 2009).

Mitigation methods are warranted to reduce the impacts of FI on dolphins and fisheries, yet no single method has been identified as an effective dolphin deterrent. Time lost handling and discarding catch reduces angler’s fishing progress, thus anglers usually expedite release of undesired fish, which often are scavenged by awaiting dolphins. Few charter captains reported consistent reliance on mitigation techniques. Irregular use of deterrents is insufficient to extinguish behaviors that are routinely rewarded with food (Ramirez 1999), thus a result of periodic success at scavenging is that dolphins will habitually approach boats in search of further opportunities for reinforcement.

Since the late 1990’s, marine mammal stranding networks have routinely examined dolphin carcasses to determine if human interactions could be linked to cause of death (Barco *et al*. 2010). NOAA’s Marine Mammal Health and Stranding Response Program database records show that cases of FI were increasing along the northern Gulf coast since 1990 (S. Shippee, unpublished data). Aside from provisioning and discards, other factors may also exacerbate FI occurrence. Severe red tide blooms in 2004, 2005 and 2007 along the Florida Panhandle resulted in fish kills composed largely of typical dolphin prey species (Landsberg *et al*. 2009, Twiner *et al*. 2012); these were similar to bloom events in Sarasota Bay, FL that have been suggested as a reason that dolphins later fed on atypical prey and engaged in FI (Berens McCabe *et al*. 2010).

The purpose of this study was to evaluate the impacts of dolphin FI with sport fishing along the northern Gulf coast, and to explore practical ways to mitigate the problems. Many desirable sport fish species are found in great abundance on offshore reefs in this region owing to the deep water topography and east-west gyres that periodically break off the Gulf loop current (Coleman *et al.* 2000, Patterson *et al*. 2001). The deep-sea reef areas off Alabama and the Florida Panhandle are historically popular fishing destinations owing to close proximity to the De Soto Canyon (Shipp and Hopkins 1978). Sport fishing is a significant economic resource for the northern Gulf coast, representing over $7.9 billion annually in fishing charters and sale of supplies (Stokes and Lowe 2013).

This study involved *in-situ* observations with cooperative captains and anglers aboard deep-sea fishing vessels and at coastal piers near Destin, FL, and Orange Beach, AL (Figure 51). My goal was to characterize the nature of dolphin FI, to explore if dolphins showed fidelity to specific locations or vessels, and to objectively assess the frequency of these interactions. An intended outcome was to identify potential mitigation techniques and provide suggestions for best practices.

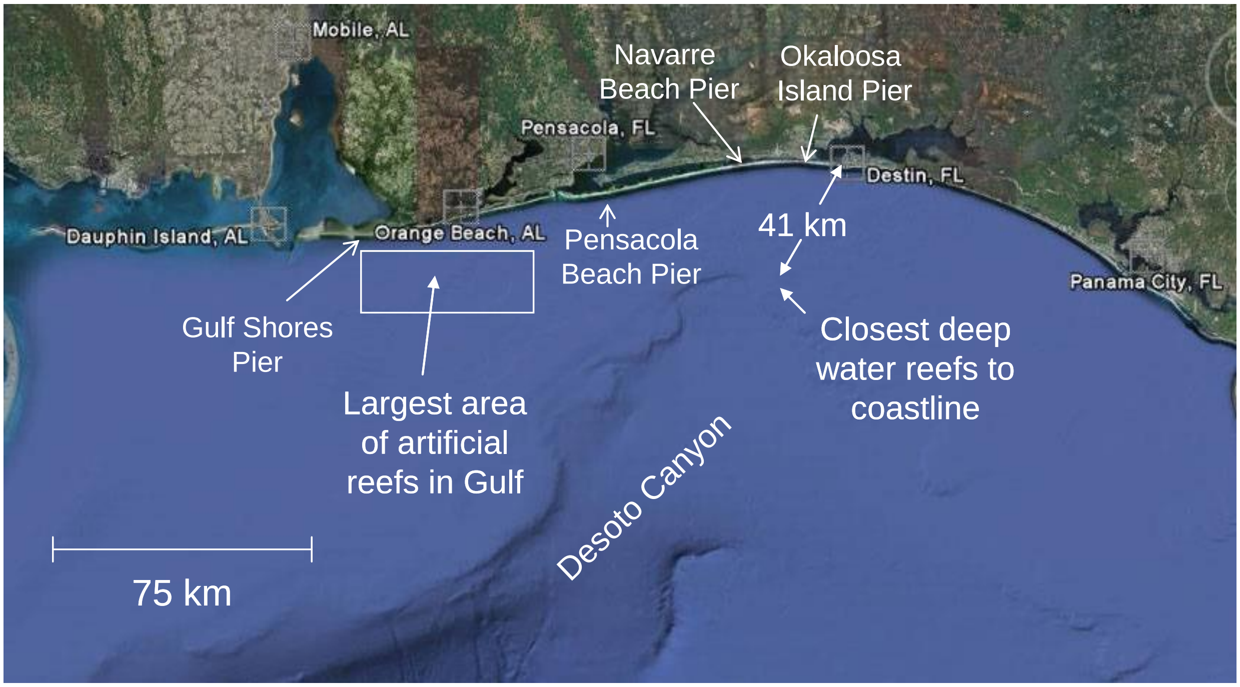


Figure 51. Topography of northern Gulf continental shelf and reef locations at study area.

Methods

Study Sites

Sport fishing was observed at Destin, Florida, and Orange Beach, Alabama along the north central Gulf coast. Both ports are popular tourist destinations and have year-round charter fishing opportunities. Deep-sea trips depart for offshore reefs located 10 - 30 km from port, typically requiring 1-2 h boat transits to reach the fishing destination. Destin hosts a substantial recreational for-hire fleet, with approximately 100 vessels offering daily offshore fishing trips as well as coastal trolling and inshore fishing on Choctawhatchee Bay. Orange Beach likewise has a sizeable recreational charter fleet of approximately 80 for-hire vessels offering offshore trips and inshore fishing around Perdido Bay. Both areas are also readily accessed by private recreational boats.

In addition, I observed four coastal fishing piers that provide anglers access to engage in shoreline and surf fishing, as well as fishing for near-shore migratory species. Frequent visits were made throughout the study to the piers at Okaloosa Island in Fort Walton Beach, FL, and at Pensacola Beach, FL. Additional infrequent trips were made to gauge dolphin presence at piers in Navarre Beach, FL, and Gulf Shores, AL; both piers were under re-construction in the first year of the study and then reopened to the public in the second year.

Fishing Vessel Observations

Three types of recreational fishing vessels were observed in this study: privately owned boats; charter vessels with 6 - 12 passengers; and multi-passenger boats carrying more than 12 passengers that include both headboats and group fishing charters, hereafter referred to as "party boats." Private boat trips were made aboard smaller vessels on an opportunistic basis. Charter and party boats trips were randomly selected by availability. Weekly trips were taken out of each port but varying seasonal conditions often limited opportunities. Greatest effort was expended during summer-fall periods of the reef fishery. Fishing trips lasting 4-8 h were preferred as they remained within 40 km of port in the areas of interest. No requests were made to alter the length or destination of any for-hire fishing trips from their normally scheduled plan. Captains and deckhands were consulted in advance about the nature of this study to assure consent, and to gather information on the planning of their fishing trips, bottom conditions, catch, seasonal priorities, and dolphin encounter experience. Good rapport with captains yielded *in situ* data about location, bottom type, depth, sonar displays of fish abundance at fishing spots, environmental conditions, and fishing strategy. As this study progressed, specific boats were repeatedly chosen that offered ideal viewing situations and that had crews familiar with assisting by relaying dolphin interaction counts.

Data were collected each trip on departure time, number of passengers and crew, weather conditions, general heading out of port, speed of transit, type of fishing gear in use (bottom rigs vs. drifting baits and lures), type of bait in use, general fishing depth, distance from port, time of return, and overall quality of catch. When allowed, a handheld GPS receiver (GPSMap 76, Garmin Ltd, Olathe KS) recorded the general position and speed of the boat during trips; otherwise boat location and speed was estimated to 0.01 decimal degrees from the wheelhouse GPS. Location and track data were managed with Mapsource v6.16 software (Garmin Ltd, Olathe, KS).

Observations for dolphins were made continuously throughout each fishing trip, including while transiting. Time and location were recorded whenever animals were spotted. Once at a fishing reef site, I watched for dolphins approaching the boat or interacting with other boats in the vicinity. Data collected at each fishing spot included start time, depth, bottom type (*e.g.*, natural reef, artificial reef, wreck, or concrete pile), sea state, tide and currents, weather and wind, number of boats nearby, and end time. Fishing activity was quantified by types of fish being caught, general quality of fish bite and catch (excellent, good, fair, or poor), approximate numbers of fish being discarded, and observations of predator interaction (*e.g.*, sharks, birds, and barracuda). Dolphins were photographed whenever present to acquire identifying images and characterize behavior.

Drifting lines and casting of bait were unlikely to extend farther than 35m from a fishing vessel, thereby arbitrarily defining a maximum approach distance for potential interactions. Dolphin encounters were characterized by:

- Dolphins present in the area but not approaching
- Dolphins approached within 35 m
- Dolphins closely approached the boat and dove under the vessel
- Dolphins observed scavenging on discarded fish
- Hooked fish were depredated as indicated by sudden hard pulls on fishing lines and inability by the angler to reel back against the strain
- Dolphin surfaced in visual or telephoto range with fish in mouth
- Fish were landed that had been damaged by dolphins (required deckhand expertise)

FI was characterized in 3 categories:

1) Dolphins came within 35 m
2) Dolphins scavenged discards
3) Catch was depredated

I watched for presumed mother dolphins with young calves in the vicinity, and any indication of dolphins becoming hooked or tangled in fishing lines. Depredation events were closely observed to see if gear was recovered or lost. Any observed mitigation response by anglers or crew was recorded (*e.g.,* held fish on board; quit fishing; moved boat; deployed deterrent; or none). On departure from each fishing spot, I watched for dolphins riding in the wake or following behind the vessel in the distance. Notes were kept on bottom conditions and fish abundance as detected on the boat's sonar unit.

Gulf Pier Fishing

Typically, 2-3 fishing pier visits were made each month throughout the study to characterize seasonal changes in fishing activity and dolphin interactions. Observers recorded daily weather conditions, sea state, and water turbidity. I noted number of anglers present, nature of the general fishing activity, target fish being sought, presence of bait schools, birds, or other predators (sharks and barracuda), and presence/absence of dolphins. When dolphins were present, I focused on their activity and recorded:

- the number of dolphins present
- presumed mothers with calves
- whether approaching pier, within 35 m, or actively engaged in fishing interactions
- depredation of bait or caught fish
- observations of hooking/entanglement

Any observed efforts by anglers to discourage or avoid dolphin interactions were noted. I would usually interview anglers about their experiences and attitudes toward dolphins at the pier, as well as their typical fishing interests and tactics. If dolphins were sighted, photos were taken for identification and to record any fishing interactions. Visits to fishing piers involved observation periods from 30 minutes when no anglers were present, to over 6 hours when high levels of dolphin interactions were noted. On occasion, several brief visits occurred in a single day. Observer notes were manually recorded and transferred into a MS Excel spreadsheet summarizing: fishing activity; dolphin presence; calf presence; bait school presence; observation of depredation or other interactions; and observation of hooking or entanglement injury.

Photo-identification and Cataloging Individuals

Dolphins were photographed during reef fishing trips to identify distinctively marked individuals. Photos were taken using digital Nikon SLR cameras with 70-300 mm VR-II zoom lens (Nikon Inc., Melville, NY) set to aperture priority ISO auto-sensitivity selected for fastest shutter speed to reduce motion blur. Date and time was synched with GPS before each trip to corroborate image EXIF data.

At-sea observations were made from an accessible point on each fishing vessel with good views of the surroundings, typically on an observation deck, flying bridge, or tower. Each boat had different circumstances, thus the ability to acquire photos varied between fishing trips. Dolphins approaching from the distance were photographed once close enough to be recognizable to capture data on group size and heading. Whenever dolphins came within range, photos were taken of their dorsal fins or other identifying features, as well as images that could describe behavior. When FI was seen, I concentrated on capturing images of the individual dolphins involved. In addition to still images, digital video was occasionally used to record behavior and angler activity.

A photo-identification (photo-id) catalog of observed individuals was developed that incorporated observer notes with location coordinates in an MS Access database for analyses. Dolphins were categorized into levels of distinctiveness of markings: high, medium, and non-distinct (Rosel *et al*. 2011). Dependent calves were identified as visually distinct in size from adults (less than 2/3 length by comparison) especially when seen drafting next to the presumed mother. Yearlings and juveniles were subjectively defined if they were easily recognized as smaller than an adult even if swimming independently. To confirm matches, images were overlaid in transparent layers using Adobe Photoshop 7.0 (Adobe Systems Incorporated, San Jose, CA). ACDSee software (ACD Systems, Saanichton, BC, Canada) was used to organize a searchable database of edited images. Complementary field metadata were combined with the photo-id catalog information in MS Excel and Access database applications that could be queried by date, sighting, location, and season.

Coastal/Inshore Photo-Id Surveys

Photo-id catalogs containing over 700 individual dolphins were available for comparison to those seen on fishing trips. Surveys for dolphins had been ongoing monthly from small boats (*e.g.*, Wells 2009a) along the Gulf shoreline and within Choctawhatchee, Pensacola, and Perdido Bays to identify individual dolphins during 2006-11. Surveys covered estuarine waters and along the beachfront extending to 5.0 km outside the passes. Visits to coastal fishing piers near Destin, Navarre Beach, and Pensacola Beach, FL, and at Gulf Shores, AL during 2008-10 were conducted to observe and photograph dolphins at those sites. Standardized dolphin photo-id protocols were followed and sighting, group, behavioral, and environmental data were routinely collected (Rosel *et al*. 2011). Boat surveys were conducted in accordance with NOAA Scientific Research Permit No. 522-1785 (issued to R. Wells), and under UCF-IACUC protocol 08-21W.

Evaluating Mitigation Methods

Modified fishing tactics - I investigated the following strategies that might be helpful to avoid dolphin interactions:

1) changing fishing methods when dolphins were encountered (*e.g.*, different bait, change depth fished, stop fishing for some period)
2) attempting to ‘sneak’ fish back into the water while dolphins were distracted
3) holding by-catch on board in live wells and discarding once underway or after dolphins left the area
4) return of live fish to depth using a descent device

A portable underwater video unit (SplashCam Deep Pro, Ocean Systems, Everett, WA) was used to observe dolphins beneath fishing vessels. The camera was lowered over the side of the boat giving a wide angle view looking either downward toward a fishing rig, or upwards to the hull. The live video allowed viewing escaping fish as they swam toward the bottom while being pursued by dolphins and to view the bottom conditions and fish abundance on reefs.

Analysis

Observer notes and data records were managed in a MS Access database and summarized by fishing trips, details of each individual fishing spot, and details on dolphins that were later photo-id cataloged. Fishes were identified using Hoese and Moore (1998). Dolphin photo-ids from each trip were used to estimate numbers of dolphins that approached vessels and engaged in depredation activity, scored by interaction type (came within 35 m, scavenging, and depredating). Individuals resighted at multiple reef spots or on more than one trip were grouped by FI score to derive a count of animals associated with each interaction type. Pooled data from all trips were used to calculate adult to juvenile ratio. Comparisons of dolphin photo-ids taken on fishing boats and the respective inshore catalogs were used to determine site fidelity and movement of individuals between areas.

Results

Deep-Sea Fishing Observations

Observations were made aboard 76 trips totaling 447.6 h on for-hire and private recreational boats during March 2008 - September 2010. Twenty one trips were made from Orange Beach, AL, and 55 were made from Destin, FL (Figure 52). Fishing trips were made in all seasons, although proportionally fewer took place at Orange Beach in the fall-winter due to lack of opportunities (low numbers of patrons). Observations were made from three vessel types; however, the majority of trips were on multi-passenger party boats as these provided the best observation opportunities. Private trips were made only from Destin aboard 6-10 m vessels typical of privately-owned boats in the region. An unplanned bias favoring offshore observations occurred on for-hire trips since captains of charter and party boats usually preferred to go into deeper federal waters (Table 24). 77.6% of the observed deep-sea fishing trips took place in waters beyond 16 km from the home port while 22.4% were within 16 km, comprised mostly of private trips entirely within Florida state waters.

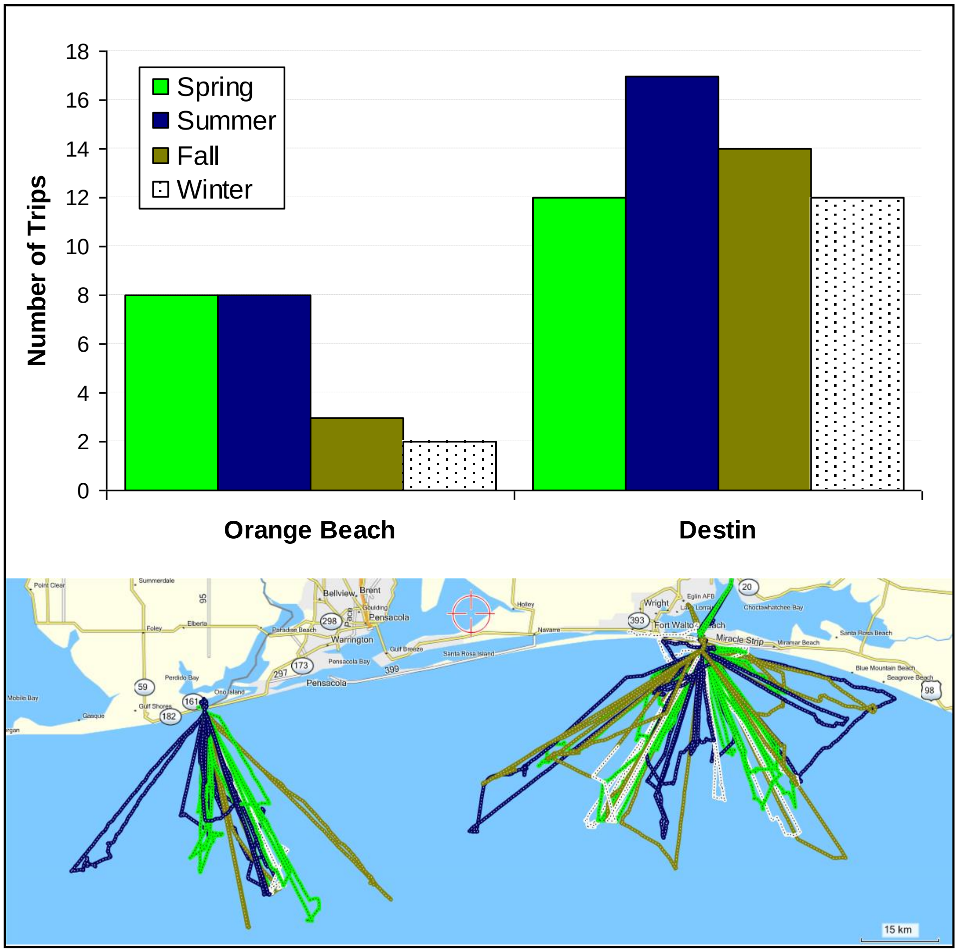


Figure 52. Distribution of fishing trips observed during 2008 and 2010.

