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DISTRIBUTION AND MOVEMENTS OF BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCATUS*) ALONG THE NORTHERN SOUTH CAROLINA COAST: A RESEARCH PARTNERSHIP WITH ECOTOURISM

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ABSTRACT

Assessments of bottlenose dolphin stocks rely on current information about the distribution and abundance of specific populations. We partnered with two ecotourism dolphin watch businesses to investigate bottlenose dolphins along the northern South Carolina coast. The temporal and spatial distribution of dolphins was examined by comparing dorsal fin images from research-based surveys with photo-identification efforts from commercial dolphin watch groups. Matches between survey locations and times revealed patterns of seasonal residency, potential migratory dispersal between seasons, and variable patterns for home range size. An enhanced understanding of the structure of local populations will contribute to the management of local fisheries, ecotour operations, and coastal ocean health.

INTRODUCTION

Overview

The assessment of bottlenose dolphin (*Tursiops truncatus*) stocks along the Atlantic coast of the United States has substantially improved over the last decade (Waring et al. 2011). In many areas, however, the ability to assess natural and anthropogenic impacts on dolphin populations still suffers from a lack of basic information (Balmer et al. 2008). Stock assessments for bottlenose dolphins are conducted and conservation plans are implemented by the National Marine Fisheries Service (NMFS), a division of the National Oceanic and Atmospheric Administration (Balmer et al. 2008). The agency draws on its own research, as well as research by universities and other non-governmental organizations, in the development of its stock assessment reports.

In this paper, we report on a partnership between Coastal Carolina University researchers and two ecotourism businesses to investigate the stock structure and distribution of bottlenose dolphins along the northern South Carolina coast (The Grand Strand). In the summer of 2013, we began a systematic survey effort that will ultimately assign Grand Strand dolphins to the

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correct federally-defined stock categories. We are able to increase the spatial and temporal scale of our surveys by partnering with local businesses. Blue Wave Adventures Dolphin Watch, located in Murrells Inlet, SC, and Thomas Outdoor Water Sports, located in Little River, SC, both run environmentally responsible dolphin sightseeing tours along the Grand Strand and have collected catalogs of individually-identifiable dolphin dorsal fin photographs for specific coastal areas over multiple years. By comparing dorsal fin images from our preliminary surveys with the existing records from these companies, we can identify the seasonal patterns and range of individual dolphins and can make early modifications to our ongoing efforts.

It is fitting to pair researchers and local businesses to address this issue, as the proper management of dolphin stocks significantly impacts regional coastal economies and quality of life. The most obvious direct impact is on the ecotourism operators themselves, whose business model depends on a healthy ecosystem. The business of dolphin and whale watching has become a billion dollar industry, involving over 80 countries and over 9 million participants (Spradlin et al. 2001). These activities can encourage conservation efforts for the target species and provide socioeconomic benefits to local communities. Ecotourism can foster a sense of environmental stewardship by encouraging travelers to conserve resources, obey animal protection laws, and guard against environmental pollution. However, if the number of whale watching operators becomes too large, or if viewing activities are not conducted appropriately, they can expose marine mammals to significant risk of injury or death. The general public is often unaware of their impacts on the animals (Garrison 2001), but most professional tour operators recognize and support clear viewing regulations based on sound scientific research (Spradlin et al. 2001).

The health of dolphin populations is also connected to the success of many commercial fisheries. The incidental capture, or by-catch, of dolphins can result from entanglement in fishing gear or by direct capture by hooks or trawl nets. High by-catch rates can be especially problematic for species like marine mammals that are long lived and have low rates of growth and fecundity. By-catch can also have catastrophic effects on small populations or populations already under pressure from other environmental stressors (Cox et al. 2003). To address these issues, NMFS regularly convenes a Take Reduction Team (TRT) to review the status of bottlenose dolphin stocks. The goal of a TRT is to reduce deaths of marine mammals related to commercial fishing, in order to ensure a sustainable population (Young 2001). Dolphins are protected under the MMPA, so if fishery by-catch removals are unsustainable for a specific dolphin stock, new regulations must be applied in the form of modifications to the fishing gear or changes to the fishing season, location, or total effort.

