RESIDENCY PATTERNS, SEASONALITY AND HABITAT USE AMONG BOTTLENOSE DOLPHINS, *TURSIOPS TRUNCATUS*, IN THE CAPE ROMAIN NATIONAL WILDLIFE REFUGE, SC

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ABSTRACT

This study documented the presence of year round and seasonally resident bottlenose dolphins, *Tursiops truncatus*, in the Cape Romain National Wildlife Refuge near McClellanville, South Carolina, USA. Trends in relative abundance, seasonality and habitat use were determined through monthly systematic photo-identification surveys from September 2003 through August 2005. Dolphins were encountered 445 times and 1,900 individuals were counted during 360 survey hours covering 5,612km. Dolphins were observed within the study site year round. Relative abundance was lowest when sea surface temperatures were below 13^{o}C, increased with temperature, and remained relatively high from March through November. Most sightings occurred in edge habitat, which in this study were salt marsh creeks, intersections and channels surrounded by vegetated salt marsh. Dolphin group size varied significantly in association with surface temperature and habitat use.

One hundred and twenty-one individual dolphins, identified by unique dorsal fin characteristics, were sighted between one and 20 times each. Twenty two recognizable individuals used this study site year round, 49 showed seasonal site fidelity, and 50 dolphins were considered transient. All of the identifiable dolphins considered year round residents were sighted exclusively within the salt marsh and never in the open ocean. Some seasonal residents showed strong site fidelity and occurred in the same temperature class over multiple years. Transients, usually sighted only once, were seen most often in the ocean. All dolphins identified interacting with shrimp trawlers were transient.

All individually identified dolphins were compared to those maintained in the Mid-Atlantic Bottlenose Dolphin Catalog. Eleven individuals from CRNWR were known from other study sites. Dolphins identified in this study exhibited movement as far north as Wilmington,

NC, (n=1), and as far south as Charleston, SC, (n=5). Patterns of seasonal movement displayed by some of these dolphins may reflect their large home ranges or the existence of overlapping communities for some coastal bottlenose dolphins in the South Atlantic Bight. One dolphin in this study also moved between existing Management Units as defined by the National Marine Fisheries Service in their on-going effort to describe stock structure of bottlenose dolphins in the mid-Atlantic. These movements suggest the need to reassess existing management boundaries to better reflect stock structure.

ACKNOWLEDGEMENTS

Laura and Will Engleby introduced me to the Cape Romain National Wildlife Refuge, and its dolphins. Laura's generosity and enthusiastic curiosity about this area planted the seed that grew into a thesis. Laura and Kim Urian both provided moral support to pursue this endeavor. Kim made arrangements for my research permit, answered endless questions about photo-identification, data management, and dolphin movements. She also compared the fins of CRNWR dolphins with Wilmington, Beaufort, and the Outer Banks of NC. Laura and Kim, in addition to their own independent and significant work, perpetually work to help others contribute to the field. I would not have done this project without their inspiration and assistance.

Bob Jones participated in almost every survey. I am grateful for his steadfast support, patience and good humor in all aspects of this process. In the context of this thesis his participation was critical to its success.

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Without the opportunities granted me as an employee of Dolphin Research Center in Grassy Key, FL I may never have developed the curiosity to learn more about dolphins, or the confidence to think I could. Personally and professionally, the people and dolphins of DRC started me on my way.

DEDICATION

Bob and Eleanor Sloan provided me with a childhood full of opportunities: Opportunities to explore fields, forests, rivers and oceans without constraint. They let me believe anything was possible and without that belief I would have missed out on so many exceptional experiences, including this project.

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INTRODUCTION

Bottlenose dolphins, *Tursiops truncatus*, have a global distribution, with the exception of polar waters (Reeves *et al.* 2002). They are found in pelagic and coastal environments, estuaries, and occasionally rivers (Reeves *et al.* 2002). In the western North Atlantic, this species occurs from the north coast of Argentina to the northeastern United States (Kenney 1990). Of the approximately 76 species of cetaceans (whales, dolphins, and porpoises) in western North Atlantic waters, only the bottlenose dolphin regularly inhabits coastal nearshore waters from New York to Florida (Kenney 1990).

References to coastal dolphins in the mid-Atlantic region of the United States appear sporadically in notes of fishermen as early as 1700 (Reeves and Read 2003). While the bottlenose dolphin is one of the most historically well-documented cetaceans, specific seasonal movements, regional associations, biology and abundance remain somewhat unknown even to the present day (Read *et al.* 2003). My study focused on bottlenose dolphins in the mid-Atlantic region of the eastern United States, specifically those inhabiting estuarine systems and adjacent nearshore waters in the Cape Romain National Wildlife Refuge near McClellanville, South Carolina, USA (Fig. 1).

There are two ecotypes of bottlenose dolphin recognized in the western North Atlantic: an inshore and an offshore ecotype (Mead and Potter 1995). Differences in seasonal distribution (Kenney 1990), parasite loads (Mead and Potter 1990), morphology (Mead and Potter 1990, 1995), diet (Mead and Potter 1995, Walker *et al*. 1999), and blood chemistry (Hersh and Duffield 1990) are among factors marking the distinction between inshore and offshore ecotypes. The inshore ecotype shows a distinct northern

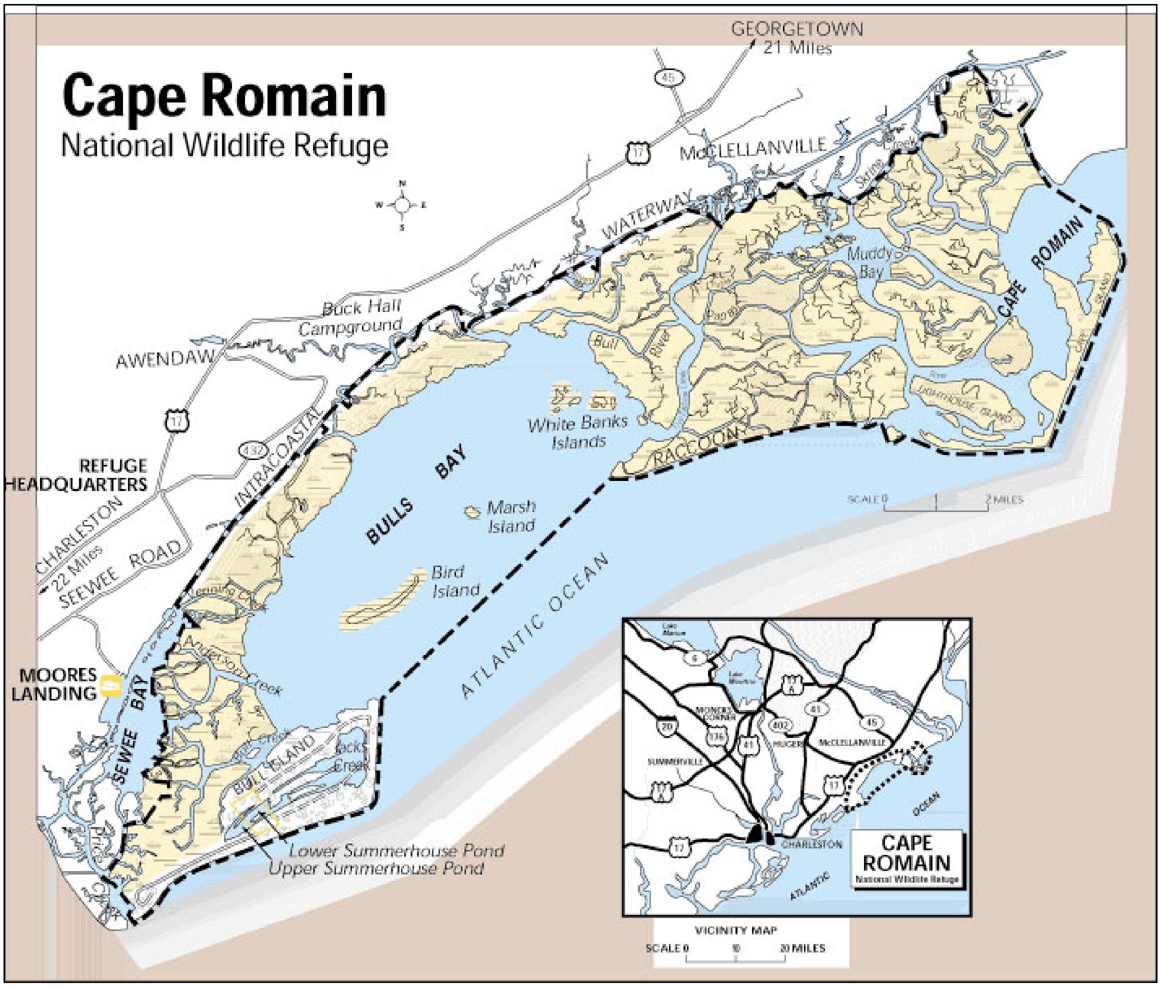

Figure 1. Cape Romain National Wildlife Refuge extends 20 miles along the coast of South Carolina. The estuary north of Bulls Bay within refuge boundaries was the site of this study. Image provided by Cape Romain National Wildlife Refuge web site courtesy of the US Fish and Wildlife Service: http://www.fws.gov/caperomain/

boundary in the winter months, when they are absent north of Cape Hatteras, North Carolina (Kenney 1990, Urian *et al.* 2005, Torres *et al.* 2005). During summer months these coastal dolphins extend their range farther north (Barco *et al.* 1999, Kenney 1990, Scott *et al.* 1988). Seasonal movements south of Cape Hatteras, NC are less well defined. However, there is evidence that dolphins south of Cape Hatteras exhibit seasonal movements in response to prey (Friedlander *et al*. 2001). Stranding patterns in this area suggest animals may also move between estuaries and coastal waters seasonally (McLellan *et al*. 2002). I attempted to identify individual coastal dolphins to aid in understanding these seasonal movements.

In 1987-1988 bottlenose dolphins in the western North Atlantic experienced an epizootic event (Geraci 1989, Duigan *et al.* 1995, McLellan *et al.* 2002). At the time it was believed that as many as 700 dolphins stranded between New Jersey and central Florida (Scott *et al.* 1988), although further analyses by McLellan *et al.* (2002) reported only 645 animals. Based on an apparent "migration" of mortality from New Jersey to Florida during the epizootic, Scott *et al.* (1988) suggested the existence of a "single coastal migratory stock" of bottlenose dolphins. Stocks are defined by spatial associations and interbreeding of groups of the same species (reviewed in Torres *et al*. 2003). Given the unusually high mortality, Scott *et al.* (1988) proposed that this stock be designated "depleted" under provisions of the Marine Mammal Protection Act of 1972 (MMPA). In 1993, the National Marine Fisheries Service (NMFS) listed the coastal migratory stock of bottlenose dolphins in the western North Atlantic as depleted (58 FR 17789 1993).