Map displays boat tracks. Different seasons each year were pooled together and defined as: Spring = March–May (black); Summer = June–August (dark gray); Fall = September–November (light gray); Winter = December–February (white).

Table 24. Fishing Trips by Port and Distance Offshore.

km from shore	Destin	Orange Beach
16	16	1
32	14	8
48	22	11
64	3	1
Total trips	55	21

In Destin, vessels typically traveled to areas with either natural rocky bottom, the 20 fathom line (De Soto Canyon head), or to artificial reefs composed of wreckage or concrete piles. The coastal region off Alabama is mostly sand bottom of 18-30 m deep with a substantial complex of artificial reef structures offering a multitude of fishing destinations ranging 12-25 km from port. Mean trip lengths were 5.9 ± 1.3 h, spending a mean of 2.1 ± 0.9 h fishing (36% of total time per voyage). Reef trips usually involved 60-90 min travel time to reach the first fishing spot, and visited an average of 5 spots for a mean of 26 (± 28) min each. Average transit distance between spots was 2.4 ± 2.2 km. Many trips included opportunities for anglers to troll for pelagic fish during long transits; however, dolphins were never observed interfering with trolling on any trips in this study.

Dolphins were sighted on 61% of trips (n=46) and FI was observed during 38% of trips (n=29). Dolphin encounters occurred at both near-shore and deep-sea locations but FI was observed more frequently at reefs located >40 km from. Individual fishing spots were considered as discrete opportunities for dolphins to interact with fishing; in total, observations were made at 369 fishing spots (Table 25) during 161.3 h fishing time. Dolphins were seen at or near 32% of spots, and were seen approaching within 35 m of the boat at 18% of spots; scavenging of discarded fish was observed or suspected at 18% of spots (n=66); and depredation of fish from gear was observed or suspected at 7% of spots (n=27). The majority of FI events were observed on party boat trips beyond 16 km from port (Figure 53); relative FI frequency on party boats and charter boats was similar (23% vs 22%) but different from private trips (3%).

Table 25. Fishing Trip Observations from Destin and Orange Beach by Vessel Type.

	Trip Details					Observations of Fishery Interactions			
Vessel Type	# trips	# Fish spots	Avg dist out (km)	≤16 km	>16 km	FI on trips	Dolphin w/i 35m (spots)	Scav. (spots)	Dep. (spots)
Party	43	219	34.9	2	41	21	50	49	23
Charter	14	63	29.2	1	13	5	14	14	3
Private	19	87	13.7	14	5	3	3	2	1
Total	76	369	25.9	17	59	29	67	65	27

FI on trips = observation of any fishery interaction while at fishing spot; Scav. = number of spots where scavenging was observed; Dep. = where depredation was observed.

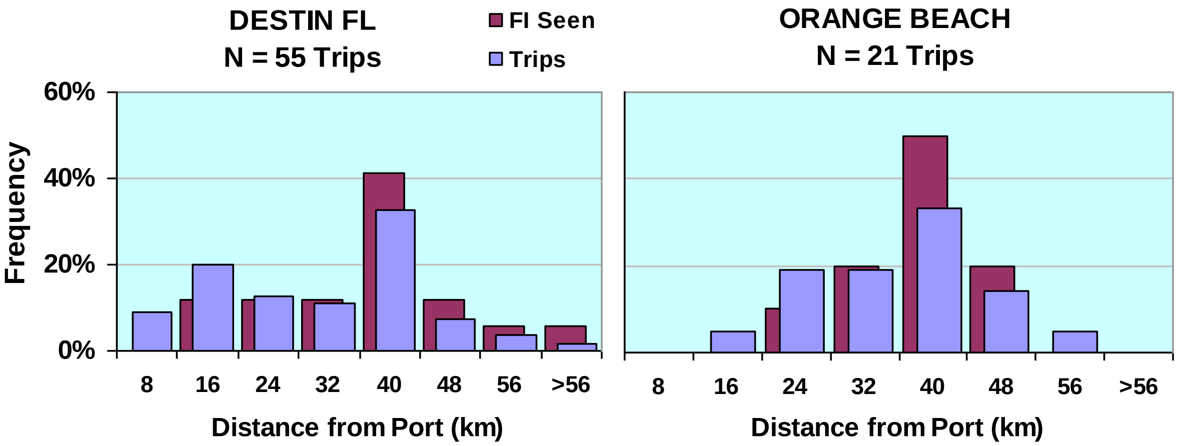


Figure 53. Frequency of fishing trips and fishery interactions by distance offshore.

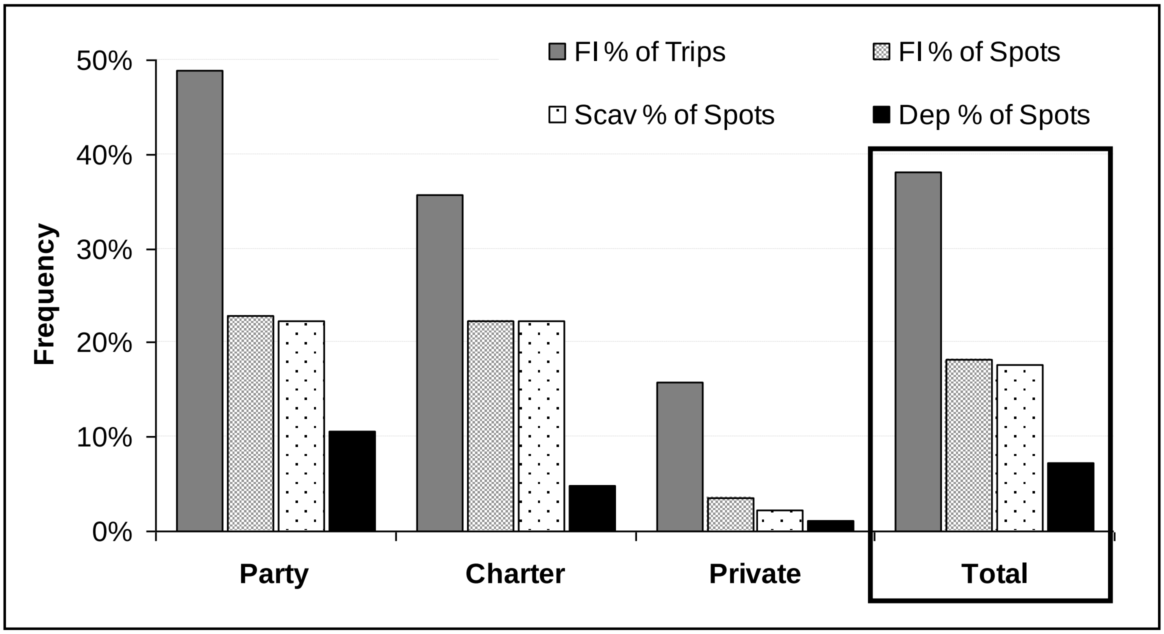


Figure 54. Frequency of observed FI by vessel type.

FI = Fishing interactions with dolphins; Spots = the 369 individual fishing reef spots observed in the study; FI % of Trips = frequency of dolphins interacting with fishing at any point during a fishing trip; FI % of Spots = frequency of dolphins interacting by spots; Scav % of Spots = frequency of observed scavenging by fishing spots; Dep % of Spots = frequency of observed depredation by spot.

Dolphin calves were observed on 30% of deep-sea trips (n=23). FI was noted on 14 days involving groups containing mothers with calves. Presumed mothers with young-of-the-year calves were observed generally staying at greater distances from the boat than other dolphins. No calves were observed directly interacting with fishing gear, however, mother-calf pairs were seen on 3 different occasions loitering beneath a vessel apparently waiting for fish to be discarded. On one trip, a distinctive adult repeatedly approached the boat with a yearling in calf position that had fishing line entangled around its mid-torso (Figure 55). Sightings of this dolphin were reported to the marine mammal stranding network the week prior. Both animals were photographed 12 months later at the same offshore reef location and the calf was free of the entanglement, but with a circular scar around its torso. This was the only mother-calf pair seen on more than 1 day. Of 14 calves seen at fishing spots where FI took place, 7 followed the boat to another spot, 3 of which persisted to a third spot. Scavenging of discarded fish was observed at all of those spots. Nine of the 14 calves were at spots where depredation also took place; the entangled calf with presumed mother persisted through more than 2 spots.

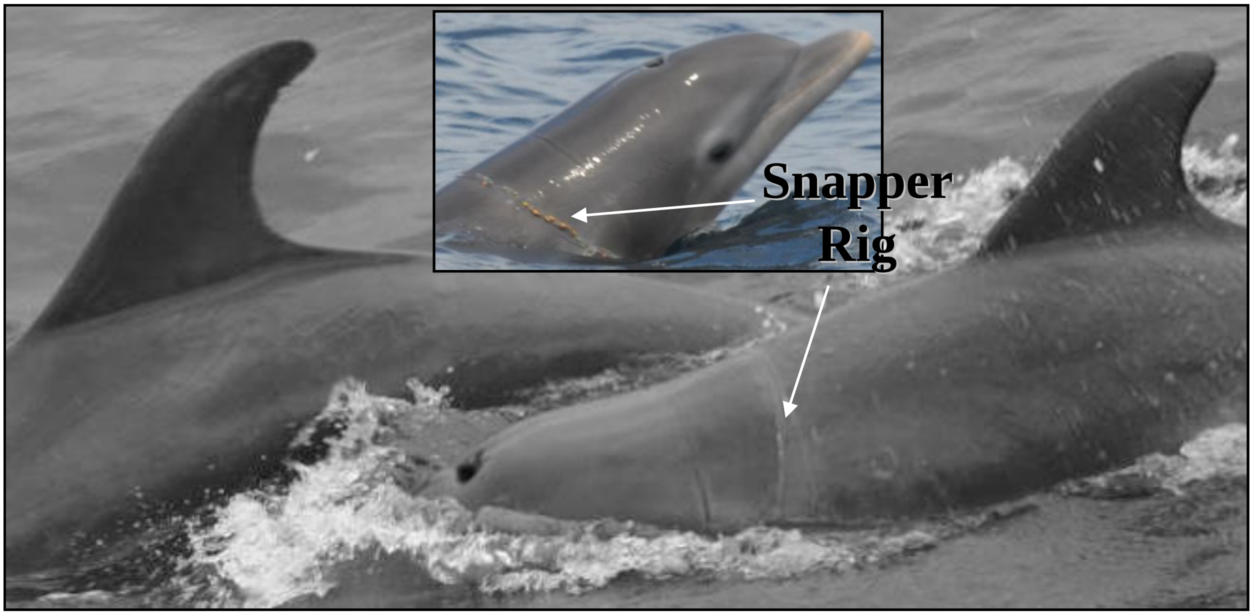


Figure 55. Entangled yearling with presumed mother near Destin, FL.

A target sport fish for deep-sea anglers was red snapper (*Lutjanus campechanus)*, which were only open for harvest during the summer months, but were routinely caught and released year-round. Reef fishing during the fall through spring targeted other species such as vermillion snapper (*Rhomboplites aurorubens*), lane snapper (*Lutjanus synagris*), porgies (*Pagrus pagrus* and *Calamus bajonado*), gag grouper (*Mycteroperca microlepis*), red grouper (*Epinephelus morio*), almaco and amberjack (*Seriola sp*.), mahi mahi (*Coryphaena hippurus*), king mackerel

(*Scomberomorus cavalla*), bonito (*Euthynnus alletteratus*), and gray triggerfish (*Balistes capriscus*). Mackerel, bonito, and mahi mahi were most frequently caught in mid-water column and when trolling baits. Catches of non-targeted reef fish were common, such as tomtate (*Haemulon aurolineatum*), remora (*Remora sp*.) and pinfish (*Lagodon rhomboides*). Dolphins were seen scavenging and depredating red snapper and vermillion snapper most often. On a few occasions, dolphins scavenged or depredated catch of amberjack and grouper, but they regularly avoided discarded triggerfish, remora, and tomtate.

The majority of fishing on reef spots involved heavy tackle (60 - 80 lb test line with 0.25-0.5 kg lead sinkers) fished near the bottom; there were no occasions when anglers were advised to change fishing depth due to dolphin presence. Baits in use primarily were cut tinker mackerel (*Scomber scombrus*), squid (*Loligo sp*.), and whole or partial round scad (*Decapterus punctatus*). Occasionally anglers used live round scad, pinfish, and blue runner (*Caranx crysos*). There were no direct observations of dolphins taking bait off hooks during this study, although many anglers and deckhands anecdotally reported experiencing this, especially on live baits. If dolphins were present, depredation usually occurred only after anglers had lowered bait to the reef; dolphins typically did not take hooked fish until they were reeled up off the bottom 3-10 m. Some charters preferred light tackle using a single hook “knocker” rig with a sliding sinker baited with whole minnows or big cuts of bait to attract large predatory fish swimming higher in the water column. Anglers lowered these rigs slowly until feeling the first “knock” and then quickly reeled in the line. Few trips (n=4) occurred when dolphins were encountered on charters that used this strategy, and depredation was not seen on those. It was not possible to conclusively assess if changing fishing depth was helpful in deterring depredation.

A subjective score of catch quality was made at every fishing spot. ‘Good’ catch was defined by either many anglers landing a satisfying number of desirable fish, or landing several larger target fish (*e.g.*, >50 cm red snapper). ‘Fair’ catch meant that only some anglers landed desirable fish, and ‘poor’ catch meant that hardly any desirable fish were caught. Dolphin presence around boats and incidences of FI occurred most often at spots with good catch quality, and rarely with poor catch quality. Depredation occurrence by bottom type could not be determined, however, FI was seen most often at concrete pile reefs and “wrecks” (these terms were used interchangeably by captains) (Figure 56).

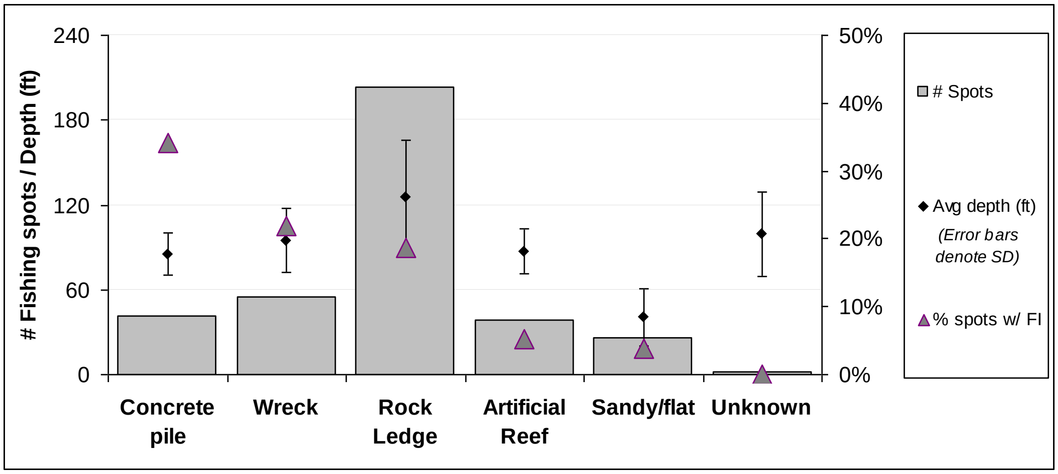


Figure 56. Observations of dolphin FI described by bottom type at the 369 fishing spots.

Dolphin persistence and site fidelity

Gulf reef sites in the study areas were divided into five zones (Figure 57). Destin boat captains typically referred to reefs by destinations toward the east, south, and west, while Orange Beach trips generally were conducted to the south-southeast. Therefore, zones were arbitrarily assigned by the fishing trips as: 1) shoreline to 6 km offshore, 2) east from Destin, 3) south of Destin, 4) west from Destin, and 5) offshore Alabama. Overall during this study, 132 unique dolphins were sighted with the highest number seen in zones 4 and 5 (Table 26). Photo-identification of individual dolphins resulted in a catalog of 124 recognizable animals. Twenty one individuals sighted in zone 1 were known from the Destin coastal-estuarine community; none of these were seen further than 2 km from shore. The remaining 103 identified dolphins were seen on trips that were beyond 6 km from shore (Figure 58). In the offshore zones, 62 photo-identified dolphins were only seen 1 time, while 70 others were seen multiple times. The greatest numbers of dolphins seen repeatedly were in zones 3 and 4. Nine dolphins were seen in both zones 3 and 4, and one in zone 3 and 5. Twenty three dolphins were seen on more than one day; 18 of which were seen repeatedly at offshore spots where depredation of caught fish was observed. One of those was sighted on 5 separate days during the study at a total of 15 separate fishing spots spanning distances up to 36 km apart. Another dolphin was seen at offshore reefs spaced over 60 km apart; first on a trip from Destin (zone 3), and 167 days later on a trip from Orange Beach (zone 5). Alabama reefs (zone 5) had the highest number of dolphin sightings on average per number of spots visited, but individuals were sighted repeatedly more often in zone 3, which included all ten dolphins that were sighted in multiple zones.

Figure 57. Fishing zones showing distribution of fishing spots.