Clearly, an accurate description of dolphin stocks is required for the effective management of numerous economically important coastal activities. Determination of a sustainable removal rate of dolphins (the potential biological removal, or PBR) has been mandated by the MMPA since 1994 and requires estimates of abundance and various population parameters for defined dolphin

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stocks (MMPA 16 U.S.C. 1386). Dolphin populations are monitored and described for this reason, as well as for basic measures of ecosystem health. As a large mammal living in coastal waters and estuaries, bottlenose dolphins are considered a sentinel species for environmental health issues that may also impact humans, such as environmental toxins or pathogens (Bossart 2006).

Coastal bottlenose dolphins along the US east coast are listed as depleted under the Marine Mammal Protection Act (MMPA 16 U.S.C. 1362) due to a massive die-off from a viral pathogen in 1987-1988 that may have resulted in as much as a 50% stock reduction (Scott et al. 1988). The east coast is currently experiencing a mass mortality of bottlenose dolphins (*Tursiops truncatus*) that is comparable in scale and causation with the 1987-1988 event. Under the MMPA, an Unusual Mortality Event (UME) was declared for bottlenose dolphins along the Atlantic coast beginning in early July 2013 ("2013-2014 Bottlenose dolphin UME" 2014), and as of this writing (April, 2013), over 1200 strandings from all age classes have occurred from New York through central Florida. Based upon preliminary diagnostic testing and discussion with disease specialists, the likely cause of the UME has been attributed to cetacean *morbillivirus*, the same pathogen that caused the 1987-1988 mortality event 25 years earlier. The *morbillivirus* group is in the family Paramyxoviridae and includes the viruses that cause measles, canine distemper, and rinderpest in cattle. Cetacean *morbillivirus* most commonly affects the lungs and brain. When exposed to *morbillivirus*, some exposed animals mount a robust antibody response and survive, which usually protects against future infections. Animals that do not acquire this antibody response can die from the disease or from secondary infections that arise due to immunosuppression. The virus is usually spread through inhalation of respiratory particles or direct contact between animals. Fortunately, it cannot be transmitted to humans ("2013-2014 Bottlenose dolphin UME" 2014). However, it has obvious and dramatic impacts on dolphin stock abundance and PBR, which may also translate into additional regulations for fisheries or other dolphin interaction activities.

Currently, five coastal stocks and seven estuarine system stocks are listed by NMFS for the US Atlantic coast (Waring et al. 2011). The dolphins of northern South Carolina are classified as including both the South Carolina/Georgia Coastal Stock and the Southern Migratory Coastal Stock. This classification is poorly supported, however, as the northern South Carolina coast is considered data-deficient and a priority area for additional study. Previous studies suggest a likely connection for Grand Strand dolphins to North Carolina stocks rather than to stocks in central and southern South Carolina. Young and Peace (1999) observed a fall population increase greater than an order of magnitude from Little River to Murrell's Inlet, and photo-identification of dorsal fins from this fall peak revealed a large number of matches with the Wilmington, NC catalog but not with Charleston, SC (Young unpublished data). Furthermore, long-term stranding data indicate two different stranding patterns in SC, dividing the state into two areas: the Grand Strand (north of Murrells Inlet) and the rest of the state to the south (McFee et al. 2006). Neonate stranding patterns along the Grand Strand are more consistent with

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those of southern North Carolina, south of Cape Lookout (Thayer et al. 2003), suggesting that at least some dolphins along the Grand Strand may belong to the Southern North Carolina Estuarine System stock. There may also be contributions from an as-yet undefined estuarine stock for northern South Carolina, as resident dolphins are known from North Inlet and Winyah Bay on the southern border of the Grand Strand (Young and Phillips 2002). Most likely, two or more stocks may overlap along the Grand Strand, with seasonal and spatial variation.