McLellan *et al.* (2002) conducted an analysis of a 25 year database of all bottlenose dolphins stranded in the region of the 1987-1988 epizootic, including 15 years prior to, and nine years after, the epizootic. This broader analysis suggested a more complex stock structure and did not support the single stock hypothesis of Scott *et al.* (1988). Further support for multiple stocks has come from studies by Petricig (1995), Gubbins (2000), Urian *et al*. (2005), Young and Phillips (2002), and Zolman (2002), all of which documented coastal bottlenose dolphins in North and South Carolina with year round and seasonal site fidelity. Caldwell (2001) also described resident and seasonal groups of coastal bottlenose dolphins on the border of Georgia and Florida. Each of the aforementioned studies surveyed estuarine habitat similar to Cape Romain National Wildlife Refuge (CRNWR). Findings from these regional studies indicate localized populations of bottlenose dolphins that apparently do not migrate and that may represent separate stocks. Little is known about the range, site fidelity, habitat use and social structure of these resident groups of coastal bottlenose dolphins inhabiting estuaries.

Thus, in the face of evidence for a complex mix of resident and migratory stocks in the western mid-Atlantic, NMFS rejected the single stock hypothesis of Scott *et al.* (1988) in 2001 (NMFS 2001). Recognizing a more complex stock structure allowed NMFS to group coastal bottlenose dolphins into several distinct management units (Fig. 2). Management units are designated based on information gathered from genetic, stable isotope, photo-identification, and telemetry studies (Hohn 1997). These management units continue to be refined. Stock management focuses on accurately defining a sustainable level of anthropogenic incidental mortality based on population abundance.

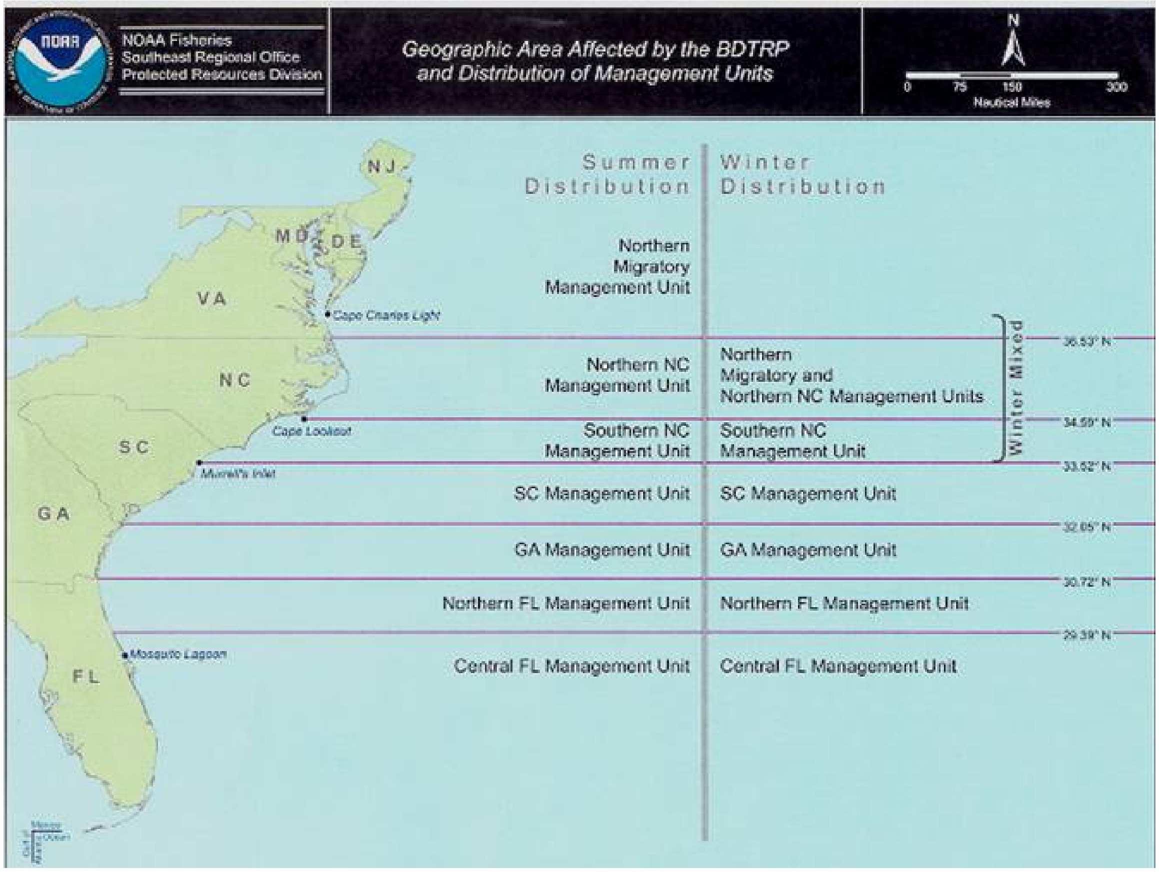

Figure 2. Management units, as defined by National Marine Fisheries Service, NOAA Fisheries Southeast Regional Office 2003

To this end NMFS formed a Bottlenose Dolphin Take Reduction Plan in February 2002 (NMFS 2001). Part of the plan included assessing bottlenose dolphin stock structure and abundance in the western North Atlantic, which required further research. To date, the bottlenose dolphin Take Reduction Plan has not been implemented.

Recognition of individual animals is a powerful tool used to aid in the identification of distinct stocks. Identifiable individuals illustrate patterns of movement and seasonal or year round site fidelity, elucidating trends within and among stocks (Würsig and Jefferson 1990). Wells and Scott (1990) and Würsig and Jefferson (1990) describe methods of photographically identifying individual dolphins based on dorsal fin scars. These methods, adopted by researchers at various sites in the western North Atlantic, contributed to the compilation of a photo-identification catalog of coastal bottlenose dolphins from Cape May, NJ to central Florida (Urian, *et al.* 1999, 2005). However, there is a noticeable gap in the contiguous data from the area north of Charleston, SC and south of Murrell's Inlet, SC. Currently the Southern North Carolina Management Unit (Waring *et al*. 2003) extends as far south as Murrell's Inlet, the last study site before an 80km gap north of Charleston, SC (Fig. 2). One of the goals of my study was to help narrow this data gap. A 200km^2 area within the Cape Romain National Wildlife Refuge (CRNWR) was thus the site for my study (Fig. 3). This area is located at 33 degrees north, a suggested "break point" of seasonal movements of bottlenose dolphins in the western North Atlantic based on an analysis of historic strandings data (McLellan *et al*. 2002). My study identifies year round and seasonal residents, and examines habitat use, in this pristine site. Distinct individuals from my study site were

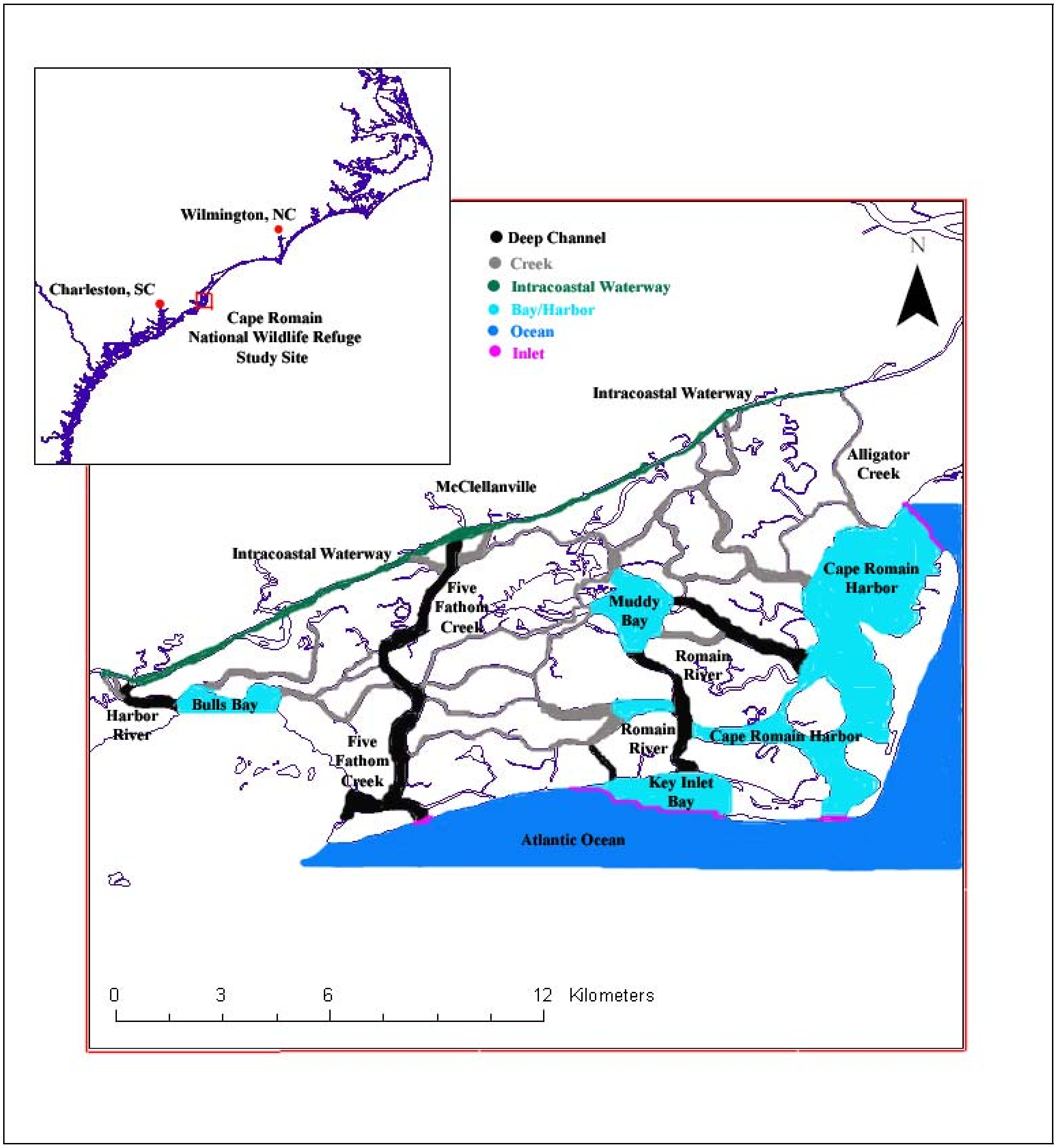

Figure 3. Cape Romain National Wildlife Refuge, SC, 200km^2 study site. Specific areas appear in the legend and are as follows: deep channel, creek, Intracoastal Waterway, bay/harbor,ocean and inlet. Intersections are not distinguished here but include all confluences between deep channels, creeks, the Intracoastal Waterway and bays/harbors.

compared to dolphins in different management units identified by researchers in North and South Carolina.