Total reef spots = 369; Light gray rings = no dolphins seen (249); Inside ring dots = dolphins present (120); Outer black rings = where FI seen (67).

Table 26. Dolphin Sightings by Zone, with Site Fidelity Score.

Zone	Spots	D total	D = 1x	D > 1x	Fidelity	D/Spot
1 - shore-6 km	61	27	6	21	78%	0.44
2 - E Destin	68	19	15	4	21%	0.28
3 - S Destin	72	16	3	13	81%	0.22
4 - W Destin	87	31	9	22	71%	0.36
5 - Alabama	81	39	29	10	26%	0.48
Overall	369	132	62	70	53%	0.36

D = dolphin; Spots = fishing reef spots.

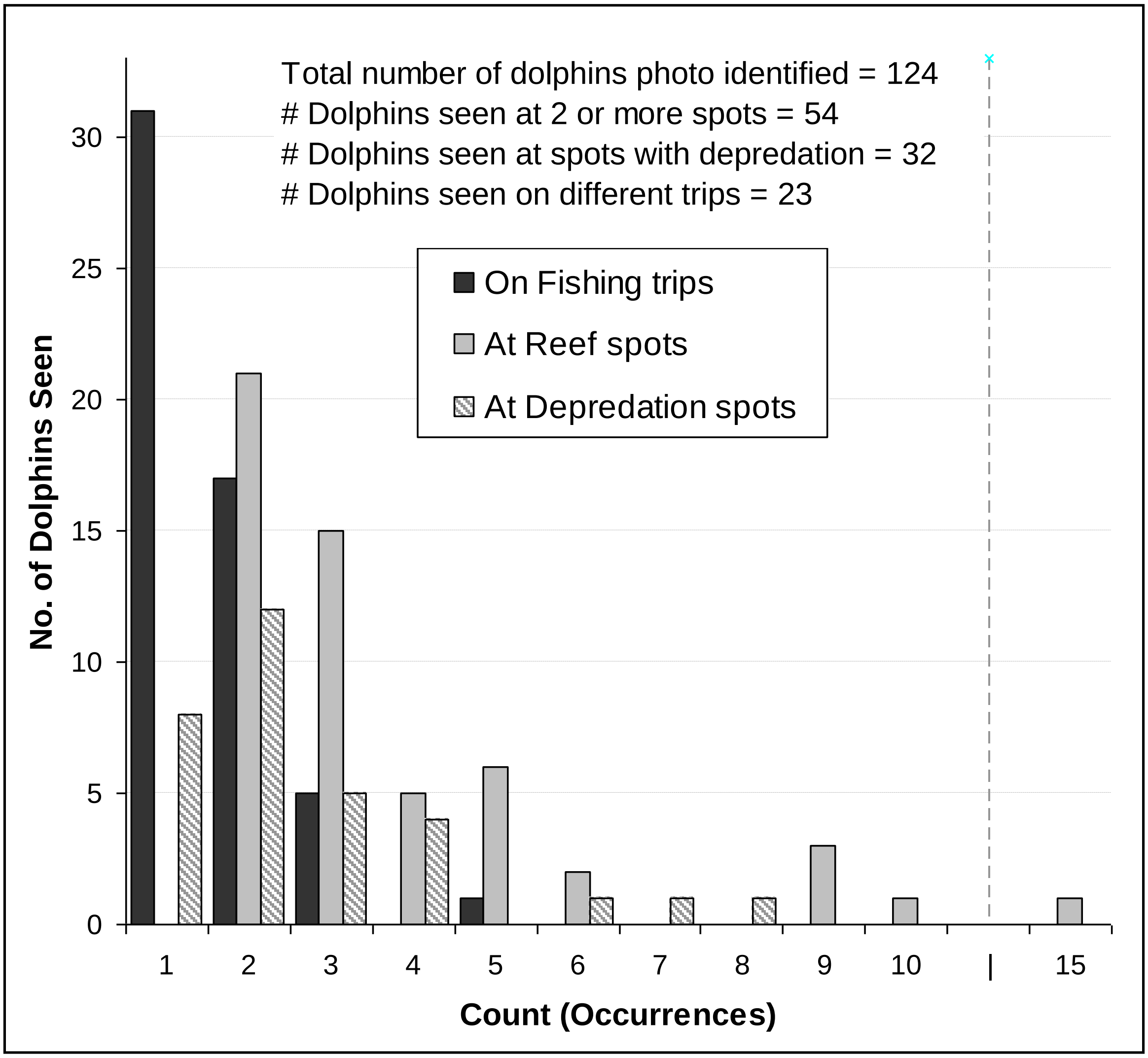


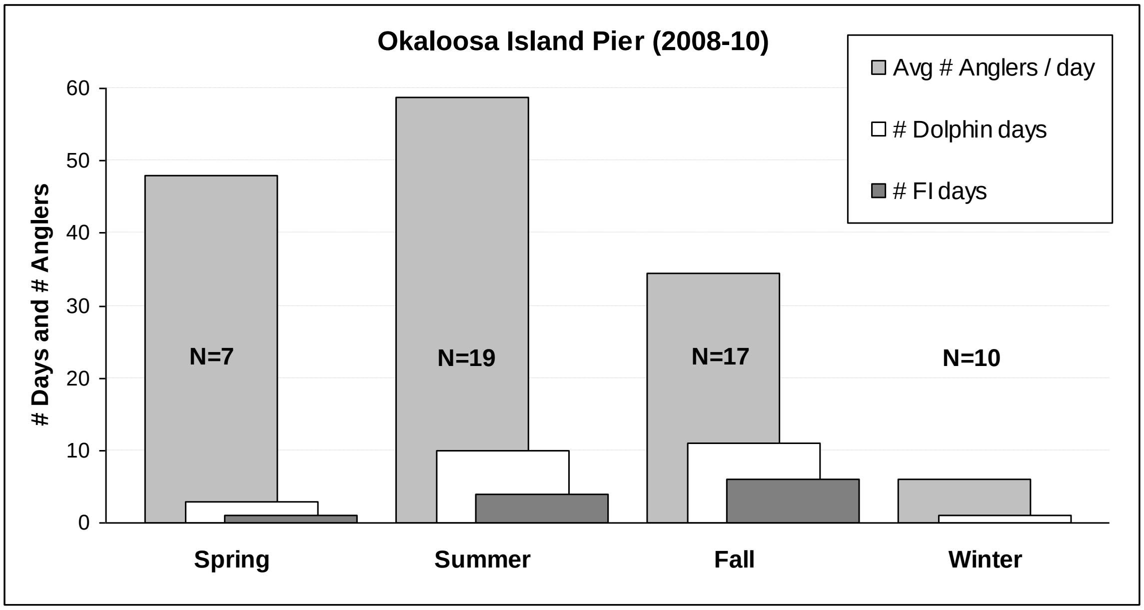
Figure 58. Dolphin resightings from photo-identifications during deep-sea fishing trips.

Pier Observations

One hundred visits to the Gulf fishing piers were made to observe fishing activity and check for presence of dolphins, encompassing 147 hours of observations (Table 27). The Navarre pier was under construction until summer of 2010 and visits were made to observe if dolphins approached this inactive pier; one visit was made after the pier was reopened. In total for all piers, sightings of dolphins occurred on 42 days, calves were seen on 22 days, and fishing interactions were observed on 17 days. Highest frequency of fishing interaction was seen at the Okaloosa Island Pier (20.8% of visits). The majority of dolphin interactions occurred in the summer and fall, with the highest frequency during months when schools of menhaden and other clupeid fish were common around the piers (Figure 59). Dolphins preferentially depredated king mackerel (*Scomberomorus cavalla*), ladyfish (*Elops saurus*) and blue runner (*Caranx crysos*). Occasionally, dolphins were seen depredating baited hooks containing round scad (*Decapterus punctatus*) and menhaden (*Brevoortia patronus*). There were few observations of dolphins scavenging discarded fish since pier anglers tend to keep all legal fish caught, either for consumption or for bait. Discarded fish were undesirable species such as sharksuckers (*Remora sp.*), barracuda (*Sphyraenea barracuda*), and sharks; no dolphins were observed showing interest in these.

Table 27. Observations at Four Gulf Coastal Fishing Piers.

Pier	Visits	Hours spent	Dolphin days	Calf days	FI (days)	Dolphins (#)	Calves (#)	Dolphins <35 m	# FI events
Okaloosa Island	53	62.6	25	12	11	92	16	38	38
Pensacola Beach	27	61.8	13	7	5	60	13	8	4
Navarre Beach (closed)	10	8.0	2	2	1	45	14	25	1
Gulf Shores, AL	10	14.8	2	1	0	17	4	2	0
Totals	100	147.2	42	22	17	214	47	73	43



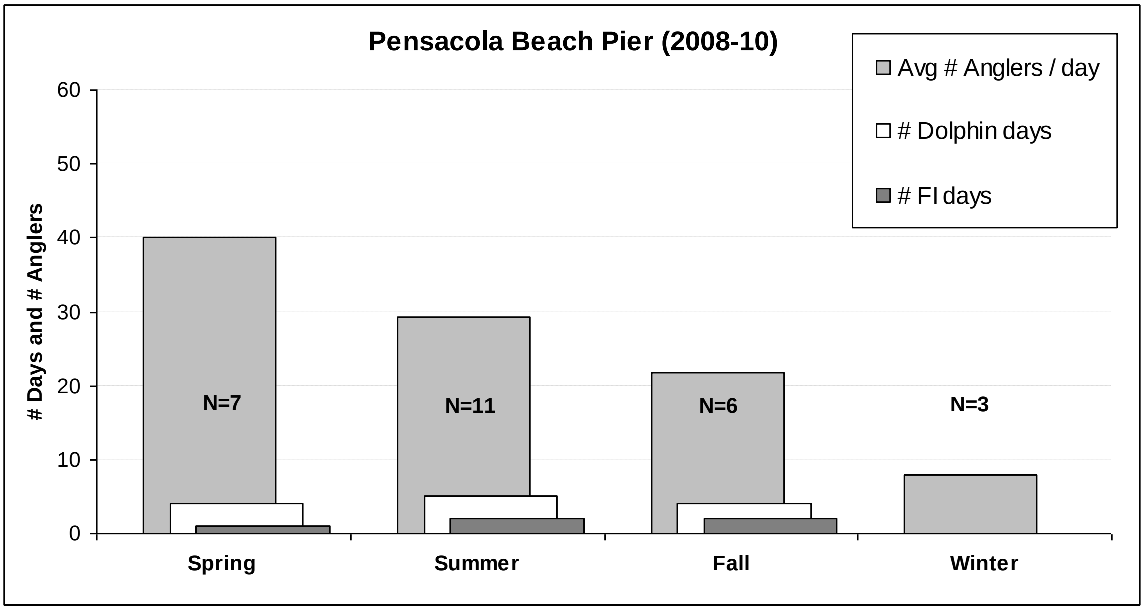


Figure 59. Seasonal activity at the two primary fishing piers observed in this study.

Highest incidence of dolphin interactions occurred at the Okaloosa Island Pier during summer and fall.

Photo identifications of 23 recognizable dolphins were made at the Okaloosa Island Pier over the study period. Of those, at least 80% were known individuals seen during surveys at Destin, and several were sighted at both the pier and during small boat surveys 7 km to the east in the inlet on the same day. At least two dolphins were also seen 54 km west of Destin at the Pensacola Beach pier at different times, and on the one day observing the newly opened Navarre Pier 33 km west of Destin, five dolphins known from the Destin catalog were photo-identified as they swam past the pier coming from the west just beyond the surf break.

Calves with presumed mothers or independent juveniles were seen at the coastal fishing piers on 22% of visits. Similar to deep-sea trips, presumed mothers with young dependent calves never were observed close to a pier; usually they remained well beyond 35 m distance. Calves or juveniles were seen around fishing piers on 13 different visits when depredation activity was observed. On many occasions, dolphin groups with calves traveled past the piers continuing along the shoreline without stopping to interact with dolphins that were loitering in the area.

Several observations were made of independent lone juvenile dolphins approaching within 35 m of a pier. During summer 2009, a recognizable juvenile was observed on three separate days lingering by the Okaloosa pier and swimming under it; on the second sighting this animal had numerous lacerations on its body resembling tooth rakes from conspecifics; they appeared to be healing on the third sighting. There was also an unconfirmed report of an injured juvenile dolphin lingering at the Pensacola Beach Pier in 2009.

Observations of inshore dolphins

Boat surveys at Destin Pass, Choctawhatchee Bay, and Pensacola Bay were ongoing from 2006-2010 (see Chapter 4 and 5). During the present study, 12 surveys were conducted at

Orange Beach in Perdido Bay to gather additional dolphin photo-ids for that area. These contributed to the inshore and coastal dolphin photo-id catalogs, which by September 2011 contained over 650 individuals in Choctawhatchee and Pensacola Bays, and 147 dolphins around Perdido Bay. None of the dolphins seen on the deep sea reefs matched any of the animals in the inshore catalogs, and none of the inshore dolphins or those seen at the coastal piers were ever sighted beyond 2 km from shore.

Injuries to Dolphins

*S*tranding data were obtained from the Emerald Coast Wildlife Refuge Marine Mammal Stranding Team, whose coverage extends from east of Choctawhatchee Bay through Perdido Key (140 linear km of coastline). Of the 22 stranded dolphin responses during 2008-10, one animal died subsequent to fishing line entanglement, one was successfully released alive from an entanglement, and one bore healed scars from an entanglement injury. During 2011-12, four more dolphins were discovered in the region with FI related injuries.

Visible scars and wounds on dolphins photographed at sea and from the coastal piers revealed the potential for long-term injury from FI. Photographs of the entangled juvenile dolphin (Figure 55) were shown to charter vessel deckhands, who identified the gear as a commercial snapper rig not used in sport fishing. However, two observations occurred during deep-sea trips of dolphins breaking terminal tackle off bottom fishing rigs while depredating, one where the animal was attached to the line longer than 20 sec. One observation at the Okaloosa Pier of a dolphin pulling a line as if hooked for more than 10 seconds ended in loss of the terminal tackle.

Of 103 dolphins photographed on the offshore reefs, 36 had visible lesions that likely were caused by line entanglement or other forms of interaction (Figure 60). Photos were graded subjectively as:

A. High probability due to contact with fishing lines or human interactions (N=15)
B. Possibly due to line or gear contact (N=16)
C. Likely from natural events (predation or conspecifics) (N=5)

Three dolphins had straight amputated dorsal fin tips of 12% to 20% of fin height; one had a circular neck scar and mid-body flank lesion; three had linear lacerations into the front or side of the fin; and four had trailing edge notches that reflected upward into the fin along straight lines; one had a healing linear cut on the flank below the dorsal fin; one dolphin had fresh penetrating wounds below the dorsal fin on both sides; and one had multiple spotty small gouging lesions on only one side of the body. C group lesions were generally dorsal fin trailing edge notches and leading edge fin scars, which could result from natural events or conspecific interactions. Two dolphins had ragged lesions resembling shark bites. All dolphins with type A and B lesions came within 35 m of the fishing boat during observations, suggesting a propensity to engage in fishing interactions.

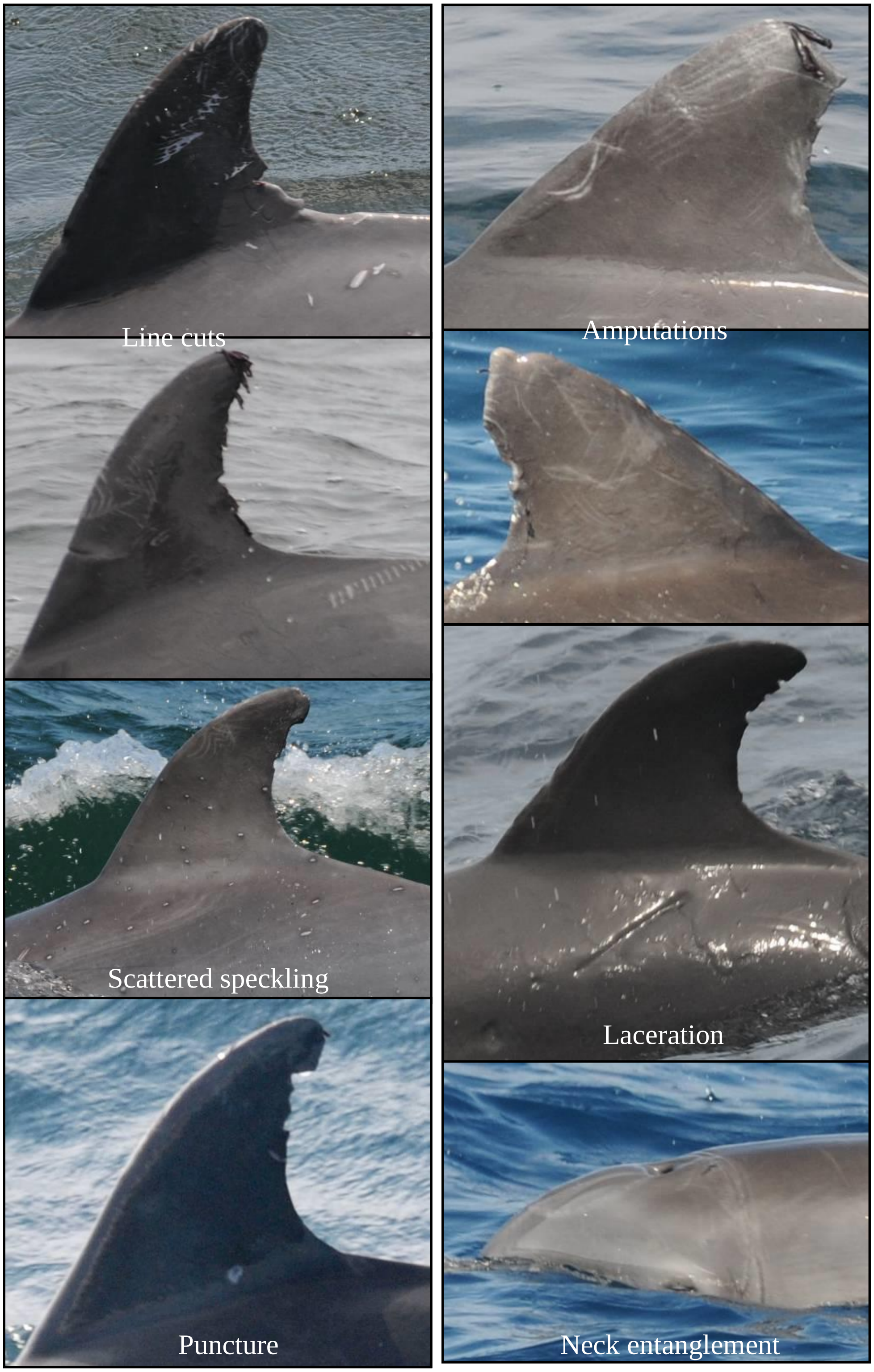


Figure 60. Examples of lesions seen on dolphins interacting with fishing at offshore reefs.