The long term scientific objective of our research is to determine the stock composition, seasonal distribution, and abundance of bottlenose dolphins along the Grand Strand, from Little River, SC to Murrells Inlet, SC. For this paper, however, our short-term objective was to compare dolphin sightings from initial research surveys with dolphin sightings from commercial dolphin ecotour operators in order to expand the temporal and spatial scale of our efforts and to use identified dolphin sighting patterns to shape our ongoing survey efforts. We hypothesized that dolphin home ranges within a season would span the length of the Grand Strand (individual dolphins would be sighted from Little River to south of Murrells Inlet) and that the dolphins occupying the Grand Strand would change seasonally.

METHODOLOGY

Coastal Carolina University Surveys

A two-year dolphin survey effort by Coastal Carolina University (CCU) researchers began in July of 2013 for coastal waters near Murrells Inlet, SC. The initial survey data from July through December, 2013, were analyzed for this paper. The study area included 500 km^2 of coastal waters (50 km shore parallel by10 km offshore), from central Myrtle Beach to the mouth of North Inlet in Georgetown (Figure 1). Boat-based surveys were carried out using two different methods: coastal contour transects and offshore transects. Most survey effort
was dedicated to coastal contour surveys, a series of shore-parallel tracks conducted every

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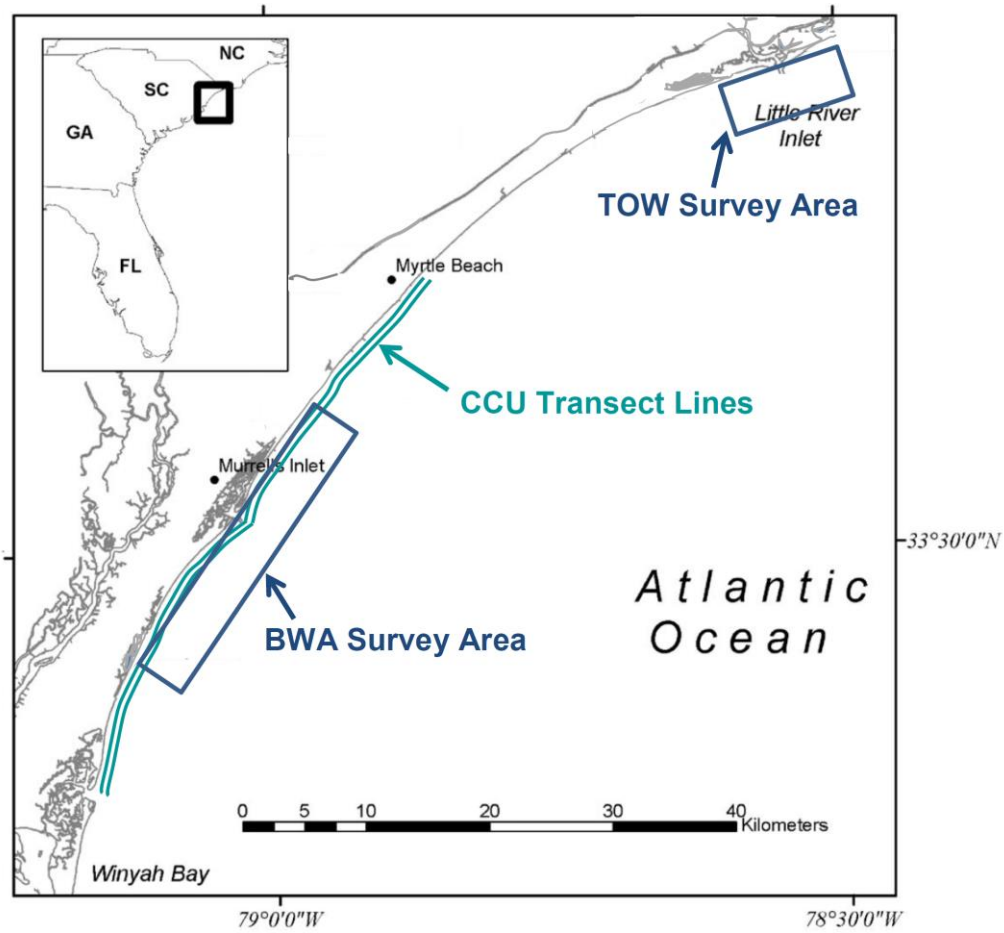