CRNWR is defined as a shallow, ocean dominated meso-tidal bar-built estuary by Dame *et al*. (2000). Bar-built estuaries form behind sand barrier islands where protected waters and sediment deposits from adjacent watersheds promote extensive marsh growth (Dame *et al.* 2000). Astronomical tides, which are responsible for most of the water exchange in the system, are semi-diurnal with a progression from the northeast to the southwest. This system is part of the southeastern coast of the United States referred to as the South Atlantic Bight (SAB), stretching from Cape Hatteras, NC to Cape Canaveral, FL (Kjerfve *et al*. 2002). Vernberg *et al.* (1992) determined that the many small bar-built estuaries in South Carolina have a greater combined total area than that of the major river systems. These small systems dominate the coastal SAB and may have a significant role in coastal ecological processes. However, little is known about most of the bar-built estuaries in the SAB, and data do not exist for evaluating historic trends for many parameters (Dame *et al.* 2000).

Torres *et al.* (2005) documented high concentrations of bottlenose dolphins, relative to other areas of the mid-Atlantic coast, off of Cape Romain, SC. In a review of ten years of inshore fish surveys conducted by South Carolina's Department of Natural Resources (SCDNR), Jennings and Kracker (2003) illustrate the importance of CRNWR as habitat for a variety of commercially important fish species. SCDNR provided fisheries data from CRNWR during the duration of this study (Fig. 4). Of the twelve most abundant fish collected during these fish surveys in CRNWR from 1989-1999, all but one

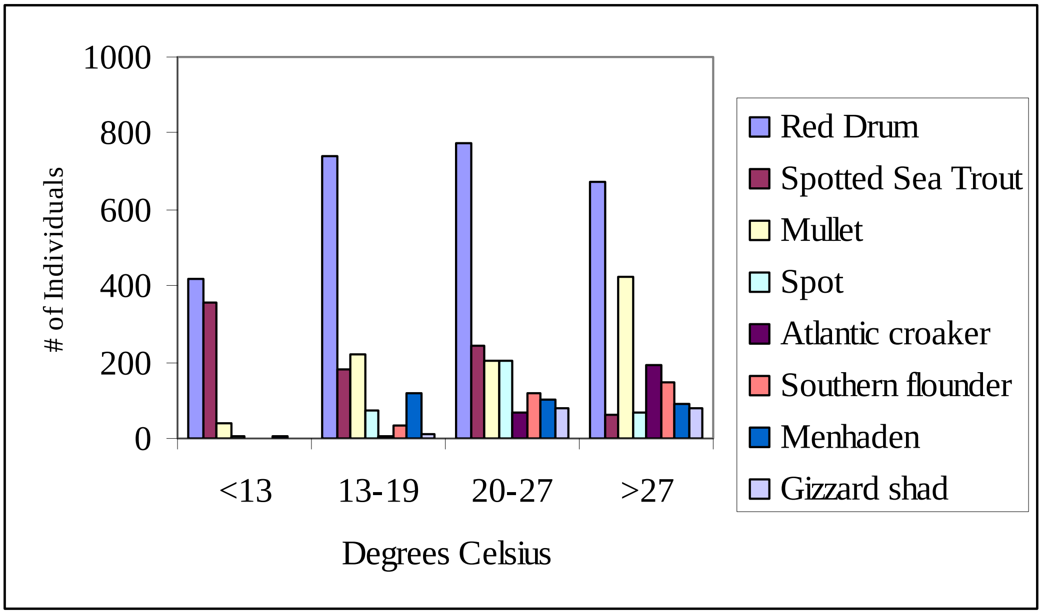

Figure 4. Catch data from Cape Romain National Wildlife Refuge from September 2003 – August 2005. Fish were collected along the marsh edge from 58 stations within my study site by South Carolina Department of Natural Resources. Values on the x axis represent water temperature in degrees Celsius. Values on the y axis represent the number of fish collected for each species. Collections were made with a trammel net from 12-14 randomly selected sites each month. All sites in the SCDNR study were selected to target red drum and there was equal survey effort across months. Catch data were provided by Charles Wenner, SCDNR Fisheries Biologist.

(the Atlantic stingray, *Dasyatis sabina*) coincide with documented prey species of bottlenose dolphins in the mid-Atlantic region (Mead and Potter 1990, Young and Phillips 2002, Gannon and Waples 2004). Fisheries data from surveys conducted in CRNWR from September 2003 – August 2005, the period of this study, indicate the presence of dolphin prey species and seasonal shifts in diversity and abundance of the same (Fig. 4). Offshore surveys show that many of these fish move offshore in fall and winter to spawn, indicating a strong connection between productivity in the estuary and adjacent offshore waters (Wenner pers. comm. 2006). Primary productivity can be up to an order of magnitude higher within 10km of estuaries compared to farther offshore (Odum 2000). Odum (2000) concluded that estuaries in the SAB are "hot spots" of trophic energy transfer to offshore waters, and that this may be represented by organisms rather than organic matter and nutrients.

I examined the seasonal occurrence of dolphins in the CRNWR, and the frequency of dolphin sightings in association with distinct areas. Selected areas were creeks, deep channels, bays, Intracoastal Waterway, inlets and the coastal ocean (Fig. 3). Intersections (creeks/channels, creeks/bays, creeks/creeks, and creeks/Intracoastal Waterway, channel/Intracoastal Waterway) were also defined as a habitat feature. The following questions were addressed in my study:

1. Are there year round and/or seasonally resident dolphins in the Cape Romain National Wildlife Refuge?
2. Are there changes in dolphin abundance and group size associated with water temperature?
3. Are there areas within the refuge where dolphins are more consistently observed, and if so, what are the physical features of these areas?

4. Do photographs of any dolphins sighted in the Cape Romain National Wildlife Refuge match those of dolphins sighted in areas to the north and south?

METHODS

Using systematic transects and photo-identification, I examined ranging histories of individually identifiable dolphins in relation to existing regional stock definitions. In addition, I examined patterns of habitat use and site fidelity.

Cape Romain National Wildlife Refuge (CRNWR) stretches from Cape Island south to Bull Island, SC along 60km of coast (Fig. 1). The northern portion of CRNWR contains a complex network of *Spartina* dominated marsh. Three major tidal creeks cut through this section of the refuge; Harbor River, Five Fathom Creek, and Romain River (Kracker 2003; Fig. 3). In addition to these deep channeled creeks, numerous smaller waterways wind through the system. Site boundaries included the Intracoastal Waterway on the western edge, the open ocean to the east, Bulls Bay (a shallow open harbor) to the south, and Alligator creek to the north (Figs. 1 and 3). A wide range of habitats existed, ranging from deep (> 5m) open ocean water to tidal mud flats and oyster reefs only navigable during high tide. This was a novel site with no documented history of bottlenose dolphin residency, site fidelity, seasonality or habitat use, and a relatively large 200km^2 area was selected (Fig. 3). Survey methods for defining residency and seasonality of bottlenose dolphins are well-described and tested in a wide range of studies worldwide (Würsig and Würsig 1977, Wells *et al.* 1980, Shane *et al.* 1986, Defran *et al*. 1990, Urian and Wells 1996, Wilson *et al.* 1997, Barco *et al.* 1999, Urian *et al.* 1999, Wilson *et al*. 1999, Brager *et al*. 2002, Chilvers and Corkeron 2002, Ingram and Rogan 2002, Zolman 2002, Guissamulo and Cockcroft 2004, Martin and da Silva 2004, Shane 2004). This study followed published protocols to achieve comparable results.

Data collection

I conducted four reconnaissance surveys in July and August 2003 to assess the survey area and determine boundaries for my study site. The only data from these surveys included in final analyses were fin photographs distinguishing individual dolphins. Additional sighting data for identifiable individuals in my study site from April – September 2002 were provided by Laura Engleby of the Dolphin Ecology Project; these data were also included in photo-identification analyses.

From September 2003 through August 2005 monthly boat-based surveys were conducted with at least two observers (Table 1). Dolphins were pursued in compliance with, and under authorization of, terms and conditions dictated in NMFS General Authorization permit number 808-1584-01. A five meter flat-bottomed skiff with a 30 hp outboard motor was used for all surveys. Survey speed averaged 15 km/h until dolphins were sighted. Traveling speed during sightings was dictated by the dolphins and generally ranged from zero to two km/h. The entire site was surveyed at least once each month (Table 1). Variation in monthly survey effort is attributed to weather, available daylight, and surveyors' schedules. At each dolphin sighting, location was recorded using

Table 1. Hours and kilometers of survey effort, number of sightings, number of dolphins sighted, and number of new dolphins identified in each survey

Month	Survey Effort (Hours)	Survey Effort (km/day)	# of Sightings	# of Dolphins	# of New Id'd Dolphins
Jul 2003	N/A	N/A	N/A	N/A	1
Aug 2003	N/A	N/A	N/A	N/A	5
Sep 2003	14.5	189.5	15	77	4
Oct 2003	22.5	353	26	129	16
Nov 2003	36	435	44	191	15
Dec 2003	10	169.5	13	32	1
Jan 2004	7	133	5	13	0
Feb 2004	10.5	134	11	31	0
Mar 2004	11	210	17	77	5
Apr 2004	19.5	273	26	90	6
May 2004	22	304	28	105	8
Jun 2004	19	289	26	125	4
Jul 2004	17.5	327.5	22	111	15
Aug 2004	21	332	20	93	2
Sep 2004	13.5	264.5	16	69	1
Oct 2004	12	154.5	13	48	1
Nov 2004	15	227.5	22	65	2
Dec 2004	11	152.5	16	37	0
Jan 2005	6.5	151	5	11	0
Feb 2005	11	229	10	50	6
Mar 2005	9.5	159	12	70	4
Apr 2005	14.5	172.5	19	74	2
May 2005	10	176	15	75	2
Jun 2005	14	256	22	128	12
Jul 2005	21	339.5	24	140	4
Aug 2005	11.5	180.5	18	59	5
TOTAL	**360**	**5,612**	**445**	**1,900**	**121**

a Garmin handheld GPS Model 12XL, salinity and temperature were recorded with a handheld meter manufactured by YSI Inc., model 85, and depth was determined with a FishEasy Fishfinder 245DS, Model 110-81, manufactured by Eagle Inc. Attempts were made to photograph the dorsal fin of each dolphin using a digital Nikon D100 camera with a 70-300 mm lens. The total number of dolphins sighted was determined by consensus between at least two observers. The presence of calves and/or neonates was noted; dolphins less than 50% of the size of accompanying adults, bearing fetal bands and/or with the appearance of a non-rigid dorsal fin, were considered neonates (Thayer *et al.* 2003). An adult dolphin seen consistently with a calf over multiple sightings was assumed to be female. Dolphins were considered part of the same group if they were within 100m of each other and behaving in a similar fashion (Shane 1990). Groups were observed until the dorsal fin of each individual was photographed, dolphins disappeared, or the vessel could no longer follow the animals due to shallow or rough water. GPS location was recorded where each group was first seen.

Additional information collected included tidal state (rising, falling, high or low). Tidal state was determined based on predictions from NOAA Charleston stations 3003, 3007, 3009, 3011, and 3013. The location of all stations was between 33^{o}01N and 33^{o}02N and 79^{o}21W and 79^{o}32W. Tides were semi-diurnal and always determined based on the closest NOAA station. Variation in tides between stations was up to one hour. Mean tidal range at all stations was between 1.4 and 1.5 meters. Sightings within one hour prior to or one hour after low tide were considered low tide sightings. Those occurring one hour after low tide up to one hour before high tide were considered incoming (rising) tide sightings. Sightings within one hour prior to or one hour after high tide were considered high tide sightings. Those occurring one hour after high tide and up to one hour before low tide were considered outgoing (falling) tide sightings.