Evaluation of Mitigation Methods

Techniques were identified that might be useful to mitigate dolphin interactions with fishing. These include avoidance, tackle modifications, and fish release methods. Mitigation devices were evaluated in the field to gauge their practical application, but it was not possible to test them in a controlled fashion with dolphins predictably approaching the boat. This testing is described in Appendix B.

Changing fishing methods (avoidance): The most practical mitigation strategy seen in regular use was to leave a fishing spot when dolphins were a nuisance. A common complaint was that dolphins "killed the bite," in other words the fish had moved down onto the reef and would not approach baited rigs. If captains made such a determination, anglers were instructed to reel in their lines. There were no occasions where a captain decided to wait idle at a spot for the dolphins to leave; rather, the boat was either maneuvered around while checking the sonar display for signs that fish were again rising off the reef, or the captain would abandon the spot entirely and try to outrun / outdistance the dolphins. I made 50 different observations of dolphins following the boat when moving off a fishing spot. The fastest speed a boat moved with dolphins following to the next spot was 28 km/h but the distance traveled was only ~500 m; the next fastest was 22 km/h and the dolphin traveled 1.2 km. Dolphins tended to fall behind the wake after about 500 m and would then swim at a slower speed lagging behind the boat, arriving 5-20 min after the boat stopped at the next spot unless the distance traveled between spots was very short. Boat speeds where dolphins gave up following between spots were always >15 km/h (4.2 ms^{-1}), while speeds where dolphins persisted to the next spot were <15 km/h. The maximum distance that at least one dolphin traveled to eventually arrive at the next spot was 8.8 km. On that occasion, the boat moved at ~12 km/h (3.3 ms^{-1}). Smaller vessels (private boats and some charter boats) generally have a faster speed of transit (>15 km/h), while larger multi-passenger vessels move at fuel efficient speeds of 10-14 km/h; dolphins were noted frequently following party boats from spot to spot. Many captains would attempt to “divert” dolphins following in their wakes by passing close by other fishing vessels that were stationary over a spot. In the absence of such diversions, larger charter/party boats typically had to move beyond 1 km to outdistance dolphins.

Fish release methods: Smaller sized red snapper (14-18 inch fork length) were caught at depths of 20-30 m to test release strategies. Attempts to “sneak” fish overboard at the surface in the presence of dolphins proved to be difficult; a single observation of this being clearly successful was when a lone dolphin was engaged in chasing one fish while a second fish was released. During most encounters, several dolphins were present around the boat and it was challenging to monitor the fate of a released fish after it swam out of sight. Two observations were captured using the underwater video camera where a dolphin was observed taking free swimming red snapper at >10 m depth below the boat, despite efforts to sneak the fish overboard. Holding fish onboard in live wells until departing a spot was equally ineffective as they became bloated and incapacitated by the time of release due to decompression barotrauma (Burns and Restrepo 2002, Rummer and Bennett 2005). Two fish descender devices were tested successfully to lower medium sized Red Snapper but not in the presence of dolphins, therefore their effectiveness as deterrents to scavenging could not be evaluated. However, monitoring fish descent with a tethered video camera was found to be a practical means to conduct future testing of this concept. None of above methods was observed in use during for-hire fishing trips, although anglers and mates frequently deflated bloated fish swim bladders before release.

Discussion

In comparison to anecdotal accounts about dolphin interactions, this study provides an objective assessment of the frequency of dolphin FI at offshore reef sites near Destin, FL, and Orange Beach, AL, and at coastal fishing piers in those same areas. Declining tourism resulting from economic circumstances in 2008-09 and the Deepwater Horizon disaster in 2010 severely reduced the number of daily fishing trips; however, my findings validate the concerns expressed by charter boat operators that FI is potentially harmful to both bottlenose dolphins from gear interactions and to fish stocks due to high by-catch mortality.

I observed that deep-sea anglers were approached within 35m of the boat by dolphins at some point on 48.7% of trips, which generally agrees with captains' comments that they see dolphins on better than half of all fishing trips. However, anglers have the option to move away from dolphins as they progress between independent reef spots, which I used as a proxy for measuring the true frequency of FI. In this study, boats were approached closely by dolphins at 26 ± 4.5% of spots. Almost all observations of FI involved scavenging of discards, which occurred at 18 ± 3.9% of fishing spots; depredation of caught fish was less frequently observed at 7 ± 2.6% of spots. My observations suggest that scavenging of discarded fish without any mitigation has the potential to recruit more dolphins into the activity over time, and that scavenging is a probable precursor to more aggressive interactions by experienced dolphins that engage in depredation of hooked fish.

For-hire sport fishing boats usually conduct two half-day fishing trips during the peak season, and one trip daily during the spring and fall periods. Deep-sea trips from Orange Beach during the winter and early spring were infrequent due to lack of patrons, while Destin trips in the winter were roughly 10% of the average at peak season. The observations in the present study did not proportionally represent the actual number of opportunities for dolphins to interact with vessels during all seasons, and it is important to recognize that fishing boat days-at-sea vary seasonally. Despite the many complaints about high dolphin abundance and frequent occurrence of FI, the paucity of boats on the Gulf in the winter would suggest that dolphins must be feeding on natural prey at least during this season. At best, it is reasonable to conclude that fishing interactions are occasionally a convenient food source, but dolphins do not depend solely on this activity for their year-round survival.

Boats often congregated around a reef fishing spot. I observed 141 fishing spots where at least one other vessel was within 2 km; on some days there were as many as 15 boats within one km of each other. Dolphins were often seen moving between boats without allegiance to any particular vessel, which may have given the impression that a much higher number of animals were present at reef spots when captains compared notes via radio. Despite some claims that increasingly large and aggressive hordes of dolphins were depredating charter fleets along the Gulf coast (GOMFMC 2007, Reeves 2009) the results of this study suggest that a smaller number of animals were actually involved.

Counts of dolphins on deep-sea trips ranged from one to as many as nine animals sighted at any spot where FI was seen (mean = 4 per encounter). Photo-identifications demonstrated that some dolphins engage in FI day after day. Of the 103 dolphins photo-identified at offshore reefs, 52% were seen at more than one spot. Eighteen individual dolphins were seen on more than one fishing day in conjunction with observation of depredation, and 14 other dolphins were sighted on single days involved in depredation episodes. It was not possible to identify which individuals actually engaged in depredation, but the presence of the same dolphins on repeated days gives reason to suspect them as likely actors. The resighting data further suggest that some dolphins show fidelity to particular offshore reef areas, especially given the example of one dolphin sighted on five different days over a two year period.

A frequent complaint by charter captains was that dolphins regularly prevented anglers from landing any catch (GOMFMC 2007, Reeves 2009), and they would toy with the fish at the surface. To the contrary, I found that FI events are not all equal. At times, observation of FI was little more than a single depredation event on one fishing pole, while at other times there were multiple strikes on many poles as 4 to 8 dolphins circled around the vessel. The most aggressive display of depredation observed in this study involved approximately 25 fish stripped off lines by five dolphins at one spot over a 43 min period. At that spot, the target fish were vermillion snapper and red porgy of 30 cm or less in length and despite the dolphins, anglers landed a “good” catch of assorted snappers and triggerfish. At another spot targeting red porgy with 37 anglers aboard, I observed two dolphins that depredated lines 15 times in 35 minutes.

Although it was rarely possible to verify the species, depredation was suspected to primarily involve catches of red snapper, vermillion snapper, porgies, and amberjack based on the target catch at the fishing spots. The average fish size was 25-45 cm. Red snapper are generally large fish with robust jaws, therefore somewhat more difficult for a predator to tear off a hook and subdue than the smaller reef fish. Observed depredation takes were always fewer at spots where red snapper was the predominant catch, perhaps because dolphins took longer to dispatch and swallow the spiny fish between depredation attempts. Direct observation of catch depredation at a deep-sea reef was impossible since dolphins would take the fish near the bottom and pull away from the vessel until breaking the fish off the hook at 40-60 m distance, but dolphins were occasionally photographed mouthing a fish after depredating a line. Live reef fish erect their dorsal and pectoral spines when attacked by predators, thus it is probable that dolphins have to subdue the thrashing live fish before ingesting them, explaining the frequent observation of tossing and mouthing fish during FI events. Dolphins were observed subduing single fish for up to five minutes while surfacing, which anglers likely mistook as playful behavior.

Observations of dolphin FI in the present study may portray a seemingly low depredation frequency, however, this does not minimize reports from charter captains about the potential severity of the FI problem. Regardless of the frequency of interactions between dolphins and fishing gear, the risk of entanglement and gear ingestion remains high and warrants concern. Lesions were seen on 31 dolphins at deep-sea reefs, most of which were likely caused by fishing line wrapping around the body and slowly slicing through tissue, in some cases resulting in notching or amputation of part of the dorsal fin. Observations of dolphins becoming entangled in gear were rare, but did occur during this study.

Depredation of fisheries by bottlenose dolphins has been studied at numerous other locations. The greatest impacts are typically those involving gill net fisheries (Cox *et al.* 2003, Read 2005, Read *et al.* 2003b), but there have been studies on depredation of long-line, crab pot, trammel net, trolling, and recreational pier fishing as well (Kobayashi and Kawamoto 1995, Bearzi *et* al. 2008, Donoghue *et al.* 2003, Noke and Odell 2002, Lauriano *et al.* 2004, Zollett and Read 2004, Powell and Wells 2011). The impact to dolphins as well as the affected fishery was usually negative. Immediate harm to dolphins may result from gear entanglement and ingestion, and in mortality from drowning or sub-lethal deterrents used by fishermen (Nieri *et al*. 1999, Wells *et al*. 2008). Long term impacts to individual dolphins include injury from entanglement, reduced reproductive viability, and nutritional stress (Wells *et al.* 1998b; 2008, Read *et al.* 2003b, Read 2005, Cunningham-Smith *et al*. 2006, Barco *et al*. 2010).

Sport anglers have valid reasons to complain about dolphin interactions. A frequent comment is that fisheries regulations result in unintentional provisioning of dolphins with discarded fish. Some state that while the MMPA prohibits feeding of dolphins, the Magnuson-Stevens Fisheries Conservation Act (www.nmfs.noaa.gov/sfa/magact) mandates the discard of regulated fish regardless of dolphin presence. Fishery regulations are intended to prevent overfishing and to reduce by-catch, in part depending on release/return of undersized and out-of-season fish. Penalties for possession of illegal fish can be severe and most anglers readily discard unwanted catch to avoid a violation. The charter captains I interviewed and fished with in this study were especially conscientious of the laws and diligent about following discard rules, while at the same time expressing discontent that the fish were often being scavenged by dolphins.

Very few captains attempted mitigation other than simply leaving a fishing spot; some voiced concern about potentially attempting actions that might violate the MMPA. Moving away from dolphins appeared to be the most effective means currently available to mitigate FI. My observations showed that successfully outrunning dolphins often was a result of moving farther than 1 km at a speed above 4.2 ms^{-1} (15 km/h), which exceeds the expected optimal swimming speed of dolphins of 1.9 - 2.1 ms^{-1} (Williams *et al*. 1992).

It is reasonable to expect that habituation to an easy supply of food will increase the likelihood of an increasing number of dolphins approaching boats over time, especially as young animals learn from adults (Weiss 2006, Finn *et al*. 2008). The photo-id findings suggest that the dolphins seen at Gulf reefs that engaged in FI were a fraction of the total population. The spatial distribution of these encounters does not appear to be concentrated around any one fishing area, however, the resightings of individuals over time provides evidence of probable home-ranges associated with the deep water drop south of Destin, and at artificial reefs off Orange Beach

(Figure 61). Further, young dolphins were sighted on many occasions during this study indicating the potential for recruitment into FI activity does exist. There were no photo matches of any recognizable dolphins at the shoreline piers and inlets with those at deep sea reefs, supporting findings that overlapping communities of dolphins occur in coastal zones and shoreline animals do not forage at offshore reefs (Fazioli *et al*. 2006, Wilson *et al*. 2013).

Figure 61. Locations of fishing spots where dolphins were present.

Circled area is where the greatest number of resighted individual dolphins was most frequently seen, with one small circle area in zone 5 showing the location of a dolphin that was also sighted in zone 4.

Observed movement of dolphins between fishing piers, inlets, and alongshore the Gulf beaches by inlet/shoreline specific dolphins gives further support that a distinct community of animals inhabits the nearshore zone. This was demonstrated through sightings of individuals moving between inlets at Destin and Pensacola (see Chapter 5), as well as by stranded dolphins found in Pensacola Bay that were previously sighted in Choctawhatchee Bay. Boat surveys of the connected estuaries showed a large number of individuals were seen in both bays during

2006-11 and fishing pier observations showed that several animals moved between the Pensacola and Okaloosa Pier (54 km). Dolphins from Perdido Bay may also periodically move eastward, as found during surveys of Pensacola Bay in 2010-11. Seasonal climate and salinity changes may possibly drive animals to seek alternate foraging resources, therefore, fishing piers may provide an easy source of prey when estuaries are impacted by storms and cold-winter freshets (*e.g*., Carmichael *et al*. 2012).

Observations at Gulf fishing piers showed a high frequency of interaction with top-cast fishing for migratory king mackerel. Deep sea reef anglers in Gulf waters are required to use circle hooks, which are less likely to embed in a dolphin's mouth or throat than J-hooks. In contrast, fishing pier anglers use treble hook rigs to top-water cast for king mackerel, which pose a high potential of embedding in a dolphin mouth or gastric lining if ingested. Dolphins identified in this activity were typically known individuals from the local resident community. Population level impacts could result from FI given the observed movements of these animals between the Gulf shoreline and nearby estuaries. Stranding records demonstrate an increase of FI related mortalities over recent decades at various Gulf coast regions (Gorzelany 1998, Thoms 2006, Wells *et al*. 2008, Powell and Wells 2011) heightening the concern about the impact of fishing pier interactions. Discussions with seasoned pier anglers revealed occasional retaliatory responses to depredation. Mackerel and cobia fishermen on the Okaloosa Pier occasionally tried to frighten away dolphins by casting lures at them, an act that could cause injury or entanglement to an unaware dolphin. I observed juvenile dolphins chasing bait being reeled up to the pier, and an adult dolphin with calf taking a whole minnow bait from a hook. A high potential exists that juveniles and dependent calves accompanying adults around fishing piers can easily become entangled in lines, get hooked, be subject to angler retaliation if attempting to steal bait or catch, or learn and spread high-risk foraging behaviors.

A goal of this project was to identify practical mitigation methods to discourage dolphins from engaging in FI. While boaters can avoid or evade dolphins by moving to another fishing spot, pier anglers do not have this option, and dolphins will remain around the piers for long periods. The potential that simple tackle modifications could be acceptable to sport anglers exists, and anglers do not all have negative attitudes toward dolphins (Appendix C). Difficulty with testing any particular deterrent device or strategy lies in being able to repeatedly encounter dolphins that are regularly depredating fishing lines. My experience on reef trips showed that FI events did not occur predictably. A second challenge will be to convince anglers to adopt awkward gear modifications, therefore practical gear designs would best come about through the assistance of a professional tackle developer, which was beyond the scope of this project.

I found that scavenging of discarded fish by dolphins was prevalent at offshore reefs, and removing opportunities for dolphins to chase down discarded fish is worthy of further evaluation. Commercially available fish recompression and descender tools appeared to be the most feasible approach to discarding fish. Recompression via rapid return to depth has been deemed an effective technique to improve survival potential of discarded reef fish such as red snapper, grouper and amberjack (Drumhiller 2012, Loftus and Radonski 2012, Stunz and Curtis 2012).

Descender devices may discourage dolphins from scavenging discarded fish because of the unpredictable twisting of a fish attached to a rapidly falling descent weight. Continued advancement of descenders and other by-catch reduction technology gives hope that dolphin FI problems are also solvable. Further development of such devices will likely help reduce FI over time if enough anglers are willing to use them, therefore participation by sport anglers should be encouraged in the design and testing of these tools.

This study focused on FI issues with recreational fishing, but the true problems are the ecological impacts of all fishing activities on dolphins. I described some visually apparent injuries that might have resulted from FI; several animals bore scars that suggested illegal retribution, which would probably be intolerable in front of paying patrons. Regardless, by-catch discard entices dolphins to approach vessels and is universal to all fishing modes, resulting in continued reinforcement of FI behavior. Angler complaints frequently result in discussions about changing discard requirements to reduce the unintentional feeding of scavenging dolphins. Marine mammal interaction problems are sometimes used as a convenient rally call to abandon management regulations, which would be to the detriment of fisheries conservation plans. Some propose that “problem” dolphins be removed akin to ranchers culling predators (*e.g.*, cougars, bears) that depredate livestock or threaten human lives. Such a drastic management measure is inappropriate, however, since wild fish stocks are neither farmed nor are dolphins a threat to humans or to any endangered species, both of which are primary conditions for approving culling decisions on predatory wildlife (Rominger 2007). To the contrary, rational management decisions must include practical aspects of mitigating FI and consideration of ecosystem scale importance of apex predators in the marine environment.