Figure 1. Dolphin Survey areas along the northern South Carolina coast. CCU is Coastal Carolina University, BWA is Blue Water Adventures Dolphin Watch, and TOW is Thompson Outdoor Watersports.

other month. These surveys will be the basis for mark-recapture abundance estimates. The sampling design consists of one 'mark' survey followed by two 'recapture' surveys within a two week period. Each complete survey consists of two 50 km transects at two distances from shore, 0.5 km and 1.5 km. Complete surveys took one to two days to complete, depending on conditions and sighting frequency. The three surveys were repeated at eight week intervals throughout the year and will continue for two years. This "robust design" follows the recommendations from a workshop on estimating abundance for bottlenose dolphins (Rosel et al. 2011).

Offshore transects took place in alternate months to provide information on dolphin distribution based on distance from shore, thus complementing our data on the distributional pattern and movements of coastal dolphins. Offshore transects extended from 0.5 to 10 km offshore and were randomly selected from 17 predetermined track lines.

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Surveys were conducted using Coastal Carolina University's 18 ft Zodiac vessel equipped with a 110 hp Mercury outboard engine. A crew of three scanned the water for dolphins at a survey speed of approximately 14 kts. Once dolphins were sighted, time, latitude and longitude (Garmin GPS 12XL), environmental conditions, group size, composition, cohesiveness, and heading were collected and recorded. An attempt was made to photograph every group member from a perpendicular angle (Wursig and Jefferson 1990) using Canon digital SLR cameras equipped with a 100-400 mm adjustable lens. Individual identification using dorsal fin photographs, a process known as photo-ID, is a fundamental tool for identifying and studying dolphins (Hohn 1997, Wursig and Jefferson 1990). The pattern of nicks and notches, primarily in the thin connective tissue of the trailing edge of the dorsal fin, may last throughout a dolphin's lifetime and can be used to identify and monitor individuals. Once all group members were photographed or 40 minutes elapsed, the sighting event was ended and the transect resumed (Melancon et al. 2011, Urian 1999).

Dolphin Ecotour Surveys

Dorsal fin photographs for photo-ID analysis were collected by two dolphin ecotour groups, Blue Wave Adventures Dolphin Watch (BWA) and Thomas Outdoor Watersports (TOW). For both groups, photographs were collected during dolphin watch tours rather than during systematic dolphin research surveys. Neither business holds a NMFS permit for close approach of dolphins during photo-ID, so photographs were taken opportunistically from a distance or when dolphins approached their boats during dolphin watches. The mission statements for both groups prominently mention environmental education of the public, protection of natural resources, and adherence to NMFS guidelines for dolphin tour operators. Both groups have worked cooperatively with state and federal agencies in South Carolina, and BWA even initiated the development of a workshop for dolphin tour operators in South Carolina in 2013, in cooperation with NOAA and the South Carolina Department of Natural Resources. Tow also participated in that workshop.

BWA operates up to 10 km to the north and 13 km to the south of Murrells Inlet, and extends out 3-5 km from shore (Figure 1). This survey area overlaps the CCU survey area. They have been running dolphin tours in this area since 2004, using a single 24-passenger tour boat for multiple 1.5 hour tours per day. Educating between 9,000 and 10,000 customers per year, dolphin watch tours are their only excursion. Photographs contributed by BWA for this study were taken between March 1 and December 1, 2010. TOW operates within 5 km to the north and south of Little River Inlet, on the north end of the Grand Strand, and extends out 3-5 km from shore (Figure 1). This survey is separated from the northern extent of the CCU survey area by approximately 30 km. They have been running dolphin tours in this area since 2004 in the form of guided jet ski outings for small groups. Educating between 6,000 and 10,000 customers per year, the company offers various jet ski, pontoon boat, and fishing trips, but the dolphin tours

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are their most popular excursion. Photographs contributed by TOW for this study were taken during the months of August through October, 2012, and May through July, 2013.