All of the aforementioned data were recorded on a sheet developed by Kim Urian for the Sarasota Dolphin Research Program photo-identification surveys and adapted for use by Duke University and UNCW (Appendix A), although not all fields of the sheet were used. Surveys were conducted over at least two days to thoroughly cover the 200km^2 area. Several surveys were incomplete due to weather; conditions forcing cancelled surveys included sea state three or higher on the Beaufort scale and/or persistent local lightning. Surveys did not consistently begin or end at a given time in relation to diurnal period or tidal state. The order in which different areas (transects) were surveyed alternated daily and monthly so that all areas were surveyed in all tidal states and during all daylight hours. In addition, data were corrected before analysis to account for variations in survey effort in different tidal states, temperature classes or areas (see below).

Data analysis

Dorsal fin images were categorized following methods cited for the Mid-Atlantic Bottlenose Dolphin Catalog (MABDC; Urian *et al.* 1999), outlined in Appendix B. Individual animals were identified by unique fin characteristics, including nicks, notches, and mutilations (Appendix C). A catalog was created for CRNWR and compared to adjacent regional catalogs in Winyah Bay, SC, 30km to the north, Wilmington, NC, 180km north, Beaufort, NC 300km north, the Outer Banks of NC approximately 350km to the north, and Charleston, SC, 50km to the south of my site. The Winyah Bay catalog includes sightings in North Inlet, SC and Murrells Inlet, SC, which are 10km and 30km north of Winyah Bay respectively. Matches at each site were determined through pair-wise comparison of the most distinct image of each identifiable fin. Over 300,000 comparisons were made between approximately 1,200 images from the

Charleston catalog, 85 images from the Winyah Bay catalog, and 1,249 images from the combined Wilmington/Beaufort/Outer Banks catalog. Matches at each site were confirmed by the appropriate catalog curator (Todd Speakman, Rob Young and Kim Urian respectively).

Seven distinct areas were defined to examine possible habitat preferences: the Intracoastal Waterway (ICW), deep channel, creek, harbor, intersection, inlet and ocean (Fig. 3). The ICW was a relatively straight and distinct navigable channel approximately 50m across at its widest point in the survey area. A deep channel included both natural and dredged channels greater then 5m depth at mean low tide and up to 100m across. A creek was as shallow as 1m at mean low tide, up to 3m at mean high tide and up to 50m across. A harbor was an area wider then 100m, and up to 1km across. An intersection included the confluence of creeks or channels with channels, the ICW, harbors and/or other creeks. Inlets included four areas with direct access to the open ocean, and the ocean described coastal waters up to 1km off shore (Fig. 3). The center of an inlet or intersection was measured between the two closest points of land defining that feature. Using *ArcGIS*, a circle was drawn around this center and confined by the nearest land. This circle was used to identify sightings in these areas. Sightings outside of the circumference were attributed to the appropriate adjacent habitat.

Data were stored and edited in Microsoft *Excel* for Office 2000, *Access* 2000, and Adobe *Photoshop 7*. *ArcGIS/ArcMap* by Esri, Version 3.6 was used to illustrate survey and habitat areas and to generate figures of the study site. Survey data were checked for errors and imported into *SAS* Version 9 from *Access*. Observations were then weighted by survey effort. Weighting for each area was calculated by dividing the effort (in kilometers) within each area by the total effort; thus weighting was based on the percentage of effort per area. These weighted data were used for all analyses of dolphin sightings in specific areas. Data on sea surface temperature and tidal state were also weighted based on the percentage of survey effort in each temperature class or tidal state. These weighted data were used for all analyses of dolphin sightings in different temperatures and tidal states.

Trends in relative abundance associated with water temperature were tested using a chi-square test for equal distribution of dolphins/km across temperatures. A significant difference in distribution across temperatures was indicated with $p<0.05$. Chi-square tests for association were used to examine relationships between multiple variables including surface temperature, area use, group size, and tidal state. In all cases the null hypothesis was that there is no relationship between any of the variables. Expected frequencies were compared to observed frequencies, with $p<0.05$ indicating a significant relationship between variables. Results for each test are shown in tables, in which the bottom row shows the unconditional distribution of sighting probabilities across categories listed in the top row, irrespective of categories listed in the left column. The last column of each table shows the unconditional distribution of sighting probabilities across categories listed in the left column, irrespective of categories listed in the top row. Thus, if there were no effect of a given variable, the distribution of conditional probabilities for that variable should be the same as that of the unconditional probabilities. In each case, the row percents represent the relationship that is of interest; for example, how group size was affected by temperature, rather than vice versa. The chi-square analyses used to test for all of the aforementioned associations showed significant associations between two variables. However, these tests do not show the significance of the effects within the tables. I chose to report and discuss results that showed relatively large differences between expected and observed frequencies. Overall percentages for the same variables are slightly different between tables due to different corrections for survey effort based on temperature, area use, and tidal state. The difference in results is negligible.

Surface water temperature during this study ranged from 6^{o}C to 33^{o}C (Fig. 5). Four distinct temperature classes were defined to assess trends associated with temperature: <13^{o}C (cool), 13 – 19^{o}C (cool transitional), 20 – 27^{o}C (warm transitional), and >27^{o}C (warm). These categories were chosen by dividing the temperature range recorded throughout the study into four equal classes. Temperatures below 13^{o}C occurred from December through February. Temperatures between 13-19^{o}C occurred in November, March and April. Temperatures between 20 – 27^{o}C occurred from September through November and from April through May. Temperatures above 27^{o}C occurred from late-May through early September (Fig. 5).

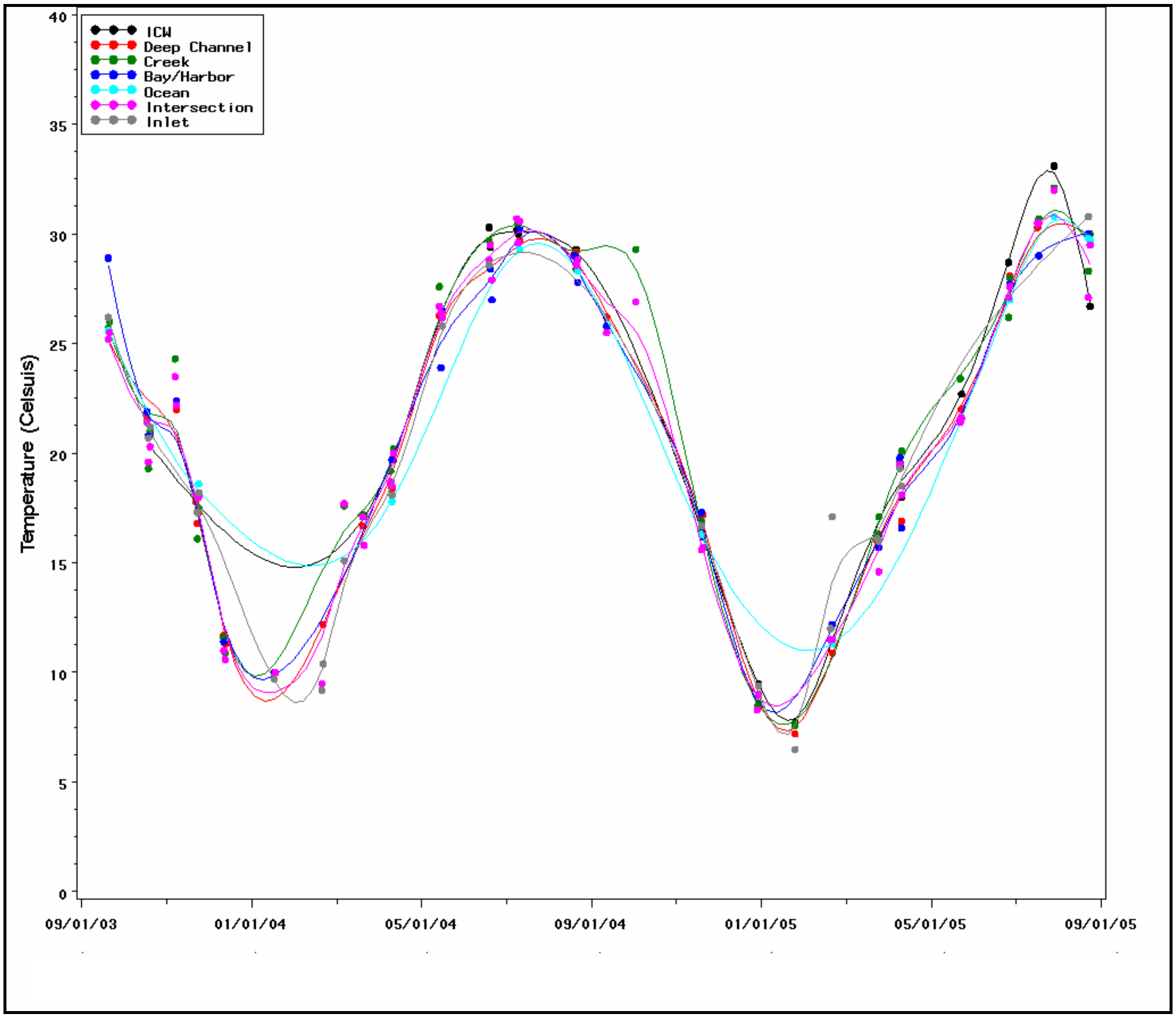

Figure 5.Temperature profile of study site from September 2003 through August 2005

Residency patterns were defined based on the sighting histories of identifiable dolphins. Individual dolphins sighted in all four temperature classes were defined as year round residents. Those sighted in one to three temperature classes over multiple years, or three temperature classes in the same year, were considered seasonal residents. Those sighted less than three times in only one year were considered transients. No identifiable dolphins were sighted more than three times in only one year in less than three temperature classes.

RESULTS

I examined 13,796 images taken from 445 sightings of 1,900 dolphins during 360 survey hours (Table 1). Based on the distinctiveness and quality of images a catalog of 121 identifiable individuals was created. Kim Urian, MABDC curator, added 107 of these fin images to the MABDC for future comparisons. The 14 fins not included in the MABDC were considered distinct enough for accurate re-identification within this study, but not distinct enough for eventual comparisons over time outside of this study. For example, a fin with a single small notch on the trailing edge of its dorsal fin could easily be identified over multiple months. However, this same fin may not be easily distinguishable among many others with similar notches outside of this study.

Residency patterns, regional movements and temperature associations

There was a significant association between relative abundance of dolphins and surface temperature ($p<0.0001$, $X^2 = 93$, df = 3, Table 2). Fewer dolphins (9.4%) were sighted in temperatures below 13^oC than expected based on survey effort (17.7% of km surveyed were in temperatures below 13^oC); Table 2). Relative abundance increased with surface temperature, with slightly more dolphins sighted than expected at all other temperatures (Table 2).