CHAPTER SEVEN:
SUMMARY AND RECOMMENDATIONS

Summary of Results

Coastal and estuarine dolphins studied at several sites along the US Atlantic coast and eastern Gulf of Mexico appeared to have similar movement patterns and daily activity levels. At all locations where tracking studies were conducted, the tagged dolphins exhibited constant movement about the habitat and were never observed being stationary for any length of time. Their overall mean swim speeds of 1.6 ms^{-1} (5.8 km/h) were within the predicted optimal range speeds reported in other studies (1.5 – 3.2 ms^{-1}). The animals initially maintained a significantly faster mean speed for the first 30 minutes post-release before slowing to routine travel speeds. There were no significant differences in swim speeds between day and night. Tagged dolphins rarely traveled at speeds that approached energetically costly rates above 2.9 ms^{-1} for more than a few minutes at a time. Hourly ranging distances for the tagged dolphins averaged 4.6 km, and animals were tracked over 4.8 – 187 km, averaging 50 km traveled per day. Dolphins in the present study spent approximately 51% of each day engaged in transit swimming, 37% foraging and socializing, and 12% resting. Focal behavioral observations showed that dolphins engaged in resting while swimming. These results indicate that dolphins optimize travel rates to access a variety of habitats and foraging opportunities.

Habitat use by dolphins varied depending on study site. Estuarine dolphins in Florida at Sarasota Bay and the Indian River Lagoon moved between rivers, open bay waters, and inlets. Some individuals showed high fidelity to limited areas while others made lengthy travels between multiple habitat types. In North Carolina, dolphins were also followed from river habitats to inlets as well as into the Atlantic Ocean. One coastal dolphin in New Jersey traveled primarily along the Atlantic shoreline but spent an overnight interval inside an estuary.

Stomach temperature telemetry revealed that dolphins fed periodically throughout the day and night. Foraging activity increased just after sunset in five of six dolphins that were tracked during the night. Meal size could not be estimated from the data in the present study. Repetitive dives just after sunset suggestive of foraging bouts were detected in some animals, and foraging also was observed while animals were transit swimming. In general, these findings suggest that dolphins constantly forage while moving across their range and utilize transitions in day/night cycles to increase their foraging opportunities when prey is more available.

The Choctawhatchee and Pensacola Bay region in the Florida panhandle is home to a resident population of bottlenose dolphins comparable in size to that at Sarasota Bay. Choctawhatchee Bay had an estimated 179 to over 230 resident individuals, while 80 to over 180 dolphins were sighted in lower Pensacola Bay and Santa Rosa Sound. The highest abundance of dolphins was seen in the fall. Dolphins were observed to have site fidelity to specific locations, and also to range across large portions of the inner bays with travel distances similar to those observed in the tagging studies. Relative abundance of dolphins inside Choctawhatchee Bay varied during surveys conducted in 2007 (a dry year) and decreased in 2009 (a wet year).

Despite high dolphin mortalities in Choctawhatchee Bay during 2005-06 due to a toxic algal bloom event, mortality levels after 2007 declined to historic background levels and algal monitoring did not reveal any toxin producing blooms during the latter years of this study. However, disproportionately more stranded perinate dolphins were found in 2007, 2009, and 2011. Other threats to survival of resident dolphins were detected: heavy rainfall in 2009 significantly lowered bay salinities, which appeared to decrease the abundance of inshore fish and shrimp that are proxies for dolphin prey; visible lesions on dolphins seen in photographs and on deceased animals showed that harmful interactions with humans and fisheries were steadily increasing and had affected up to 20% of free ranging dolphins; and bay resident dolphins potentially came in contact with contaminants from the massive Deepwater Horizon oil spill during 2010.

Three distinct communities of dolphins appear to use different regions in the bays: an eastern Choctawhatchee Bay group associated with the low-salinity river dominated region; an inner bay group that travels across tidally influenced parts of middle Choctawhatchee Bay through Santa Rosa Sound into Pensacola Bay; and an inlet associated group with some individuals ranging along the Gulf shoreline between bays. Only the lower tidally influenced portion of Pensacola Bay was explored, thus no data were obtained to predict dolphin abundance in the higher river dominated areas for comparison to the eastern Choctawhatchee Bay region. Further study is needed to better define dolphin movements and habitat use in these bays.

Photo-identification of dolphins engaged in fishery interactions at Gulf shore fishing piers near Destin and Pensacola, FL, revealed that most dolphins approaching the structures were resident to the nearby inlets. The majorities of interactions at coastal fishing piers involved depredation primarily of scombrid and elopid fishes. Angler frustration with dolphins was common and often vocal.

At the offshore reefs near Destin, FL, and Orange Beach, AL, recreational fishery interactions with dolphins were observed at 18% of reef fishing spots visited over a 29 month period. Scavenging of discarded fish was seen during 99% of interactions, while depredation was seen during 40% of interactions. The majorities of interactions involved depredation/scavenging of lutjanid, serranid, sparid, and carangid fishes that were target species of the recreational fishery. Scavenging of discarded fish may play a significant role in by-catch mortality and is believed to be a precursor to attracting dolphins to depredate caught fish.

Photo-identifications of 103 individual dolphins at offshore reefs showed as many as 48% of animals were repeatedly present at different spots, with 22% seen during more than three different fishing trips spaced months apart. Calves were observed on 30% of fishing trips within dolphin groups that were sighted, although mother/calf pairs generally did not approach closely to vessels. Visible injuries that appeared to be caused by fishing line entanglement or other human interactions were seen in photos of 35% of the offshore reef animals. Dolphins identified at offshore reefs were never matched to photo identification catalogs of dolphins at the coastal and inshore sites, suggesting these are separate non-overlapping communities.

Moving away quickly from dolphins for greater than 2 km appeared to be the best means currently available to avoid dolphin interactions. Another method with possible utility to discourage scavenging by dolphins involves rapid descent of discarded fish back to depth. Anglers and charter boat operators did not usually make efforts to mitigate dolphin interactions; some expressed concern of violating seemingly conflicting federal laws that protect marine mammals and regulated sport fish. Anglers complaining that dolphins “toy” with fish at the surface rather than eating them may have mistaken the behavior of the animals trying to subdue large live fish before being able to swallow them. Sentiment toward dolphins by experienced sport anglers was generally negative.

Conservation Implications

Bottlenose dolphins are a well-studied delphinid, with much known from animals that have been maintained in human care (*e.g.*, Ramirez 1999, Wells 2009b). Observation of free ranging dolphins provides a different perspective of the daily lives of these animals. Movement distances and activity levels in free ranging dolphins contrast significantly with managed animals (Wells *et al*. 2013). Interactions between dolphins and human activities that disturb their ability to forage and rest may play a role in reducing their long-term fitness and reproduction. Cultural sources of nutrients cause eutrophication of estuarine waters that can depress prey resource availability for dolphins. Management of dolphin stocks in areas where populations are threatened by algal blooms, human interactions, and culturally derived pollution will require increased research into dolphin habitat choice and juvenile survivorship, and needs to involve public outreach and education to reduce the incidences of harmful interactions with fisheries and recreational activities.

Future Research

- Advancing development of tagging technologies will increase data collection on dolphin foraging, such as by ingestion measuring techniques using stomach temperature telemetry. Development of a GPS-enabled satellite-linked tag for small cetaceans would be a new dawn for remote tracking studies on fine-scale movements and habitat use.
- Completion of the dolphin photo identification catalog spanning 2006-current will provide a baseline of resident dolphin sighting history in the Choctawhatchee and Pensacola Bay region for comparing population changes in future years. Spatial examination of long-term

resident dolphin’s habitat use with GIS techniques will identify important sites for foraging and juvenile development. Continued monitoring of dolphin abundance and movement patterns in the Florida panhandle and Alabama estuaries through collaborative regional sharing of photo-id catalogs will increase knowledge of the stock structure of estuarine and coastal dolphins along the entire northern Gulf coast.

- Continued vigilance and stranding response by marine mammal stranding network organizations is vital to understanding dolphin morbidity and mortality trends in the Florida panhandle following multiple unusual mortality events. Collection of vital tissues for life history studies will improve management of dolphins by providing information on genetic diversity, foraging dynamics, and harmful human interactions.
- More study is needed into dolphin prey fish abundance and variability in the coastal estuaries of the northern Gulf coast. Seasonal weather extremes and subsequent freshets may have deleterious impacts on dolphin reproductive capacity, which can be elucidated by research into trophic ecology of these river dominated bays. More research into shrimp fishery interactions with dolphins is warranted in this region.
- Cooperating with sport fishing communities is necessary to develop novel methods for mitigating dolphin interactions with recreational fishing. Investigating the use of modified fishing tackle that may reduce dolphins’ depredation of hook and line gear, and that can discourage dolphins from scavenging discarded fish is highly recommended. Anglers should be encouraged to use demonstrated methods that reduce dolphin interactions via effective community outreach and education programs.

APPENDIX A:
TAG DYNAMICS AND DRAG

TRAC PAC DRAG MEASUREMENTS AND CALIBRATION IN A WATER TUNNEL

Steve Shippee

Drag measurements were conducted in October 1996 on two designs of dorsal fin packs developed for bottlenose dolphins by Trac Pac, Inc. Testing was conducted using the water tunnel located at Naval Command, Control and Ocean Surveillance Systems Lab in San Diego, CA. The packs consisted of a vacuum formed polyethylene plastic saddle lined with foam padding and a layer of suction cup mats. The packs adhere to the dolphin's dorsal fin by the action of the suction cups, a rear Velcro closure strap, and hydrostatic force of water movement over chines on each side of the pack. Drag measurements were needed to determine relative load to the animal caused by swimming with the packs applied to the dorsal fin, and comparative hydrodynamic efficiency of the two pack designs.

Drag measurements depend on the following general calculation:

Drag = ½ density of the fluid x velocity^2

Ratio of drag area gives the proportional increase as shape changes:

e.g., if fin drag = 1 lb and whole animal drag = 10 lbs, fin alone = 1/10 drag of whole

or: pack drag to fin drag = bare fin^2 / pack with fin^2

Drag areas were derived using laser measurement of velocity deflection of uniform particles passing through the water stream in the tunnel. A model of a bottlenose dolphin dorsal fin was prepared from a foam casting coated with vinyl paint. The fin was placed on a support frame designed for the water tunnel and mounted in the measurement chamber. Three measurements series were taken:

1) Bare fin
2) Fin with Trac Pac 1
3) Fin with Trac Pac 2

The tunnel velocity was held constant at 3.8 m/s for each series of measurements, which is generally at the higher range of measured swimming speeds for bottlenose dolphins. Velocity deflection measurements were made in the water stream posterior to the fin at various heights relative to the tip of the fin. Drag area measurements were calculated from the resulting data by utilizing the double integration shown below:

Drag = $D = \rho \int_0^y \int_0^z \mu (\mu_\infty - \mu)\, dzdy$

Where ρ = density of fluid

μ = local velocity (measured deflection around shape in tunnel)

μ_∞ = tunnel velocity

Drag coefficient = $C_D = D / (\frac{1}{2} \rho \mu_\infty^2) A_{ref}$

Where A_{ref} = reference area (not measured)

Drag Area (mm^2) = $C_D \times A_{ref} = 2 \int_0^y \int_0^z \mu / \mu_\infty (1-\mu)\, dzdy$

Results of the drag area calculations are shown in Appendix A, Figures 1-4. Drag areas for the three measured shapes were:

1) bare fin = 456 mm^2
2) fin + Trac Pac 1 = 3535 mm^2
3) fin + Trac Pac 2 = 5929 mm^2

The associated cross sectional areas in cm for the shapes are thus $\sqrt{(X_{mm}{}^2/100)}$.

1) bare fin = 2.14 cm^2
2) Trac Pac 1 = (5.95 – 2.14) cm^2 = 3.81 cm^2
3) Trac Pac 2 = (7.7 – 2.14) cm^2 = 5.56 cm^2

This represents a proportional increase of 12.9% for Trac Pac 1 and 7.7% for Trac Pac 2.

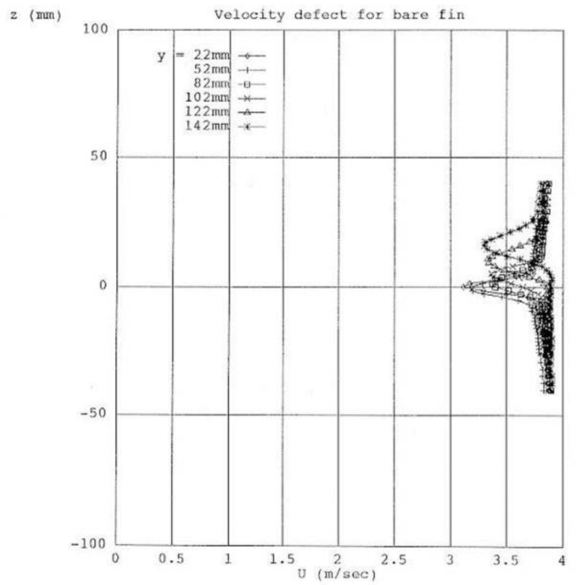


Figure 1. Bare fin measurements

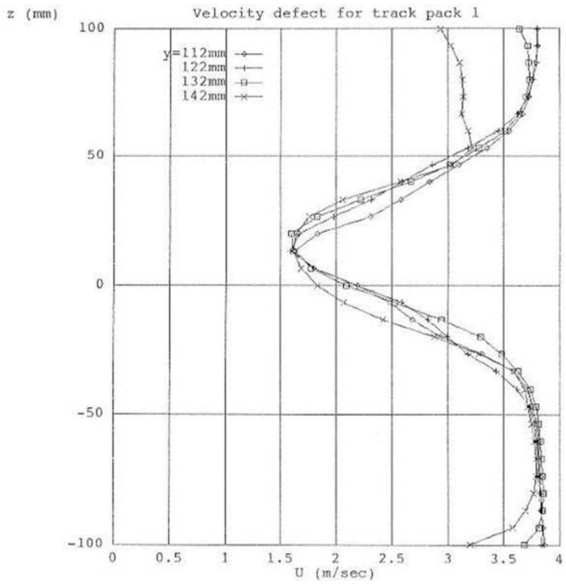


Figure 2. Trac Pac 1 measurements

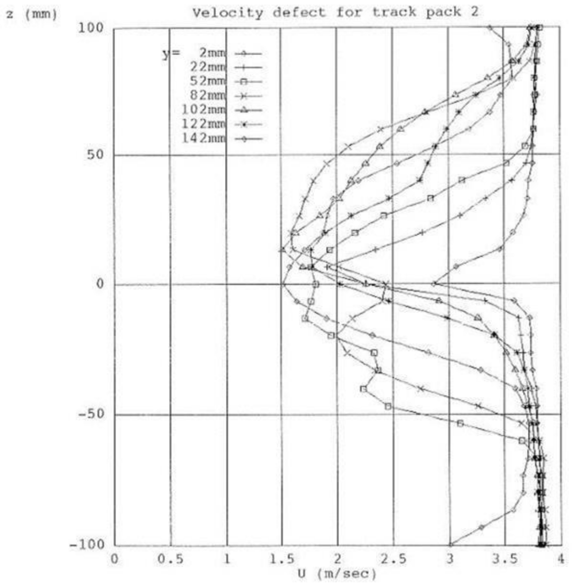


Figure 3. Trac Pac 2 measurements

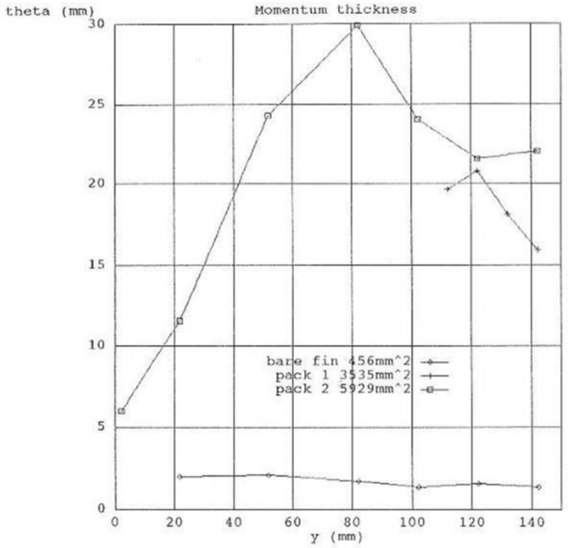


Figure 4. Drag Area calculations

Pack calibration:

Velocity meter calibrations were made by running the tunnel velocity at a series of constant speeds for 60 s. The time stamp of the data collection for the tunnel and the velocity meter readings were adjusted *post-hoc* to fit the curves. Results are presented in Appendix A, Figure 5 and Figure 6.

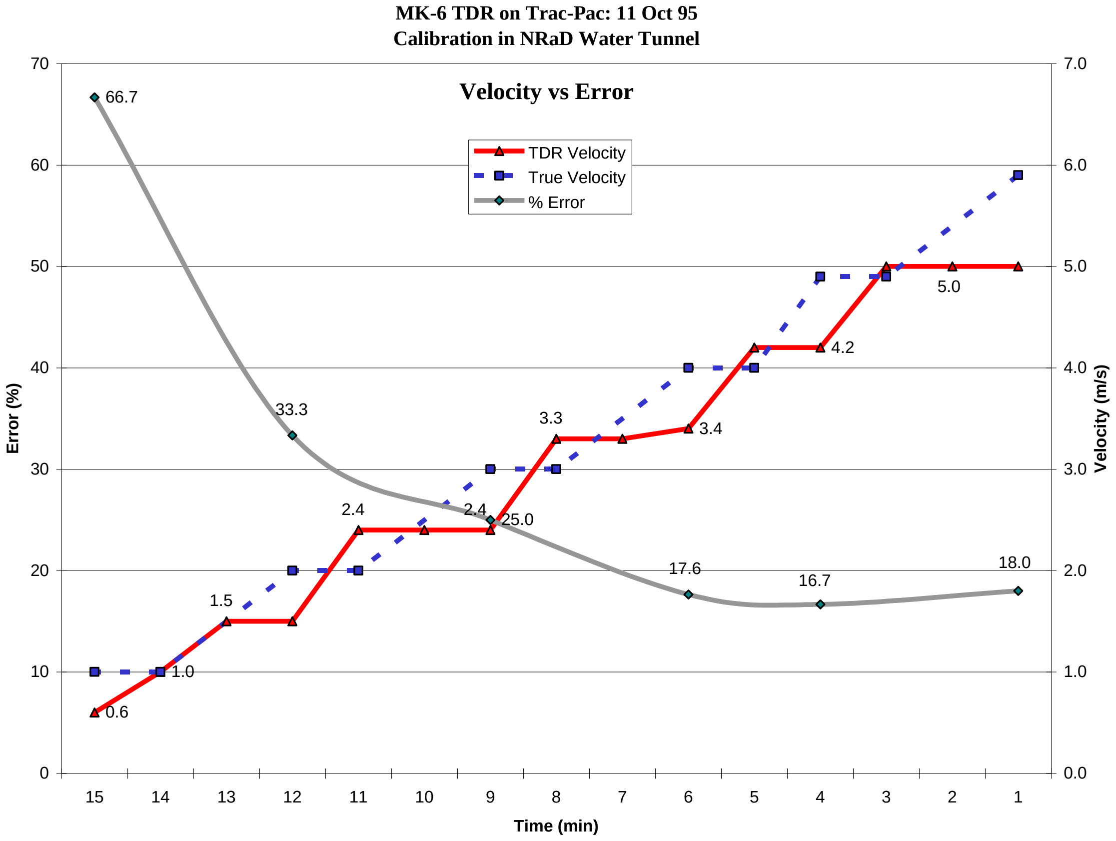


Figure 5. Water tunnel calibration runs.