Data Analysis

Dorsal fin photographs of all individual dolphins from CCU surveys were input into FinBase, a customized Microsoft Access database for dolphin sighting data (Melancon et al. 2011). Images from initial CCU surveys were then compared to photo-ID images from the two dolphin ecotour groups. Dolphins were identified by notches along the trailing or leading edges of their dorsal fins, fin scars, chopped fins, distinctive shapes, and notches or

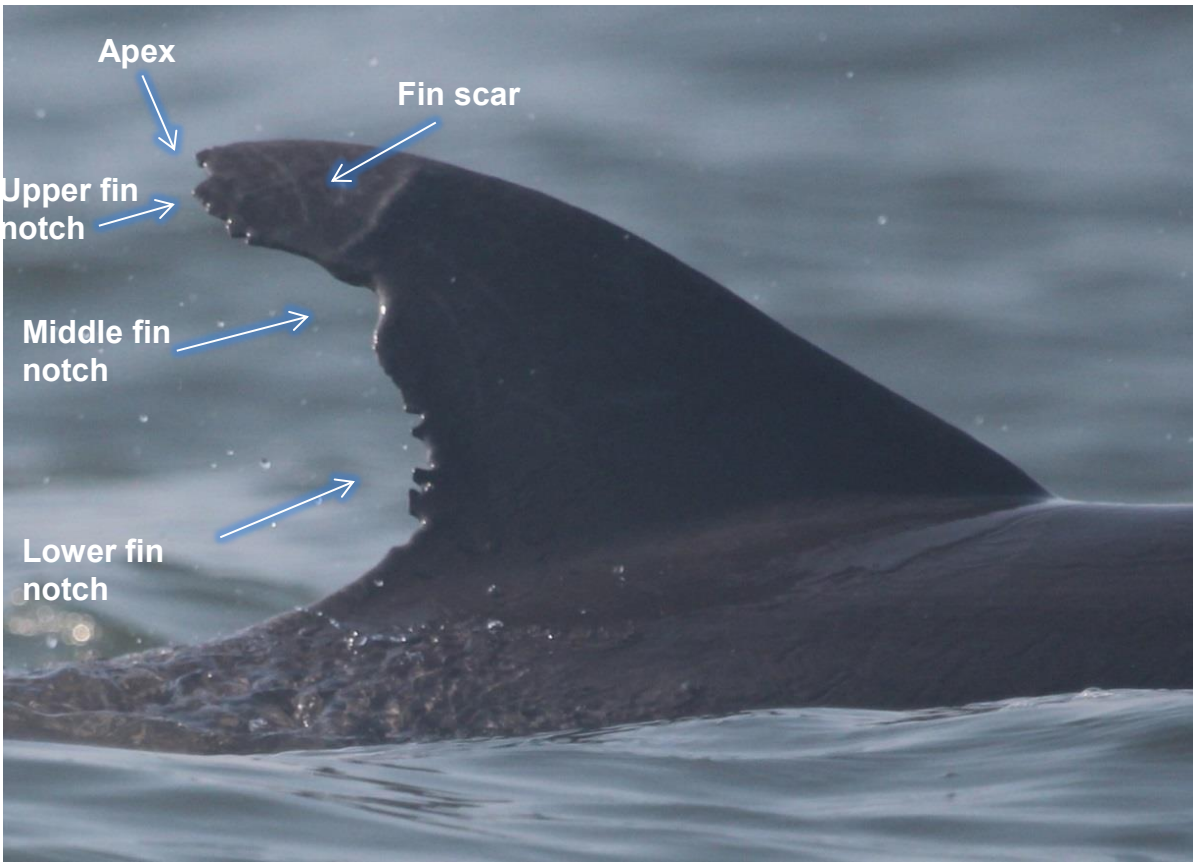

Figure 2. Photo-ID of dolphin dorsal fins is used to identify individuals. Re-sightings provide a long-term record of spatial and temporal distribution. (Photograph by R. Young, NOAA/NMFS Permit No. 16104).

scars anterior or posterior to the dorsal fin (Figure 2). Photos were scored for fin distinctiveness and photo clarity following the methods of Urian et al. (1999), and only images suitable for a potential match were included for analysis.