Dolphins were present in CRNWR in all water temperatures surveyed. New individuals were discovered throughout the study period (Fig. 6). Only 36% (687) of fins were identifiable from the 1,900 dolphins sighted. This includes multiple sightings of the same individuals. Individuals with unmarked fins could not be reliably re-identified although it is likely many of these animals were sighted on multiple occasions. Identifiable individuals were categorized as either year round residents (n = 22), seasonal residents (n = 49), or transients (n = 50) based on their sighting histories. Appendix D details sighting histories of these identifiable dolphins, including how often individuals were seen over how many years in each temperature class.

The 22 year round residents were sighted between four and 20 times each. Fifteen of these dolphins were sighted in 2002 by Laura Engleby, and thus have sighting histories that exceed the length of this study. Two transient dolphins, one seen in cool waters and one seen in warm waters, were also recorded by Engleby in May and September of 2002, respectively. More transients were identified in warm waters (Appendix D), but this may be a reflection of greater survey effort when temperatures were warm (Table 1). Seasonal

Table 2.Trends in relative abundance associated with water temperature. ($p<0.0001$, $X^2 = 93$, df = 3). Fewer dolphins (9.4%) were sighted than expected (17.7%) based on kilometers of survey effort in waters <13^{o}C. Abundance remained higher than expected in all other temperatures classes.

Temp. Celsius	Effort (km)	% dolphins sighted
< 13^{o}C	17.7%	9.4%
13-19^{o}C	21.5%	25. 9%
20-27^{o}C	27.8%	29.4%
>27^{o}C	33.0%	35.4%

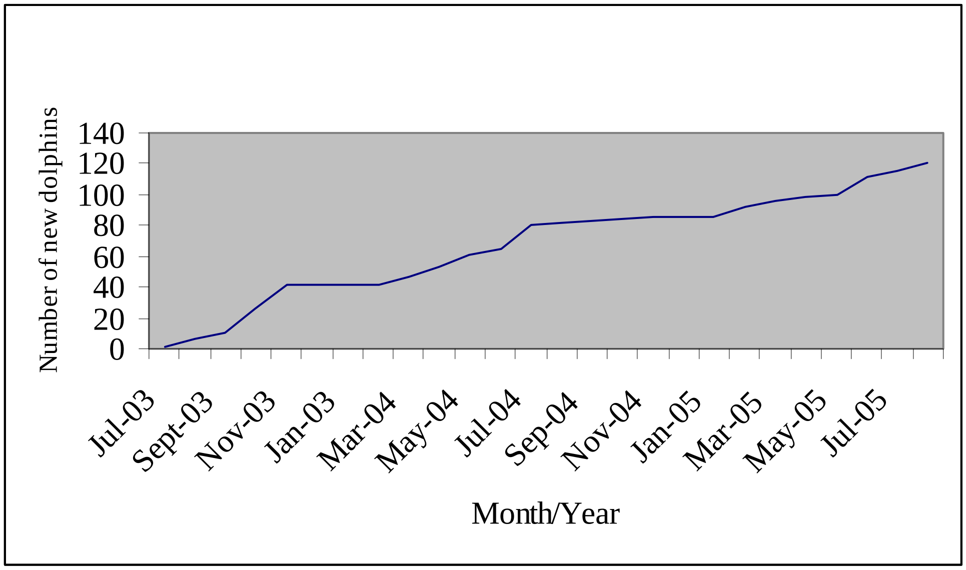

Figure 6. Cumulative discovery of identifiable dolphins throughout the study period from July 2003 through August 2005, including data from reconnaissance surveys.

residents 80000, 80003, and 20003, sighted 19, 11 and ten times respectively, may be year round residents missed during months with less survey effort.

Eleven fin photographs were matched between CRNWR and other sites along the coast (Charleston, SC, Winyah Bay, SC, North Inlet, SC, Murrells Inlet, SC and Wilmington, NC). No matches existed between sites farther north than Wilmington, NC, including Beaufort, NC and the Outer Banks of NC (Fig. 7). No comparisons were attempted with catalogs south of Charleston, SC. Of the six matches to Winyah Bay, four were dolphins sighted exclusively in the estuary in this study (70006, 70011, 70016, 80008). Dolphins 70016, 70011 and 70006 were sighted together in Winyah Bay in June 2001. Dolphin 70016 was considered a year round resident in CRNWR, and 70011 was a seasonal resident that was sighted with 70016 in CRNWR in 2005. The 2005 sighting occurred in February in Cape Romain Harbor (Fig. 3). Dolphin 70006, seen only once in this study, was sighted with three other dolphins on October 19, 2003 in a creek leading from a deep channel to another creek. On this occasion, 70006 was seen with another Winyah Bay dolphin, 80008, which was sighted with dolphin 70011 in Winyah Bay in July 1999. Dolphin 80008 has an extensive year round sighting history in North Inlet, SC, which is 40km north of my site and 10km north of Winyah Bay. Winyah Bay inlet is 10km north Cape Romain Inlet, and the North Inlet marsh system is connected to and adjacent to Winyah Bay (Fig. 7). The sighting in CRNWR of 80008 and 70006 also included a seasonal resident, 80003, sighted 19 times over four years in CRNWR. Dolphin 80003 was also sighted at least once with 70016 and with 70011 on separate occasions. The other two dolphins matched to Winyah Bay (80015 and 30005; Figure 7)

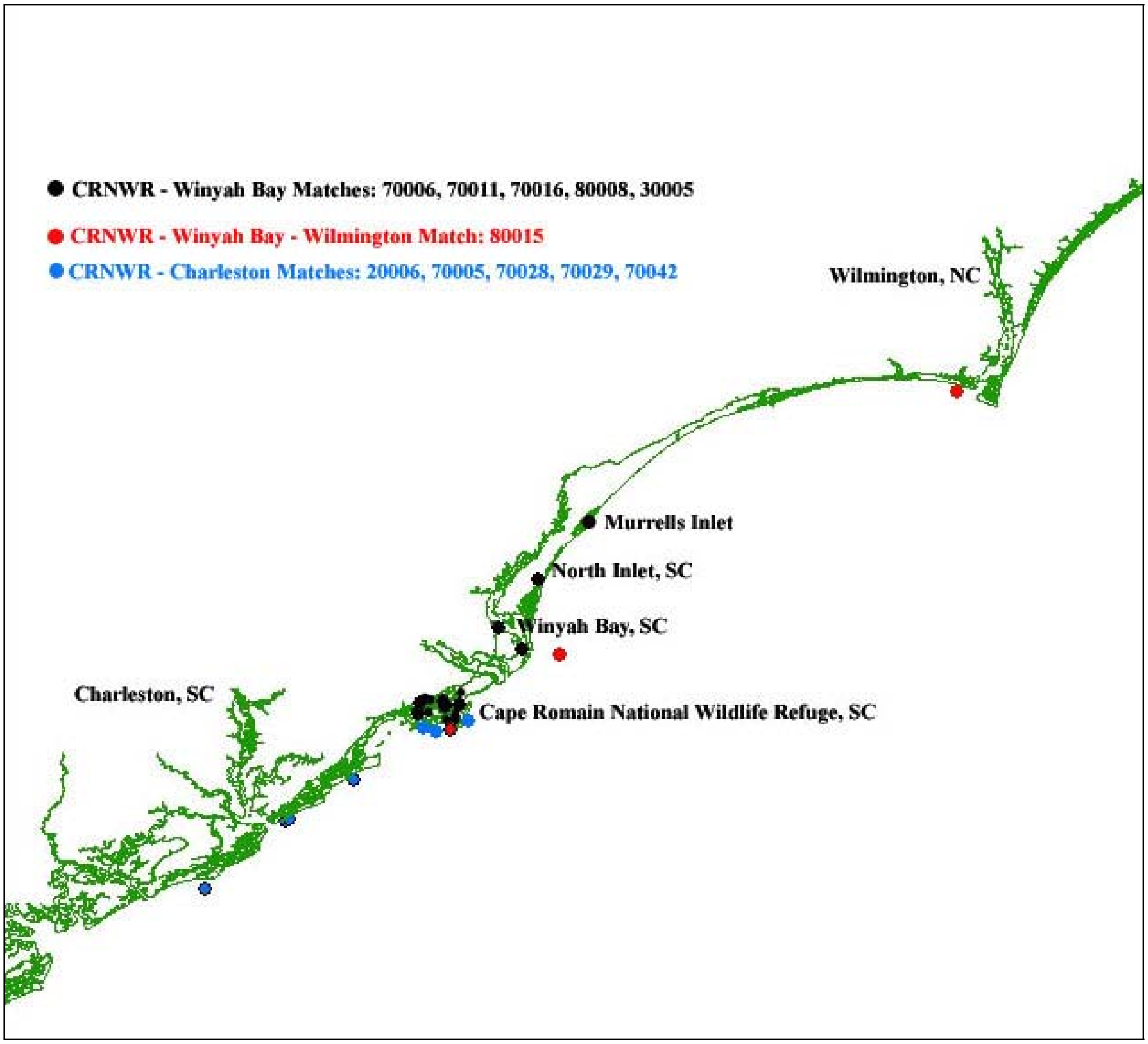

Figure 7. Regional movements of dolphins matched between catalogs. Matches between CRNWR and Winyah Bay shown in black represent dolphins 70006, 700011, 70016, 30005 and 80008. Dolphin 80015, which was matched between CRNWR, Winyah Bay and Wilmington, NC, is represented in red. Matches between CRNWR and Charleston are represented in blue.

were sighted once in this study, each in separate events in the ocean. Dolphin 80015 was sighted in CRNWR in April 2004, in the ocean outside of Winyah Bay in July 1999, and in Wilmington, NC in August 2002, also in the ocean (Fig. 7). Dolphin 30005, sighted in CRNWR on June 27, 2005, was photographed in association with a shrimp trawler. This dolphin was sighted on October 29, 2004 in Murrells Inlet, SC, which is 60km north of CRNWR. Although 30005 was not matched to the Charleston catalog, this sighting included a Charleston match, dolphin 70042.

The remaining five CRNWR dolphins matched to other field sites were seen in Charleston, SC (20006, 70005, 70028, 70029, 70042; Fig. 7). In my study, these five dolphins were all sighted only once, and all were in the ocean. Three of these dolphins, 20006, 70028 and 70029, were seen together in CRNWR in July 2004 in association with a shrimp trawler. Dolphin 70028 had a year round sighting history in Charleston from January 1999 through August 2004 and had been seen in association with shrimp trawlers in Charleston. Dolphins 20006 and 70029 were seen once in Charleston in November 2003 and May 2003 respectively; dolphin 20006 was associated with a shrimp trawler. Dolphin 70042 was sighted once in Charleston in May 2004, and was sighted in June 2005 in CRNWR in a group of 20 dolphins associating with a shrimp trawler. One of the dolphins in this large group was 30005, which was mentioned previously as having been sighted in Murrells Inlet. The remaining Charleston dolphin, 70005, was sighted in the ocean in this study in September 2003 with a group of over 30 dolphins. This animal was seen twice in Charleston in January 1999 and February 2005.