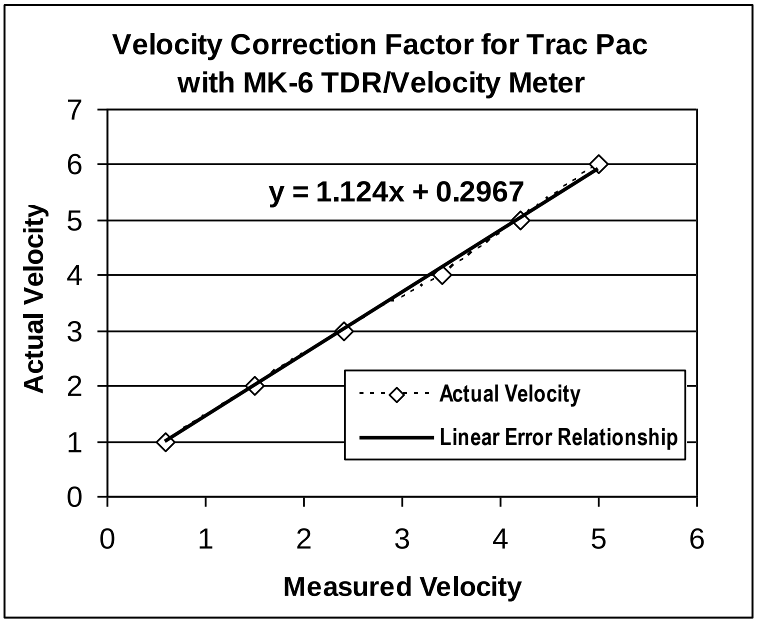


Figure 6. Calibration curve for adjusting the MK-6 TDR used in the Trac Pac

APPENDIX B:
FISHERY MITIGATION DEVICES

EXPERIMENTAL GEAR TESTS: MITIGATION OF FISHERY INTERACTIONS

Steve Shippee, UCF Department of Biology

During 2009 through summer of 2010, I conducted several tests of fishing gear modifications as well as changes in tactics, to assess their potential to discourage dolphins from depredating catch off hooks, or to prevent scavenging of released fish.

Deterrent devices - Two designs of “tickler” wires were developed that attached to the terminal tackle of bottom fishing rigs (Appendix B, Figure 1). Each consisted of #19, 400lb test stainless steel leader wire (Malin, Inc., Cleveland, OH) that would extend 60 to 100 cm outward around the hooks. One consisted of a wire pair that added 1.0 m of line from the fishing pole tip to the terminal tackle (weight and hooks); the second was more compact four-segment folding design that would unfold when triggered. Both designs trapped the wire tips against the fishing line using a plastic tube; the wires dislodged from the tube when a fish bit onto the baited hook and made a strong tug. The tickler wires were designed to fall outward toward the hook(s) in the belief that they would discourage dolphins from attempting to mouth/bite the hooked fish (per Zollett and Read 2006). Testing of the devices was conducted on deep-sea fishing trips with the tickler wires attached to the typical gear types and bait employed by sport anglers. Results were recorded as whether or not the devices deployed correctly, if fish were caught, and the observed performance (positive and negative) of the designs. Since dolphin encounters on fishing trips could not be predicted in advance, there were no planned controlled tests of the effectiveness of these devices, although opportunistic situations were sought. The folding design was taken to the Okaloosa fishing pier on several occasions for testing and to seek angler comments.

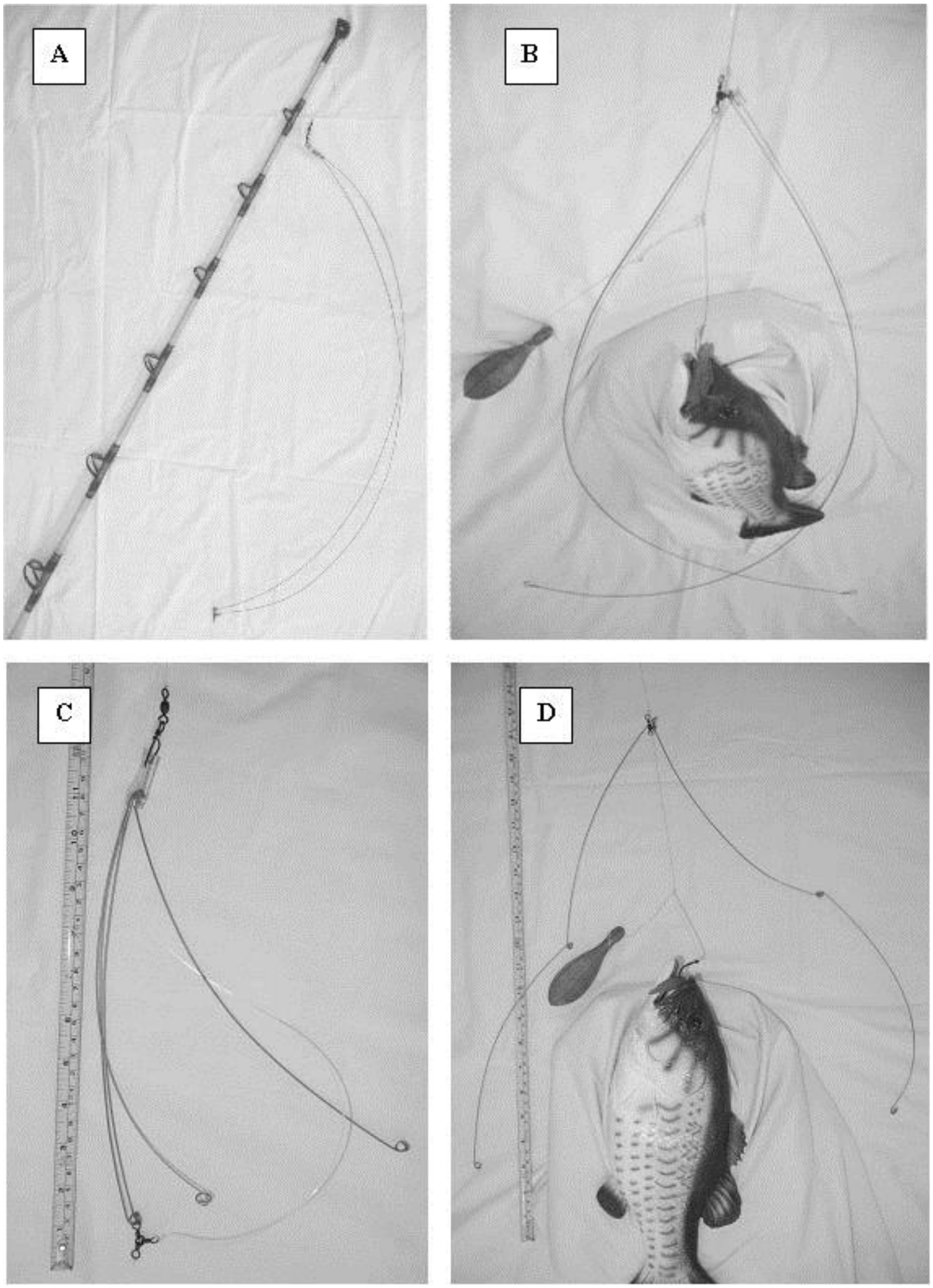


Figure 1. Tickler wire devices.

(A) 1.0 m length, non-segmented in “loaded” position with free ends of wire held in plastic tubing; (B) wires deployed after fish had pulled hook and fell down encircling fish; (C) segmented wire, 30.0 cm length folded, in loaded position; (D) wires deployed from tube and fell around fish on hook.

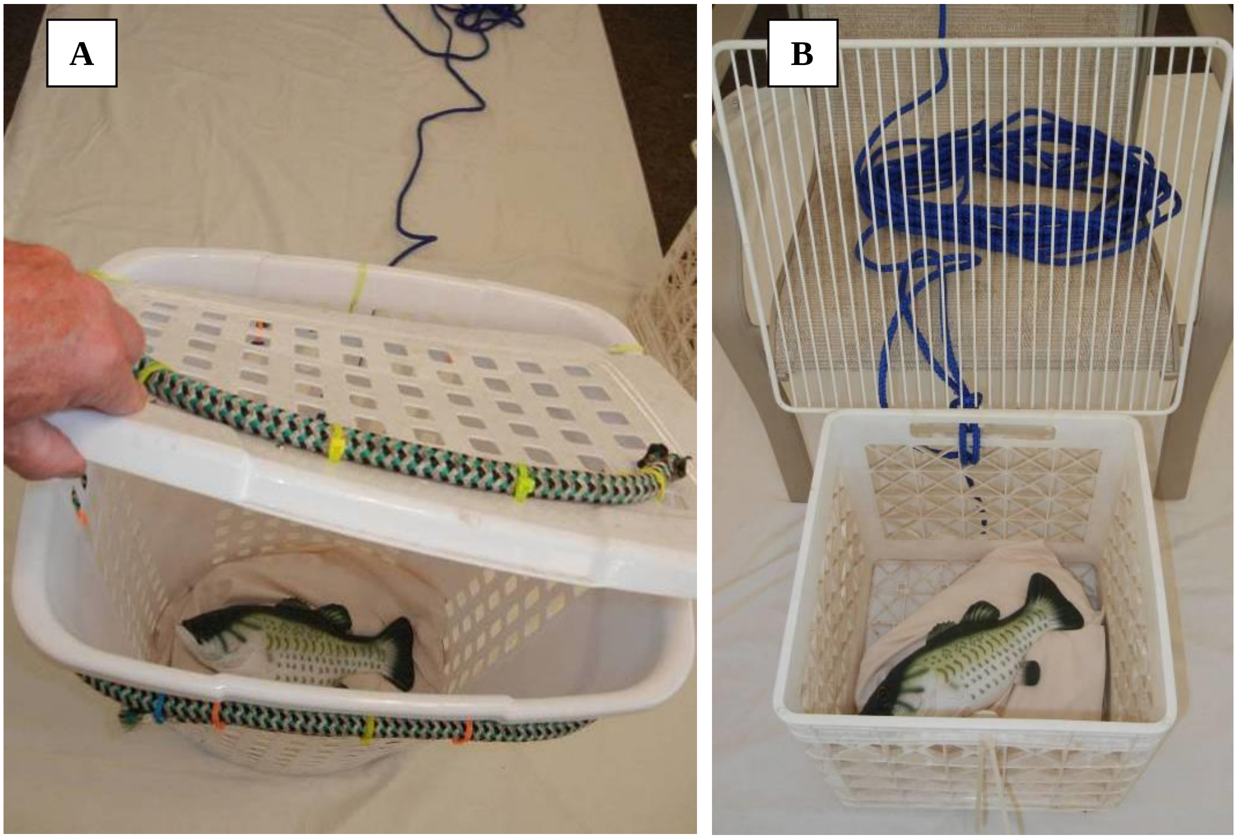


Figure 2. Fish release cages.

(A) Modified laundry basket weighted with leaded line; (B) Plastic milk crate with hinged lid.

Two home-made designs of release cages were tested, one fashioned out of a weighted laundry basket and the second a small plastic/wire mesh milk crate (Appendix B, Figure 2). The cage was tied to the side of the boat and was then lowered with a hand line in an inverted position to 15-20 m after loaded with fish; both cage designs were equipped with swing doors that fell open on descent. Two different descender rigs were tested for lowering fish back to the reef: a home-made modified barb-less grouper lure (Capt. G. Parsons, Niceville, FL); and the Shelton SFD (Shelton Products, Newark CA, www.sheltonproducts.com. Most release devices could not be tested on for-hire trips due to the probability they would disrupt fishing activity or cause tangled lines, therefore, test deployments were conducted from private boats to allow experimenting with various techniques and strategies, either at anchor or while holding station against tides, wind, and waves. Reef fish of various species (primarily red snapper) were caught using drifting baits or bottom rigs and were landed on the boat for the testing release devices.

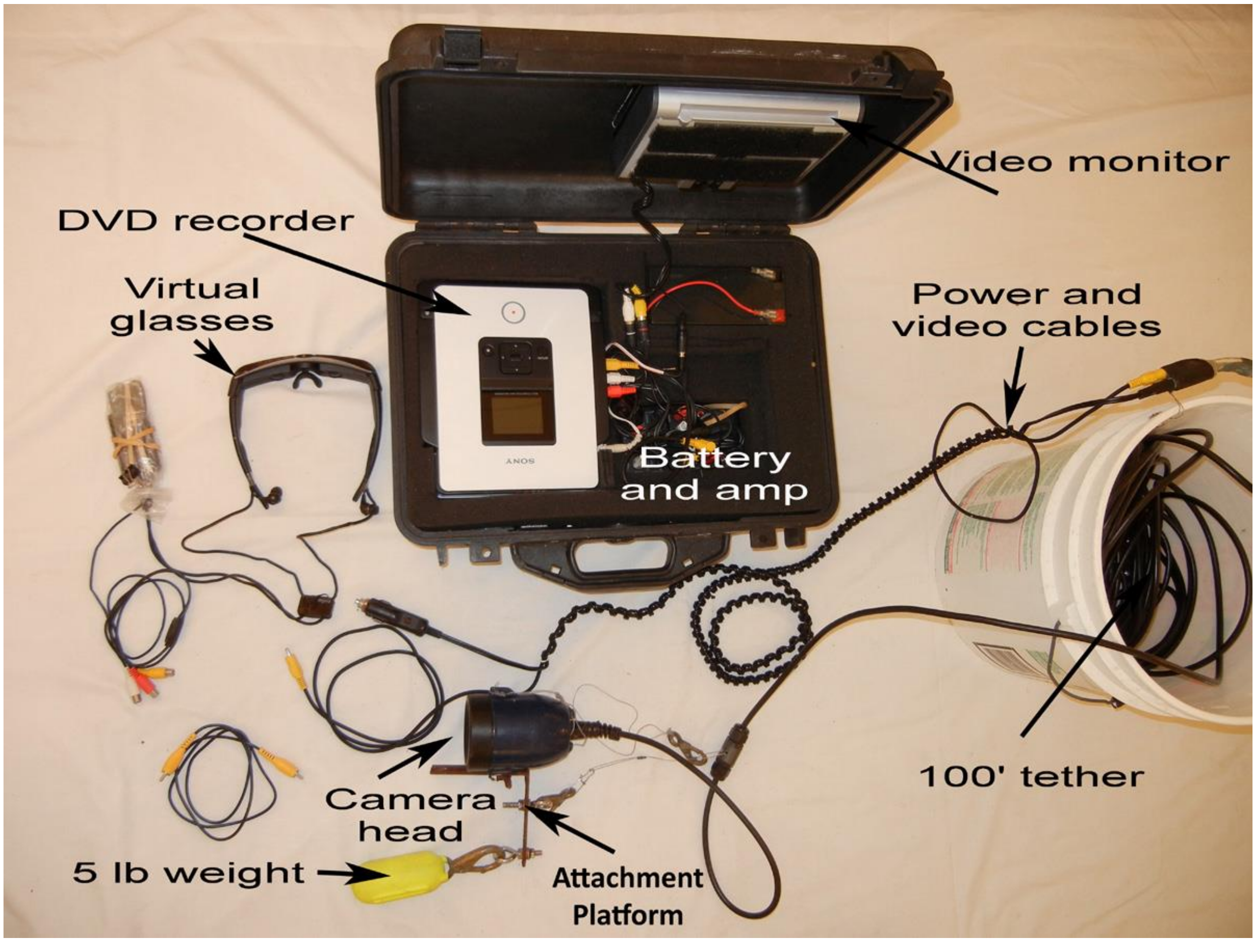


Figure 3. Portable underwater camera system.

Recorder unit in customized inside splash-proof case. The camera head was lowered to depth with a 1.0 kg weight, and had 30 m of cable.

A portable underwater video unit was used to observe the effectiveness of these techniques (Appendix B, Figure 3). The unit consisted of a tethered SplashCam Deep Pro underwater camera (Ocean Systems, Everett, WA) with a 12-volt gel cell battery and a portable

DVD recorder attached to a distribution amplifier with a video monitor mounted in a splash-proof case. A remote video headset was added to enable the angler to view the underwater image. The camera was lowered over the side of the boat giving a wide angle view looking either downward toward a fishing rig, or upwards to the hull. The live video was used to observe the performance of devices intended to discourage depredation, for returning fish to depth, and to view escaping fish as they swam toward the bottom while being pursued by dolphins. The camera was also used to view the bottom conditions and fish abundance on reefs.

RESULTS

Modified terminal tackle: I tested the two “tickle device” designs during deep-sea fishing trips but there were few opportunities to use these devices when dolphins were encountered. Tests were made with single and two-hook bottom rigs on 5 fishing trips; dolphins were present on one trip and no FI was experienced while using the rig. Both designs were successful at catching fish, although no control trials were done to compare how well the angler may have performed without the rig. The tickler wires did not always deploy successfully, or at times they would deploy without a fish being caught on the hook. Two issues were identified in using this device: the wires would tangle with the monofilament line during ascent; and the unsegmented wire rig was not practical for use on short poles. The design with segmented wires was able to successfully catch fish but suffered from being somewhat time-consuming to refold after deploying, and it entangled the line on approximately 50% of trails. Improvements were suggested by an experienced tackle designer (Doug Read, pers. comm. Oct 2010) that should decrease the tangling problem. A similar design intended for use on fishing piers was presented for his evaluation; he suggested that a braided coiled wire might be a better approach due to the nature of the light weight tackle used by top-cast anglers targeting king mackerel. No testing of the pier fishing rig was done following his recommendation that the current design would be too difficult to implement.