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Dorsal fin images from the BWA Murrells Inlet catalog and the TOW Little River catalog were scored similarly for distinctiveness and clarity, and then all fins from all three catalogs were compared with one another. All matches were confirmed by at least two researchers. The BWA and TOW catalogs were also compared with fins from Charleston, SC, using the NOAA/National Ocean Service Charleston fin catalog, available on line through the Mid-Atlantic Bottlenose Dolphin Catalog ("OBIS SEAMAP" 2014) and with permission of the curator of the Charleston catalog, Todd Speakman.

RESULTS

Eight complete CCU survey transects were completed from July through December, producing a catalog of 463 dolphins with dorsal fin images that met the criteria for clarity and distinctiveness. A similar analysis resulted in 44 dorsal fin images representing 44 dolphins for the BWA catalog and 186 images representing 122 different dolphins for the TOW catalog. The BWA catalog only contained one image per dolphin and therefore did not allow internal re-sightings within its own catalog.

All three catalogs were combined and compared for matches. Thirty-one dolphins were re-sighted in either more than one catalog or in more than one year. Of these, 12 matches were between TOW and CCU only, 4 matches were made between BWA and CCU only, and 2 matches were made between all three catalogs (Table 1). Two fins were also matched to the Charleston catalog, approximately 180 km from the southern end of the CCU transect. Dolphin 9007 was sighted in coastal waters near Charleston in April of 2005 and was sighted by BWA in July of 2010 and by CCU in July of 2013. Dolphin 9003 has the most interesting sighting history, as it was matched to historical CCU sightings in Murrells Inlet from October of 2000 and 2006, coastal waters near Charleston in 2004, BWA in July of 2010, CCU in July of 2013, and 12 separate sightings by TOW in August of 2012 and May through July of 2013.

The sighting patterns in Table 1 reveal regular movements for a number of dolphins between the north and south end of the Grand Strand. Nine dolphins were sighted in both Little River (TOW) and Murrells Inlet (CCU) in 2013. Of particular interest was dolphin number 1011, who was seen in Little River on July 7, 2013, then again on July 29, 2013 at 0953 in Myrtle Beach near the Myrtle Beach State Park and again on the same day in Little River around 1500. The latter sightings represent a roughly 50 km distance covered in five hours, indicating an average speed of about 10 km/hr.

Despite these examples of dramatic movements, the majority of re-sightings remained in the same general area over entire seasons or for multiple years. Four of the six BWA matches with CCU were seen only near Murrells Inlet, though separated by three years (2010 to 2013). Four other matches between TOW and CCU were sighted only in Little River in 2012 and then only in Murrells Inlet in 2013.

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Table 1. Sighting history of dolphins re-sighted more than once. Columns represent survey months from three separate years, 2010, 2012, and 2013. Cells are color-coded according to the survey area or organization, and the numbers in each cell represent the number of sightings (days) during that month. Split cells represent sightings by more than one survey team in the same month.

BWA Surveys (Murrells Inlet) | CCU Surveys (North of Murrells Inlet)
TOW Surveys (Little River) | CCU Surveys (South of Murrells Inlet)

	2010		2012			2013						
Dolphin ID	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Dec**
BWA138	1							1				
BWA178	1							1				
BWA184	1							1				
BWA208		1						1				
1003			1					1				
1005					1		1					
1006				1				1				
1007				1							1	
1008								2 | 1				
1011			1					2 | 1				
2003								1 | 1				
6005			1					1				
6012			1	2		1	1					
6020					1	1						
6025			1	2		1	1					
6031							1	1				
6033							1	1				
6047			3	1		2						
7002			1	1		2						
7003			1			1						
7004			1			1						
7005			2	2							1	
7026							2		1			
8003			2	1			1					
8004			2			1		1				
8006			2				2	1				
8010				1		1		1				
9003	1		7			3	1	1 | 1				
9007			2			3	1					
9011	1						1	1				
9013							1		1			

Based on the historic pattern of a strong migratory peak each fall, we have hypothesized that dolphins along the Grand Strand may migrate seasonally, with a warm season assemblage from May through September, a cold season assemblage from November through March, and transition months in October and April. Although CCU surveys continued through December of 2013, no matches were made between December dolphins and any of the warm season surveys from any survey group, and only two matches were made during the transition month of October.