The number of sightings with neonatal calves (n=51) was too small to carry out statistical tests relating them to water temperature. Sightings that occurred in each month are shown in Fig 8; peaks occurred in November, July and August. However, data were not corrected for survey effort; therefore the November peak may simply reflect greater survey effort. Almost half (n=22) of the sightings with neonatal calves were in groups of six to ten animals, 17 were with three to five dolphins, eight were with groups of more than ten animals, and only four were sighted with just one adult.

Habitat use, group size and temperature associations

More dolphins were sighted in groups of three to five in all temperatures. Still, dolphin group size varied significantly with sea surface temperature ($p<0.0001$, $X^2 = 87$, df = 12, Table 3, Figure 9). In Table 3, the bottom row and far right column are overall (unconditional) percentages of sightings corrected for survey effort in all temperatures. Thus, 35.7% of all groups contained between three and five dolphins and 30.6% of all sightings occurred at 13-19^oC. All row percentages are conditional distributions of group size based on the temperature category that defines the row. All column percentages are conditional distributions across temperatures, based on the size of the group for that column. These conditional percentages can be compared to the overall (unconditional) percentages. Only row percentages are considered, as discussed previously. Thus, 17.5% of all groups encountered contained just one dolphin, indicating that single dolphins were seen more than expected (27.1%) in waters <13^oC. In contrast, groups larger than six were seen less frequently (6.8% and 3.4%) than expected (20.1% and 5.1% respectively) in waters <13^oC.

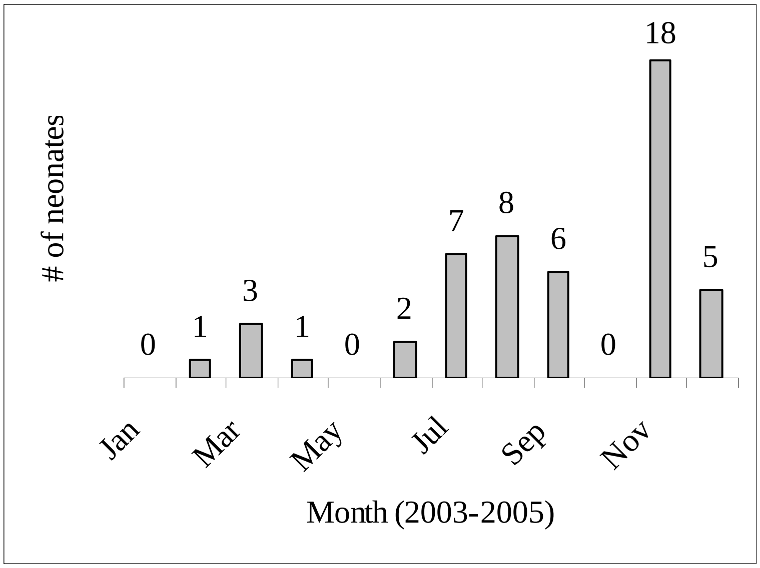

Figure 8. Neonate sightings by month (not corrected for survey effort).

Table 3. Association between temperature and dolphin group size. ($p<0.0001$, $X^2 = 87$, df = 12). The 'Overall' values represent overall percentages of each group size or temperature class; for example, 35.7% of all groups, irrespective of temperature, contained 3-5 dolphins, and 19.8% of sightings occurred in waters <13°C, regardless of group size. For example, single dolphins were seen more than would be expected (27.1%) in waters <13°C, as only 17.5% of sightings overall consisted of single dolphins. Groups with six or more dolphins were seen less than expected (6.8% and 3.4% vs. 20.1% and 5.1%) in <13°C. In temperatures >27°C there were less single dolphins and pairs and more groups with 3 or more animals. Only row percentages are used for comparison in this and all other tables as they reflect the association of interest in each case (here, the effect of temperature on dolphin group size).

	Group Size					Overall
Temperature Celsius **Row percent** *Col. percent*	**One**	**Two**	**Three to Five**	**Six to Ten**	**More than 10**	
< 13	**27.1** *30.6*	**28.8** *26.4*	**33.9** *18.8*	**6.8** *6.7*	**3.4** *13.1*	*19.8*
13-19	**15.3** *26.7*	**21.6** *30.6*	**36.0** *30.9*	**22.5** *34.2*	**4.5** *26.9*	*30.6*
20-27	**16.8** *24.3*	**21.9** *25.6*	**31.9** *22.7*	**24.4** *30.6*	**5.0** *24.9*	*25.3*
27 or more	**13.2** *18.4*	**15.4** *17.4*	**40.4** *27.7*	**23.5** *28.5*	**7.4** *35.1*	*24.4*
Overall	**17.5**	**21.6**	**35.7**	**20.1**	**5.1**	100.0

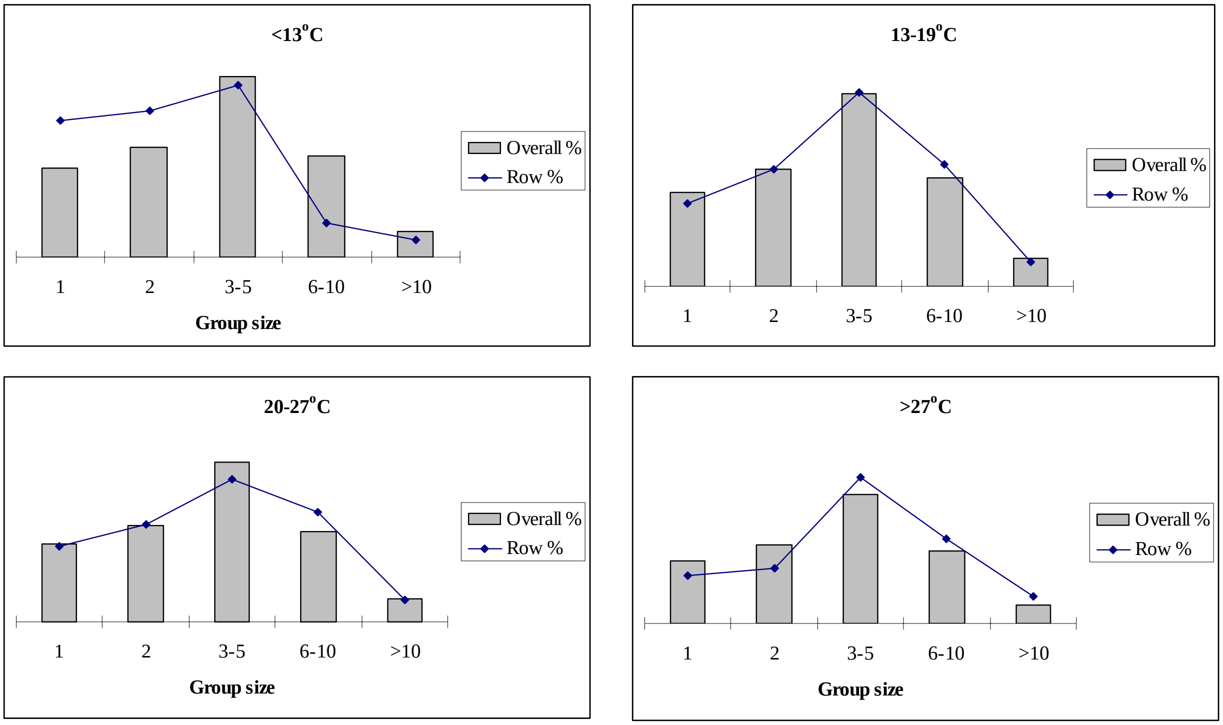

Figure 9. Association of temperature and dolphin group size (data from Table 3). Gray bars represent overall percent occurrence of each group size, irrespective of temperature; thus, these are the same in all four graphs. Lines represent actual percentage of each group size in a given temperature class; thus, more sightings of small groups and fewer sightings of large groups occurred in temperatures less than 13 degrees than were expected.

Dolphin area use (corrected for survey effort) also varied significantly with water temperature ($p<0.0001$, $X^2 = 2983$, df = 18, Table 4, Figure 10). More sightings occurred in the ocean in temperatures >27°C (6.5%) than expected (3.5%), and in inlets in temperatures <20°C (12.2% and 11.8%) than expected (5.3%). More sightings also occurred in harbors between 20-27°C (16.3%) than expected (9.3%). Overall (irrespective of temperature), more sightings occurred in creeks (28.5%) and intersections (35.2%) than in other areas. Most sightings at intersections occurred at the confluence of creek/channel (n=48) and harbor/channel (n=34) as opposed to creek/creek (n=24); creek/harbor (n=14); creek/ICW (n=13); or channel/ICW (n=3). There were only seven intersections between creek/ICW, two between channel/ICW, 11 between creek/channel, eight between channel/harbor and ten between creek/harbor, as opposed to 21 between creek/creek. However, these sightings were not corrected for the amount of effort spent surveying each type of intersection. I observed dolphins pursuing two of the most abundant species collected during SCDNR fish surveys, red drum (*Scianops ocellatus*) and striped mullet (*Mugil cephalus*), in creeks and intersections.

Dolphin group size varied significantly with area use ($p<0.0001$, $X^2 = 8538$, df = 24, Table 5, Figure 11). More sightings of single dolphins occurred in deep channels (31.1%) than expected (15.7%). Groups with between six and ten animals were sighted more in harbors (26.1%) than expected (9.7%). Groups with greater than ten dolphins were sighted much more often in the ocean (54.2%) than expected (3.4%). Dolphin area use varied significantly with tidal state ($p<0.0001$, $X^2 = 890$, df = 18, Table 6, Figure 12). More sightings occurred in inlets (15.5%) and harbors (20.5%) at high tide than expected (7.3% and 11.8%, respectively).

Table 4. Association between temperature and area use ($p<0.0001$, $X^2=2983$, df=18). See legend to Table 3 for explanation of table format.