Fish release methods: Smaller sized red snapper (14-18 inch fork length) were caught at depths of 20-30 m for this testing. Attempts to release fish by “sneaking” them overboard at the surface proved to be difficult; only one observation of this being clearly successful was when a single dolphin was engaged in chasing one fish while a second fish was released. During most encounters, more than one dolphin was present around the boat and it challenging to monitor the fate of released fish after descending out of sight although a few observations were captured using the underwater video camera where dolphins were seen to take a freely descending fish.

Holding fish onboard in live wells until departure was equally ineffective. Bloating from decompression barotrauma increased with amount of time that fish were held at the surface due to continual off-gassing from the blood (Burns and Restrepo 2002, Wilde 2009, Loftus and Radonski 2012), rendering them incapacitated by the time of release at the surface unless hypodermic abdominal venting was conducted. The two enclosure designs (laundry and milk crate) were evaluated for recompressing fish by lowering them back down into the water column. Both proved to be too difficult to use on any size vessel due to the slapping of the cage against the hull and the dynamics of sloshing waves floating the fish out the top while at the surface; the underwater camera views revealed that the fish in the cages remained overly buoyant, preventing them from swimming downward even at 20+ m depth. Evaluation of the cages was discontinued after three attempts each, being deemed impractical for ordinary recreational use.

Two fish descender devices were tested for lowering medium sized red snapper (16-20 inches fork length): the Parson design (weighted 0.5 kg grouper lure with a large barbless hook) and the Shelton SFD. Caught fish were attached to each descender and lowered over the side to freely sink to the bottom. Underwater video images were taken to assess the performance of the devices. Video images showed that each fish swam away out of view on every release. Barotrauma compromised fish regained vigor once descended past half the water column (~20 m) and began to actively swim before release. Although effective for descending fish, the Shelton SFD was more cumbersome than the Parson rig due to its separate dangling sinker and because the wire gauge was too light to use on average size red snapper. No descender testing was accomplished in the presence of dolphins, therefore the effectiveness of these devices as deterrents could not be evaluated. However, the ability to monitor the fish descent using a live video camera was found to be a practical means to conduct future testing of this concept.

DISCUSSION

Difficulty with testing any particular deterrent device or strategy lies in being able to repeatedly encounter dolphins that are regularly depredating fishing lines. My experience on reef trips showed that FI events did not occur predictably. A second challenge will be to convince anglers to adopt awkward gear modifications; my simple designs were imperfect for common use, either due to tangles that slowed fishing progress, or because they might reduce the ability to catch fish.

Experienced pier fishermen asked to review my folding tickler wire for use in king mackerel fishing expressed concern that the mere weight of the wire and extra swivels would cause their floating baits to sink too quickly, making them ineffective in luring fish. King mackerel anglers depend on light line and the ability to feel the fish hit the bait, at which point they release the bale on the reel and allow the fish to run away with the bait for 40-70 m before resisting. Because king mackerel have keen vision, the anglers that I interviewed were very suspicious that an attached tickler wire would not pass inspection by fish viewing their floating bait in the typically clear water at the end of a Gulf fishing pier. Further development might involve either a light stranded coiled wire, or a traveling wire that could be attached at the pole end of the line once a fish was on the hook. The potential that simple tackle modifications could be acceptable to sport anglers exists; suggestions were offered that with refinement, tickler wires were worthy of further testing. Success with a similar device modification was reported in a pelagic fishery experiencing interactions with toothed whales (Rabearisoa *et al*. 2012). For pier fishing, the finesse that experienced anglers employ necessitates that practical gear designs would best come about through the assistance of a professional tackle developer, which was beyond the scope of this project.

I found that scavenging of discarded fish by dolphins was prevalent at offshore reefs, and removing opportunities for dolphins to chase down discarded fish is worthy of further evaluation. Holding fish onboard and delaying discard until sufficiently far away from scavenging dolphins was not seen as practical since state and federal guidelines recommend releasing fish as soon as possible after de-hooking while they still have enough vigor to descend against their internal buoyancy. Likewise, holding fish in live-wells for later release would probably not improve their survival or reduce dolphins' scavenging since the fish suffer increasing barotrauma over time at the surface. Although gas can be relieved with a venting tool, it is debatable if venting is actually effective at enhancing fish survival (Wilde 2009). Brief tests of release cages indicated these were also impractical for most sport anglers on deep sea reefs. Commercially available fish recompression and descender tools appeared to be the most feasible approach to discarding fish. Recompression via rapid return to depth has been deemed an effective technique to improve survival potential of discarded reef fish such as red snapper, grouper and amberjack (Drumhiller 2012, Loftus and Radonski 2012, Stunz and Curtis 2012).

Descender devices may discourage dolphins from scavenging discarded fish because of the unpredictable twisting of a fish attached to a rapidly falling descent weight. Though it was not possible to test descenders in the presence of dolphins in this study, they were relatively easy to employ. Recently, several commercially available tools have become available. A design used on dhufish and breaksea cod (Release Weight, Sunset Sinker Supply, Clarkson, WA) would be more amenable to descending medium to large red snapper than the thinner gauge SFD. The Blacktip tool is grip device that reached markets in 2010 (www.git-r-down.com). More recently, the Seaqualizer^{TM} tool (www.theseaqualizer.com, Miami, FL) won recognition in the 2011 WWF Smartgear Competition (www.smartgear.org) based on its pressure activated release jaw. Continued advancement of descenders and other by-catch reduction technology gives hope that dolphin FI problems are also solvable. Further development of devices such as tickler wires will likely help reduce FI over time if enough anglers are willing to use them, therefore participation by sport anglers should be encouraged in the design and testing of these tools.

APPENDIX C:
FISHING BOAT CAPTAIN AND ANGLER SURVEYS

SURVEYS OF DEEP-SEA SPORT FISHING CAPTAINS, CREWS, AND PATRONS ABOUT THEIR ATTITUDES TOWARD DOLPHIN INTERACTIONS

Steve Shippee, University of Central Florida, Jerry Luebke, EdD, Chicago Zoological Society, and Tara Kirby, LMHC

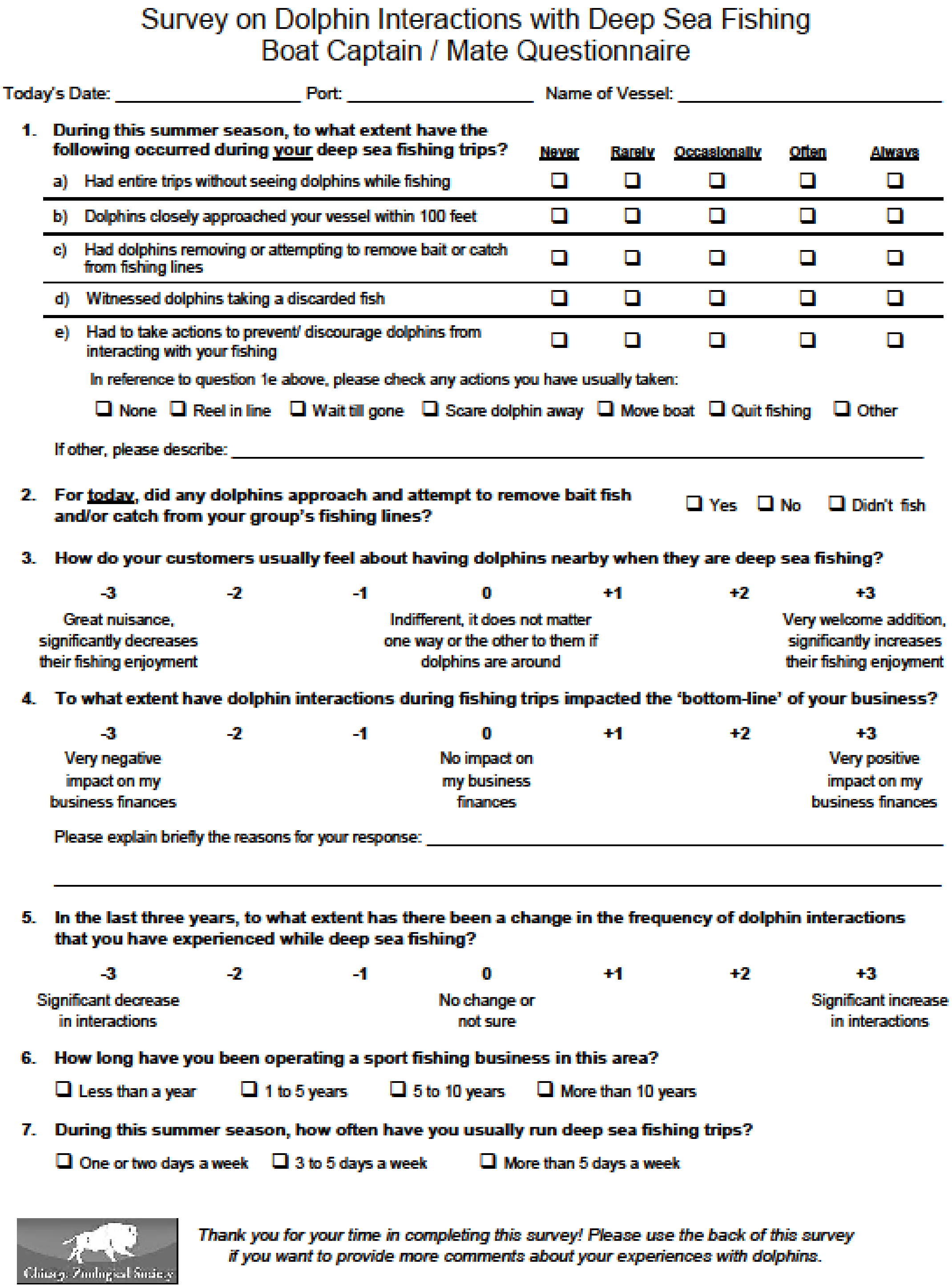
Introduction

In recent years, complaints from anglers about interactions between dolphins and sport fishing were being heard with increased frequency along the Northern Gulf Coast. Charter captains reported unwelcome interactions with dolphins that approached their boats, manifested by depredation of bait, removal of hooked fish from lines, and scavenging of discarded fish. Captains also indicated that young dolphins were being recruited into the activity by adults (GOMFMC 2007). In addition, frequent interactions with dolphins were reported from fishing piers along the Gulf Coast. Simultaneously, wildlife touring was becoming popular with an increasing number of operators providing dolphin-watching excursions (McDunough, 2008). Thus, by 2007 concerns emerged that the dichotomy of recreational pursuits (fishing interaction and desire for viewing of dolphins) was posing compound threats to localized populations of bottlenose dolphins in the region, where sport fishing and eco-touring are major economic drivers (McDonough 2010). To explore angler attitudes on this issue, we conducted a structured survey to gauge how dolphin interactions affected fishing charter patrons.

Methods

Two survey questionnaire forms were developed by the Chicago Zoological Society Conservation Psychology department for use in measuring angler attitudes and experiences with dolphins while fishing (Appendix C, Figures 1 and 2). Cooperating fishing boat captains and mates in the Destin and Orange Beach fleets were randomly approached and asked to provide answers to a verbal survey about dolphin interactions on their trips. The questions were structured to gather recollections of the frequency of dolphin interactions, the impact on their business, and their experiences with mitigation. Patrons of fishing trips were surveyed with a detailed questionnaire that sought information about the angler's fishing history, current trip experience, dolphin encounters, degree of satisfaction with the fishing trip, a relative scale of like-dislike with dolphin interactions, shark interactions, and desire to go on future fishing trips. Surveys were administered at fishing marinas in Destin, Pensacola Beach, and Orange Beach.

The angler survey typically required less than 5 minutes to complete. Anglers were either asked to fill out the form themselves or have their spoken answers marked by the interviewer. Anglers were usually approached dockside after fishing trips while waiting for fish to be cleaned, or were interviewed by an observer onboard fishing trips during transits. For observed trips, the answers were corroborated with the experience of the observer on those same trips. A few surveys were conducted at boat ramps and at public docks. Space was provided for comments and suggestions for mitigation of dolphin-fishing interactions. To avoid replication bias of answers by fellow anglers on the same fishing trips, we chose to only seek survey responses from 10-15% of the patrons on any single fishing trip. Party boats with a high number of passengers (~50) might produce 5 to 7 surveys, while 6-passenger trips would result in one or two surveys. The interviewer presented the questionnaire as a societal survey on the impact of dolphin interactions with sport fishing conducted by Chicago Zoological Society, and angler's questions about the survey were always answered after completion of the questionnaire to avoid introducing bias.



Survey on Dolphin Interactions with Deep Sea Fishing
Boat Captain / Mate Questionnaire

Today's Date: ____________________ Port: ____________________ Name of Vessel: ____________________

1. During this summer season, to what extent have the following occurred during your deep sea fishing trips?	Never	Rarely	Occasionally	Often	Always
a) Had entire trips without seeing dolphins while fishing	☐	☐	☐	☐	☐
b) Dolphins closely approached your vessel within 100 feet	☐	☐	☐	☐	☐
c) Had dolphins removing or attempting to remove bait or catch from fishing lines	☐	☐	☐	☐	☐
d) Witnessed dolphins taking a discarded fish	☐	☐	☐	☐	☐
e) Had to take actions to prevent/ discourage dolphins from interacting with your fishing	☐	☐	☐	☐	☐

In reference to question 1e above, please check any actions you have usually taken:

☐ None ☐ Reel in line ☐ Wait till gone ☐ Scare dolphin away ☐ Move boat ☐ Quit fishing ☐ Other

If other, please describe: ____________________

2. For today, did any dolphins approach and attempt to remove bait fish and/or catch from your group's fishing lines? ☐ Yes ☐ No ☐ Didn't fish

3. How do your customers usually feel about having dolphins nearby when they are deep sea fishing?

-3	-2	-1	0	+1	+2	+3
Great nuisance, significantly decreases their fishing enjoyment			Indifferent, it does not matter one way or the other to them if dolphins are around			Very welcome addition, significantly increases their fishing enjoyment

4. To what extent have dolphin interactions during fishing trips impacted the 'bottom-line' of your business?

-3	-2	-1	0	+1	+2	+3
Very negative impact on my business finances			No impact on my business finances			Very positive impact on my business finances

Please explain briefly the reasons for your response: ____________________

____

5. In the last three years, to what extent has there been a change in the frequency of dolphin interactions that you have experienced while deep sea fishing?

-3	-2	-1	0	+1	+2	+3
Significant decrease in interactions			No change or not sure			Significant increase in interactions

6. How long have you been operating a sport fishing business in this area?

☐ Less than a year ☐ 1 to 5 years ☐ 5 to 10 years ☐ More than 10 years

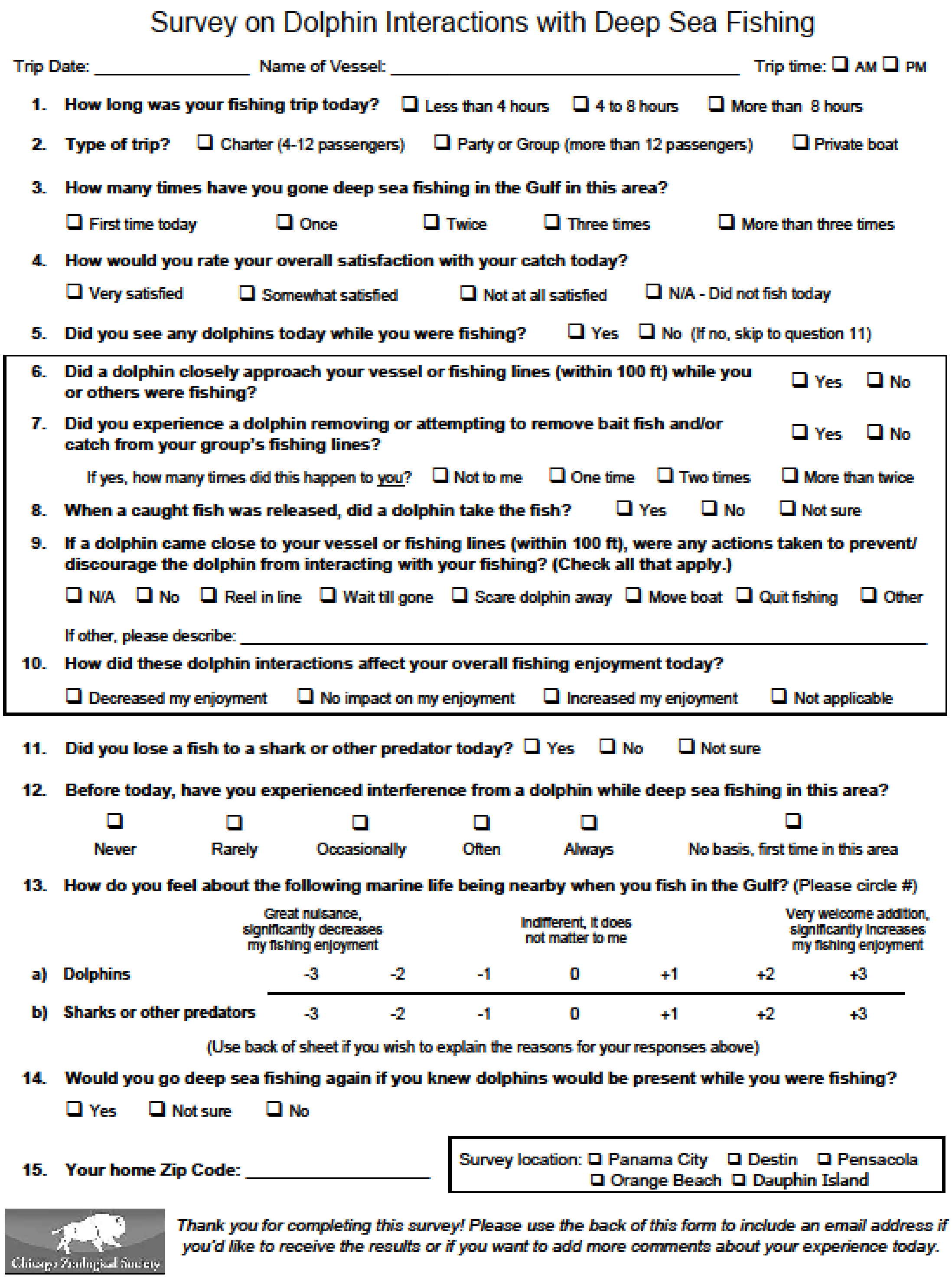
7. During this summer season, how often have you usually run deep sea fishing trips?