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DISCUSSION

Consistent with our original hypothesis, home ranges for individual dolphins spanned the entire Grand Strand. Also, a lack of matches between warm and cold seasons supports the concept of two distinct seasonal assemblages along the Grand Strand, though the data are preliminary. Perhaps the most obvious result is the variability in spatial and temporal patterns for individual dolphins. During the warmer months, some dolphins were sighted repeatedly within only one survey area, while others moved back and forth between survey areas, in one case up to 50 km in five hours. A number of dolphins were seen in the same survey areas in multiple years, and at least one has been sighted in the Murrells Inlet area multiple times between 2000 and 2013, though it has also been sighted from Little River to Charleston during the same time frame.

The two matches with the Charleston catalog are the first known matches between Murrells Inlet and Charleston, and support the current designation that at least some dolphins along the Grand Strand are part of the South Carolina-Georgia Coastal stock (Waring et al. 2011). Matches between Murrells Inlet and Little River were common, and since part of the TOW survey area extended into the official boundaries for the Southern North Carolina Estuarine System (SNCES) stock (Waring et al. 2011), it is likely that many of the dolphins all along the Grand Strand may be connected to that stock. Under current stock definitions, SNCES dolphins do not extend into northern South Carolina, so this will be an area of continued interest with further analysis. As expected, the Grand Strand appears to be a mixing ground for several potential stocks of bottlenose dolphins.

This study represents an analysis of preliminary data from a multi-year project. Many of the apparent patterns and outstanding questions will be further explained in the next two years. However, partnering with Blue Wave Adventures Dolphin Watch and Thomas Outdoor Watersports has done much to reveal unknown patterns and to review our continuing survey design. Without this partnership, we would have data only from areas surrounding Murrells Inlet, and we would know nothing about the distribution of dolphins across the length of the Grand Strand. We would also know very little about re-sightings and temporal connections across multiple years, and we would not have identified the connections to Charleston, yet. This information reinforces that our current survey design is appropriate, but it also suggests that we should add formal transect surveys in Little River to explore connections with the SNCES and to attempt to identify an "average" home range for dolphins along the Grand Strand.

Understanding the stock structure and movement patterns of coastal dolphins is essential for the implementation of protection laws and conservation efforts for these charismatic creatures and for the sustainable management of fisheries, ecotour group activities, and ocean health.

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Assistance from commercial organizations that spend large amounts of time at sea is a boon for researchers, expanding their data sets and also alerting them to potential problems.

By partnering with responsible ecotour operators, we also help to provide them with up to date information relevant to the health of their target species and ecosystem, thus enhancing their own public education efforts. These groups are typically a much more effective vehicle for educating the general public than the scientific publications of researchers, and as visible research partners in the community and role models for environmentally responsible business practices, they have a substantial impact on the behaviors and attitudes of both their customers and competitors. As a team, scientist and ecotourism groups can help maintain local populations of bottlenose dolphins, and protect the future of these animals.

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ABOUT THE AUTHORS

Courtney N. Dunn is an undergraduate student at Coastal Carolina University. She will graduate with her Bachelor's degree in Marine Science in May 2014. Ms. Dunn has been working with graduate student, Dani C. Silva and Dr. Rob Young, for about a year assisting in dolphin research. Her research interests pertain to the impacts of the current mass mortality event

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occurring along the East coast of the United States, population structure, and migratory patterns of bottlenose dolphins (*Tursiops truncatus*).

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