	Area							
Temp. Celsius **Row Pct** *Col Pct*	**ICW**	**Deep Channel**	**Creek**	**Bay/Harbor**	**Ocean**	**Intersection**	**Inlet**	**Overall**
< 13	**1.2** *8.1*	**13.6** *10.8*	**22.1** *9.9*	**5.0** *6.8*	**0.5** *1.8*	**45.4** *16.4*	**12.2** *29.4*	*12.8*
13-19	**2.5** *32.8*	**23.5** *38.2*	**28.0** *25.8*	**5.7** *16.0*	**2.3** *17.3*	**26.2** *19.5*	**11.8** *58.4*	*26.3*
20-27	**1.9** *28.6*	**3.2** *5.9*	**36.2** *37.8*	**16.3** *52.2*	**2.8** *23.4*	**38.0** *32.2*	**1.6** *9.3*	*29.8*
27 or more	**1.9** *30.5*	**23.4** *45.1*	**24.2** *26.5*	**7.5** *25.0*	**6.5** *57.6*	**36.1** *31.9*	**0.5** *2.8*	*31.2*
Overall	**2.0**	**16.2**	**28.5**	**9.3**	**3.5**	**35.2**	**5.3**	100.0

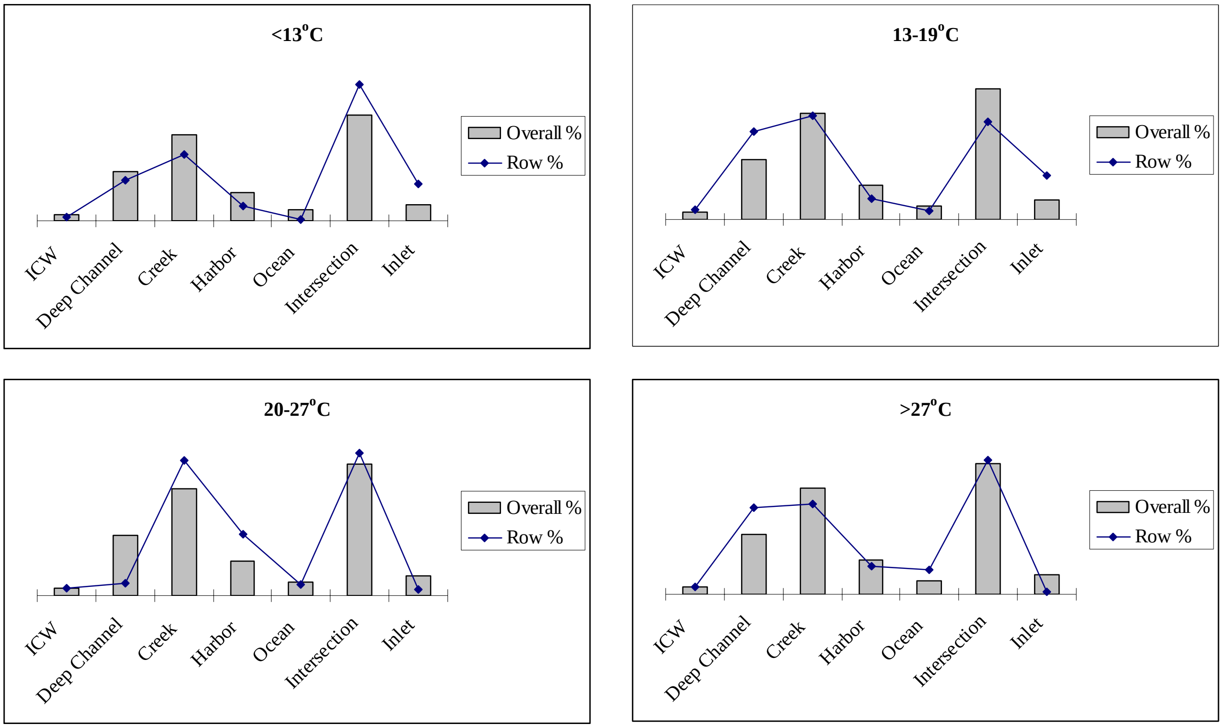

Figure 10. Association between temperature and dolphin area use (data from Table 4). Gray bars represent overall percent occurrence in each area, irrespective of temperature; thus, these are the same in all four graphs. Lines represent actual percentage of sightings in a given temperature class; thus, more sightings occurred in inlets and intersections in temperatures less than 13 degrees than were expected, in deep channels and inlets in 13-19°C, in creeks in 20-27°C, and in the ocean and deep channels in >27°C.

Table 5. Association between dolphin group size and area use ($p<0.0001$, $X^2 = 8538$ $df = 24$). See Table 3 for explanation of table format.

	Area							**Overall**
Group Size **Row Pct** *Col Pct*	**ICW**	**Deep Channel**	**Creek**	**Bay/Harbor**	**Ocean**	**Intersection**	**Inlet**	
One	**2.5** *22.8*	**31.1** *34.3*	**29.3** *17.0*	**3.6** *6.3*	**0.9** *4.6*	**30.7** *15.4*	**1.8** *6.0*	*17.3*
Two	**3.0** *29.0*	**5.1** *6.1*	**47.0** *29.5*	**2.5** *4.8*	**1.1** *6.1*	**38.6** *21.0*	**2.7** *9.7*	*18.7*
Three-Five	**1.8** *38.8*	**15.0** *40.4*	**29.6** *41.8*	**8.5** *36.9*	**1.3** *15.8*	**35.2** *43.2*	**8.6** *70.0*	*42.1*
Six-Ten	**0.7** *6.4*	**15.4** *18.1*	**17.7** *11.0*	**26.1** *49.8*	**3.4** *18.9*	**33.3** *18.0*	**3.4** *12.1*	*18.5*
> Ten	**1.7** *3.0*	**5.1** *1.1*	**4.9** *0.6*	**6.3** *2.2*	**54.2** *54.6*	**24.4** *2.4*	**3.3** *2.2*	*3.4*
Overall	**1.9**	**15.7**	**29.9**	**9.7**	**3.4**	**34.3**	**5.1**	100.00

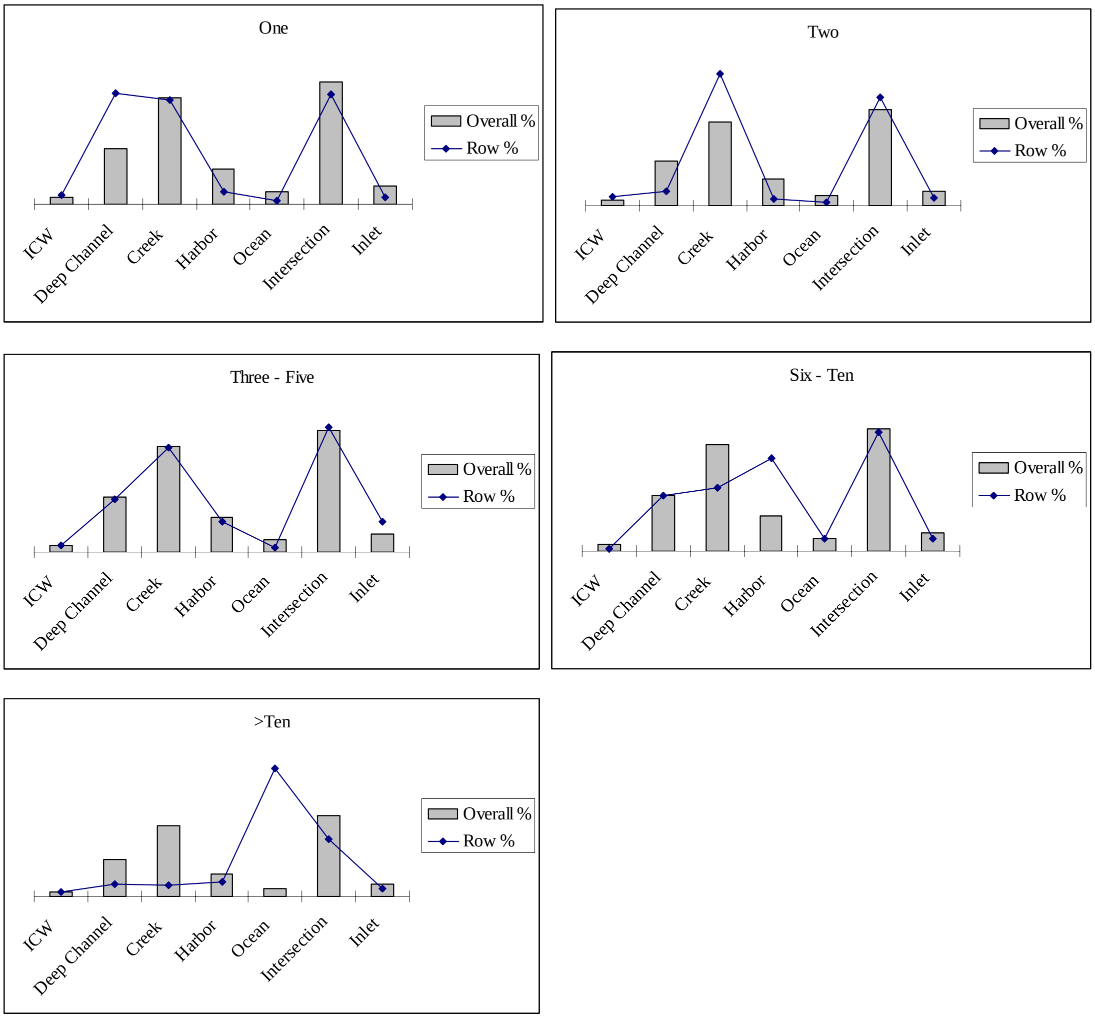

Figure 11. Association between dolphin group size and area use (data from Table 5). Gray bars represent overall percent occurrence of sightings in each area, irrespective of group size; thus, these are the same in all five graphs. Lines represent actual percentage of sightings of each group size in each area; thus, more sightings of single dolphins and pairs occurred in deep channels and creeks and more sightings of groups with 6 or more dolphins occurred in harbors and the ocean than would be expected.

Table 6. Association between tidal state and dolphin area use ($p<0.0001$, $X^2 = 54$, $df = 18$). See Table 3 for explanation of table format.

	Area							Overall
Tide **Row Pct** *Col Pct*	**ICW**	**Deep Channel**	**Creek**	**Bay/Harbor**	**Ocean**	**Intersection**	**Inlet**	
Rising	**7.4** *38.3*	**11.5** *24.9*	**20.2** *32.8*	**9.5** *25.1*	**6.1** *52.3*	**39.5** *33.1*	**6** *25.5*	*31.4*
Falling	**6.8** *29.6*	**17.7** *32*	**17.3** *23.3*	**10.3** *22.9*	**2.3** *16.2*	**40.6** *28.3*	**5** *17.8*	*26.1*
High	**5.4** *17.1*	**15.6** *20.6*	**18.6** *18.4*	**20.5** *33.3*	0.00 0.00	**24.5** *12.5*	**15.5** *40.4*	*19.1*
Low	**3.9** *15.1*	**13.9** *22.5*	**21.1** *25.5*	**9.4** *18.6*	**4.0** *31.5*	**41.8** *26.1*	**5.1** *16.2*	*23.4*
Overall	**6.0**	**14.5**	**19.3**	**11.8**	**3.6**	**37.4**	**7.3**	100.0