☐ One or two days a week ☐ 3 to 5 days a week ☐ More than 5 days a week

Chicago Zoological Society

Thank you for your time in completing this survey! Please use the back of this survey if you want to provide more comments about your experiences with dolphins.

Appendix C, Figure 1. Captain and Mate survey form.



Survey on Dolphin Interactions with Deep Sea Fishing

Trip Date: ________________ Name of Vessel: ____________________________________ Trip time: ☐ AM ☐ PM

1. **How long was your fishing trip today?** ☐ Less than 4 hours ☐ 4 to 8 hours ☐ More than 8 hours
2. **Type of trip?** ☐ Charter (4-12 passengers) ☐ Party or Group (more than 12 passengers) ☐ Private boat
3. **How many times have you gone deep sea fishing in the Gulf in this area?**
   ☐ First time today ☐ Once ☐ Twice ☐ Three times ☐ More than three times
4. **How would you rate your overall satisfaction with your catch today?**
   ☐ Very satisfied ☐ Somewhat satisfied ☐ Not at all satisfied ☐ N/A - Did not fish today
5. **Did you see any dolphins today while you were fishing?** ☐ Yes ☐ No (If no, skip to question 11)
6. **Did a dolphin closely approach your vessel or fishing lines (within 100 ft) while you or others were fishing?** ☐ Yes ☐ No
7. **Did you experience a dolphin removing or attempting to remove bait fish and/or catch from your group's fishing lines?** ☐ Yes ☐ No
   If yes, how many times did this happen to you? ☐ Not to me ☐ One time ☐ Two times ☐ More than twice
8. **When a caught fish was released, did a dolphin take the fish?** ☐ Yes ☐ No ☐ Not sure
9. **If a dolphin came close to your vessel or fishing lines (within 100 ft), were any actions taken to prevent/ discourage the dolphin from interacting with your fishing? (Check all that apply.)**
   ☐ N/A ☐ No ☐ Reel in line ☐ Wait till gone ☐ Scare dolphin away ☐ Move boat ☐ Quit fishing ☐ Other
   If other, please describe: ____
10. **How did these dolphin interactions affect your overall fishing enjoyment today?**
    ☐ Decreased my enjoyment ☐ No impact on my enjoyment ☐ Increased my enjoyment ☐ Not applicable
11. **Did you lose a fish to a shark or other predator today?** ☐ Yes ☐ No ☐ Not sure
12. **Before today, have you experienced interference from a dolphin while deep sea fishing in this area?**
    ☐ Never ☐ Rarely ☐ Occasionally ☐ Often ☐ Always ☐ No basis, first time in this area
13. **How do you feel about the following marine life being nearby when you fish in the Gulf?** (Please circle #)

	Great nuisance, significantly decreases my fishing enjoyment			Indifferent, it does not matter to me			Very welcome addition, significantly increases my fishing enjoyment
a) **Dolphins**	-3	-2	-1	0	+1	+2	+3
b) **Sharks or other predators**	-3	-2	-1	0	+1	+2	+3

(Use back of sheet if you wish to explain the reasons for your responses above)

14. **Would you go deep sea fishing again if you knew dolphins would be present while you were fishing?**
    ☐ Yes ☐ Not sure ☐ No
15. **Your home Zip Code:** ________________

Survey location: ☐ Panama City ☐ Destin ☐ Pensacola ☐ Orange Beach ☐ Dauphin Island

Chicago Zoological Society

Thank you for completing this survey! Please use the back of this form to include an email address if you'd like to receive the results or if you want to add more comments about your experience today.

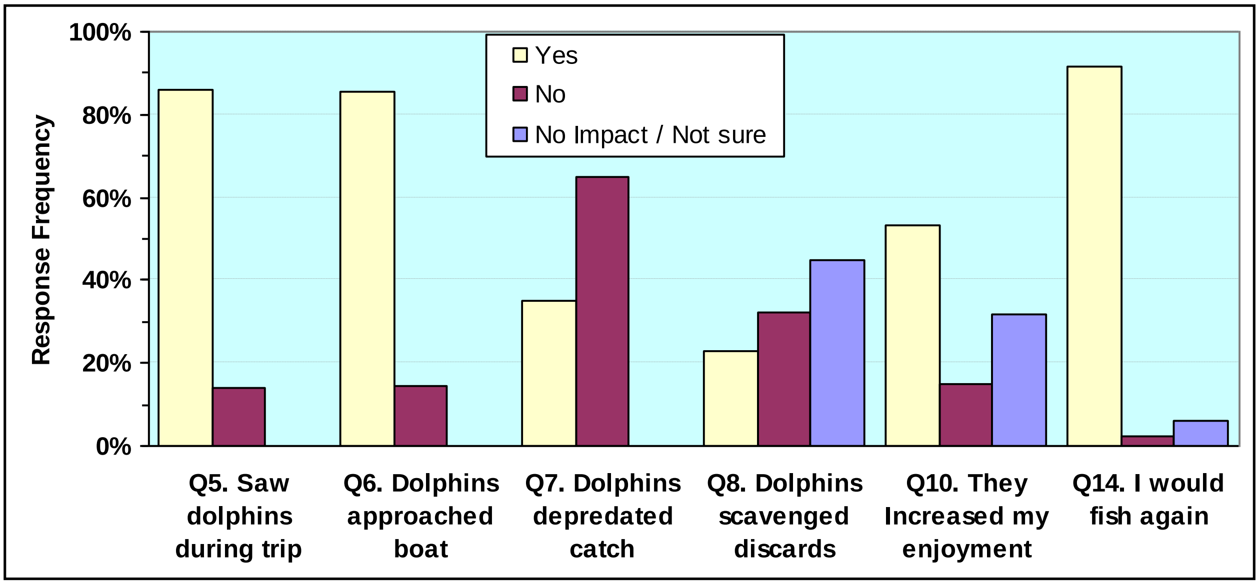
Appendix C, Figure 2. Dockside angler survey form.

Dockside angler survey data were tested for trends in responses using ANOVA analysis, and a priori between-subject tests to discriminate differences. A linear regression model was developed for exploring the differences and to determine significance using Chi Square and Symmetric measures. Survey results were transferred for analysis into both an Excel spreadsheet and into SPSS statistical software (SPSS Inc, Chicago IL; now IBM SPSS).

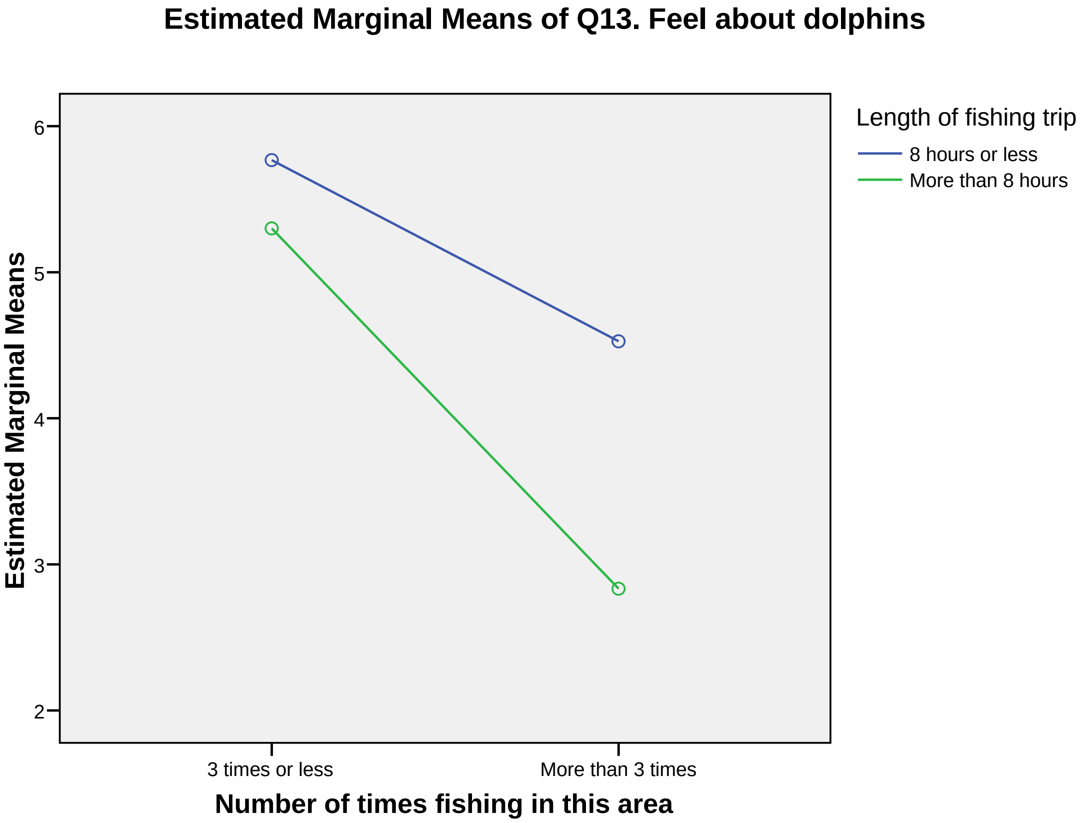
Results

We recorded responses from 176 patrons of fishing trips to our angler survey. Of the anglers surveyed, 86% responded that dolphins were seen during fishing trips approaching the boat (Appendix C, Figure 3). Of those, 35% of anglers responded that dolphins depredated their catch at some point during their trip, 79 % of which reported they personally lost a fish while the others stated they saw it happen to anglers nearby. Over 67% of anglers reported either seeing dolphins scavenge discards or were not sure if they saw scavenging. When asked how presence of dolphins around the boat during the trip affected them, 15.2% responded it decreased their enjoyment while 84.8% reported either an increase or no impact on their enjoyment. Only 2.3% of anglers responded they would not go fishing again if they knew in advance that dolphins would be around the boat during the trip. Chi-Square tests produced a significant finding that 'dislike' of dolphins tended to increase with more experienced anglers compared to patrons who rarely went fishing (Appendix C, Figure 4).

We routinely discussed dolphin interaction problems with charter boat captains and deckhands. Although not a formal structured survey, it became obvious early in the course of this study that the overwhelming majority of captains and mates harbored negative attitudes about dolphins, and would readily express this in conversation. A few captains that felt dolphins rarely impacted their fishing trips, and on two occasions captains stated that dolphins saved their fishing trip by providing a visual attraction for patrons when they otherwise had poor catch results.



Appendix C, Figure 3. Angler survey results for dockside interviews. While anglers usually reported seeing dolphins and having them approach (>80%), replies to Q7 regarding depredation were 64.9% no, and to Q8 (scavenging) were 32.2% no. More patrons saw scavenging or were not sure (67.8%). Regardless of FI experience, patrons overwhelmingly said that dolphins either increased enjoyment of trip or had no impact (84.8%), and >91% said they would fish again.



Appendix C, Figure 4. Angler survey results showing trend that attitudes towards dolphins declined among patrons with increased fishing experience in the area.

Discussion

We did not encounter any animosity on board fishing trips, but did find that a few captains and mates were unapproachable at dockside. Many charter operators consider dolphins to be nuisances that they feel powerless to deter from feeding on discards. Frequent concerns were expressed about not violating the MMPA or MSFCA, thus it comes as no surprise that some captains were unwilling to participate in interviews. The experience of many sport fishing operators that had assisted in the past with fisheries management studies also plays a role – many stated that when they participated with NOAA by providing data or solutions, it resulted in more restrictions on fishing seasons, catch quotas, and bag limits. It became apparent that dolphins are only a small component of angler frustration with fisheries regulations, and that entrenched attitudes are limiting progress in solving this problem.

The paying sport fishing customer is perhaps the best resource to overcoming indifference about solving dolphin FI problems. Our angler questionnaire was intended to elucidate how patrons of charter fishing perceive dolphin interactions, and whether their experiences would discourage them from going on future charter trips. Overwhelmingly, the survey results show that very few would let dolphin FI stop them from engaging in sport fishing, despite the trend that more experienced anglers had negative attitudes about dolphins. In fact, most responded that they welcomed seeing dolphins during fishing trips, or at a minimum that there was no impact on their enjoyment of fishing. Some anglers expressed disappointment in a boat captain that remained too long on spots where dolphins were present because it slowed their fishing progress, while others said they would have liked more time to watch and photograph dolphins. The most frequently repeated comment involved the notion of the angler being in the dolphins' habitat and not being upset by an animals' natural pursuit of prey. A lesson gleaned from these divergent comments is that charter operators could benefit from an improved understanding of the desires of their patrons and how to best satisfy them. Rather than tell a patron that dolphins "were eating the bottom out of boat" resulting in a poor catch of fish, captains might consider ways to utilize deep-sea encounters with dolphins to enhance the angler's experience by allowing wildlife observation and appreciation while taking a break from fishing.

APPENDIX D:
COPYRIGHT PERMISSION LETTER
DR. SAM H. RIDGWAY

UNIVERSITY OF CENTRAL FLORIDA

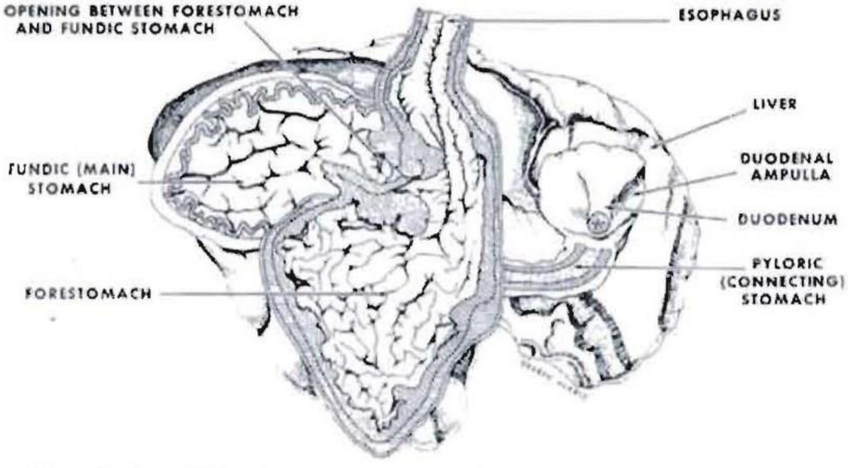
Steve Shippee, PhD Candidate
Department of Biology, University of Central Florida
c/o 1555 Hwy 98 W
Mary Esther, FL 32569

Dr. Sam Ridgway
National Marine Mammal Foundation
2240 Shelter Island Drive, Ste 200
San Diego, CA 92106

March 6, 2014

Dear Dr. Ridgway,

I request your permission to reprint in my dissertation a copy of an image showing the anatomy of the dolphin stomach, as shown here:



Dorsal view of the stomach and liver of an Atlantic bottlenosed dolphin *Tursiops truncatus*. (Drawn by Sharon Harris from dissection by Robert F. Green.)

The image will be included in the discussion of chapter 1 describing the use of stomach telemeter pills to measure ingestion events. The source of the image comes from your classic work "Mammals of the Sea" and appears on page 265. I will credit the image as:

"anatomical drawing of forestomach and main stomach (from Ridgway 1972)"

The requested permission extends to any future revisions and editions of my dissertation, including non-exclusive world rights in all languages. These rights will in no way restrict republication of the material in any other form by you or by others authorized by you. Your signing of this letter will also confirm that you own or your company owns the copyright to the above-described material.

If these arrangements meet with your approval, please sign this letter where indicated below and return to me. Thank you for your attention in this matter.

Sincerely,

Steve Shippee
Steve Shippee

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

By: Sam H Ridgway
Date: 03/05/2014

APPENDIX E:
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DR. GREGORY BOSSART

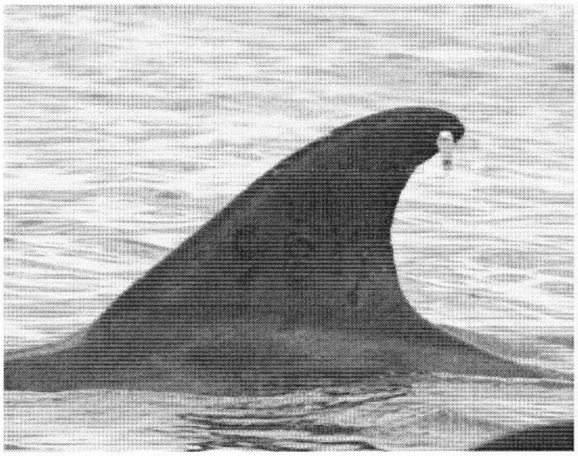
UNIVERSITY OF CENTRAL FLORIDA

Steve Shippee, PhD Candidate
Department of Biology, University of Central Florida
c/o 1555 Hwy 98 W
Mary Esther, FL 32569

Dr. Gregory Bossart
Chief Veterinary Officer and Senior Vice President
Georgia Aquarium
225 Baker Street, NW
Atlanta, GA 30313
March 6, 2014

Dear Dr. Bossart,

I would like your permission to reprint in my dissertation a copy of a photo showing the dorsal fin of dolphin FB984, as shown here:



The image will be included in the results to indicate that no ill effect was observed for the dolphin from our attachment of a Trac Pac dorsal fin tag several days prior to when the photo was taken. The caption for image will read: FB 984 two days after release of Trac Pac that was attached for 36 h. Photograph taken under the authority of NMFS Permit No. 998-1678, issued under the authority of the Marine Mammal Protection Act. The internal reference for the photo is: 2004 07 01 S2040.

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Sincerely,

Steve Shippee

Steve Shippee

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By: ______________________________

Date: 3/11/14

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