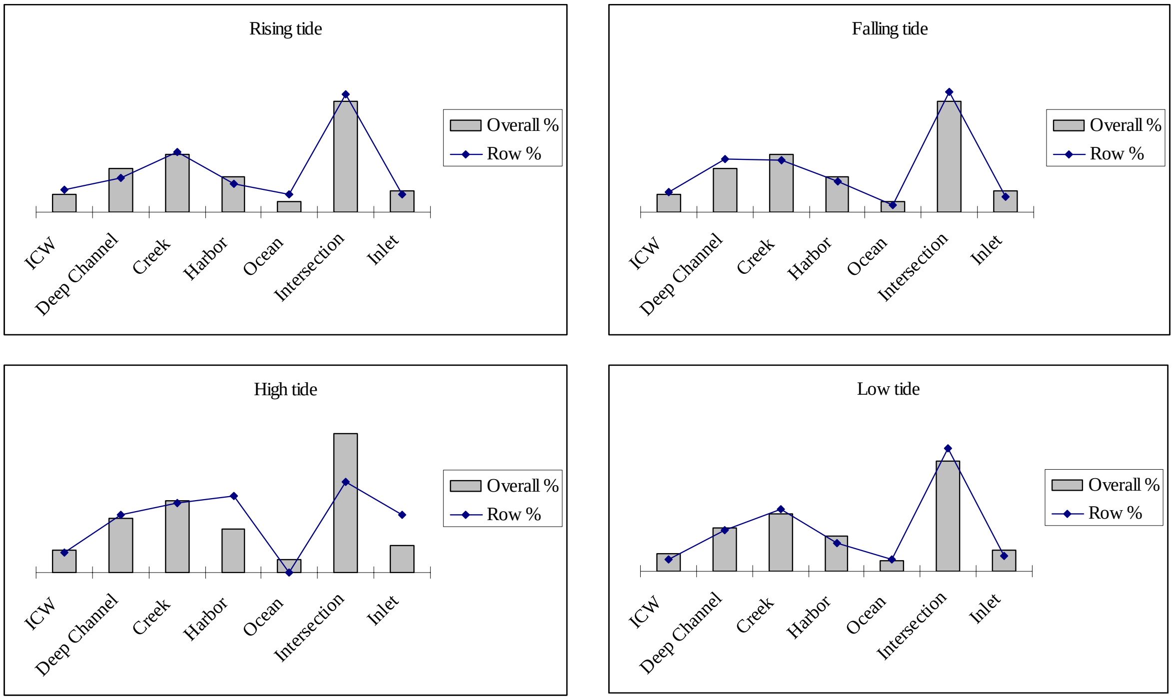

Figure 12. Association between tidal state and dolphin area use (data from Table 6). Gray bars represent overall percent occurrence of sightings in each area irrespective of tidal state; thus, these are the same in all four graphs. Lines represent actual percentage of sightings in each area in each tidal state; thus, more sightings than expected occurred in harbors and inlets at high tide.

DISCUSSION

This study documented the presence of year round and seasonally resident dolphins within the Cape Romain National Wildlife Refuge (CRNWR) near McClellanville, SC. Dolphins, although present year round, exhibited shifts in abundance with changes in sea surface temperature, and showed clear habitat preferences within the refuge. Distinct individuals illustrated movement to the north and south of this study site through confirmed matches between regional fin catalogs.

Based on the presence of at least 22 distinct dolphins in waters ranging from $6^{o}C$ to $33^{o}C$, it is clear that some dolphins use CRNWR year round. Twelve of these residents showed some degree of long-term site fidelity. Ten were sighted over three years and two were sighted over four years in this area. Dolphins sighted repeatedly over multiple years, yet classified as seasonal residents, are quite likely year round residents that were missed in one temperature class during surveys. The remaining seasonal residents were sighted more than once and up to ten times in various temperature classes and/or over multiple years.

Fewer dolphins were present in temperatures below $13^{o}C$, which occurred from December through February. Relative abundance increased with sea surface temperature through April, and remained relatively high through November. Clearly, CRNWR provides seasonal habitat for bottlenose dolphins throughout much of the year.

Seasonal shifts in the abundance of coastal dolphins are documented elsewhere in the South Atlantic Bight (SAB). Friedlander *et al.* (2001) documented a dramatic increase in dolphin local abundance which was associated with spot (*Leiostomas xanthurus)* abundance in October – November just south of Wilmington, NC.

In an analysis of ten years of survey data in CRNWR, South Carolina's Department of Natural Resources (SCDNR) fisheries data indicated a significant peak in the abundance of spot during spring and summer, approximately 20km south of this study site directly across Bulls Bay at its southern shore (Jennings and Kracker 2003). This seasonal peak in spot abundance coincides with an increase in the relative abundance of dolphins in this study. Species diversity and abundance among the fishes in CRNWR exhibit seasonal fluctuations (Jennings and Kracker 2003, Wenner pers. comm. 2006; Fig. 4). A seasonal shift in relative abundance, and group size, of dolphins may be a response to the abundance and behavior of prey. Most sightings in the ocean consisted of large groups of animals, and many of these large groups were in warm water, coinciding with an increase in abundance of dolphin prey species including red drum (*Scianops ocellatus*), spotted sea trout (*Cynoscion nebulosus)*, spot (*Leiostomus xanthurus)*, Atlantic croaker (*Micropogonias undulatus*), and striped mullet (*Mugil cephalus*) (Mead and Potter, 1990, Gannon and Waples, 2004, Young and Phillips, 2002; Fig. 4). These temporal correlations may indicate an association between dolphins and their prey in CRNWR.

Fishes listed here as primary prey for dolphins are all defined as marine transient species (Deegan *et al*. 2000), that is, they move offshore when water temperatures drop, presumably to spawn. The dependence of marine transient fish on estuaries is supported by dietary, behavioral, and isotopic evidence (Deegan *et al.* 2000). Since many of the primary prey for bottlenose dolphins are marine transient fishes, it seems likely that movements of these prey influence dolphin movements, and estuaries provide significant habitat for transient dolphins as well as residents. Considering evidence presented by Odum (2000) illustrating high levels of trophic transfer from estuaries to coastal waters, these seasonally resident and transient dolphins may undertake latitudinal movements based on biotic factors. Estuarine fishes that move offshore to spawn in winter, presumably cued by water temperature, may attract associated predators including bottlenose dolphins.

Torres *et al*. (2005), in a distribution and abundance study of bottlenose dolphins along the US mid-Atlantic coast, documented the greatest relative seasonal abundance of coastal bottlenose dolphins up to 3km offshore of Cape Romain in fall/winter. This corresponds with apparent movement of both fish and dolphins out of CRNWR in winter. No photo-identification information exists for dolphins found up to 3km offshore of CRNWR in winter. The hypothesis that seasonally resident and transient dolphins in CRNWR and elsewhere in the SAB move offshore in winter, primarily up to 3km, should be tested through photo-identification and biopsy research.

Temporal and spatial fluctuations in dolphin group size and area use in response to sea surface temperature may also be associated with prey. The most common group size was three to five animals, which is consistent with findings for bottlenose dolphins in coastal habitats (reviewed by Connor *et al.* 2000). Group size is apparently influenced by habitat structure and dolphin activity (Shane *et al.* 1986). More single dolphins were sighted in cool water, when primary prey species are less abundant, and are spread out evenly within the marsh (Wenner pers. comm. 2006; Fig. 4). It may be more efficient to forage in smaller groups when prey is scattered, or there may simply be less food in winter and subsequently fewer dolphins. However, larger groups could be expected where and when prey school together. In open waters, the likelihood of predation may increase for dolphins; thus traveling in larger groups may be a useful strategy to detect and avoid predators. Most sightings in harbors and in the ocean occurred in temperatures above 20^{o}C, when schooling fishes such as mullet, spot and croaker were more abundant in CRNWR. Likewise, most groups with more than ten dolphins were sighted in temperatures above 20^{o}C, and in harbors and the ocean.

Hastie *et al*. (2004) found a strong link between habitat features and foraging behaviors of bottlenose dolphins within the Moray Firth, Scotland. Habitat features in CRNWR may also be associated with foraging, although this was not tested. Most sightings overall occurred in intersections, creeks and deep channels, suggesting a strong preference for these areas over the ICW, harbors, inlets and the coastal ocean. Habitat selection among fishes in tidal marshes indicated that multiple factors interacting over time influence where these animals reside (Craig and Crowder 2000). The same is no doubt true for their predators. Craig and Crowder (2000) also noted that fish habitat preferences primarily included vegetated areas of the marsh. In CRNWR, intersections, creeks and deep channels are edge habitats, bordered by *Spartina* marsh and dissected by numerous small creeks that drain the flooded marsh .A high abundance of fish in these areas could be driving the relatively high abundance of dolphins observed. Intersections serve as conduits between areas within the marsh, create dynamic physical features such as eddies, and concentrate prey in water flowing in and out of the system (Kneib 2000). Dolphins may prefer these areas for travel within the marsh and/or for locating prey concentrated in ebbing or rising tides. Results in this study suggested intersections of creek/channel and harbor/channel were preferred over other combinations by dolphins. Future studies looking at physical features and prey abundance at different types of intersections may shed light on why these areas may be preferred.

Fewer sightings overall occurred in the ICW, harbors, inlets and open ocean. These habitats provide relatively little concentrated fish habitat comparable to marshes. However, most of the sightings in inlets and harbors occurred at high tide, which may indicate a connection between dolphins from nearshore waters and fish coming into the estuary with the tide. Boat traffic in the ICW may also be a factor in the relative paucity of sightings in this area.

Fluctuations in dolphin group size may result from influences other than foraging, such as reproductive cues. Thayer *et al.* (2003) documented a peak in reproductive seasonality among bottlenose dolphins in North Carolina estuaries in April and May. In CRNWR more sightings with neonates occurred in waters 13-19^{o}C, which correlates with temperatures in March, April and November. Most sightings of neonates occurred in group sizes of six to ten animals, which occurred more often than expected in waters warmer than 13^{o}C. In South Carolina, stranding patterns of neonate calves indicate a calving peak in spring and fall, with the strongest peak in November (McFee pers. comm. 2006). In this study most sightings with neonates occurred in November.

Other biological factors, including predator avoidance, may influence dolphin group size and area use. Creeks within the marsh provide pathways between habitats as well as access to drainage areas from flooded marsh (Kneib 2000). In addition, these areas may provide some protection from predators. Among dolphins on the west coast of Florida, complex inshore habitat is thought to provide protection from sharks and influence dolphin group size (Shane *et al.* 1986). Several dolphins in this study bore scars from apparent interactions with sharks, including healed and fresh wounds on the dorsal body surface matching the mouth profile of a large shark. Predator avoidance may influence the preferential use of creeks, intersections, and deep channels within the marsh.

Trends showing a decrease in relative abundance in cool temperatures supported existing hypotheses of seasonal movements among coastal bottlenose dolphins in the mid-Atlantic. Barco *et al.* (1999), Mead and Potter (1990), Torres *et al*.(2005), Urian *et al*. (1999), and Zolman

(2002) document seasonal movements of coastal bottlenose dolphins relative to sea surface temperature. Coastal migratory patterns have been confirmed through stranding analysis (Mead and Potter 1990, McLellan *et al.* 2002), aerial surveys (Torres *et al*. 2005), regional studies (Barco *et al.* 1999), and photo-identification (Urian *et al*. 1999) north of Cape Hatteras, NC. Coastal dolphins present north of Cape Hatteras, NC to Long Island, NY in summer months are absent in winter months (Mead and Potter 1990, McLellan *et al*. 2002). These dolphins apparently leave northern waters when surface temperatures drop below 16^{o}C (Barco *et al.* 1999). Identifiable dolphins were matched through MABDC between sites in Cape May, NJ in the summer and Cape Hatteras, NC in the winter, indicating that these northern coastal dolphins over-winter off Cape Hatteras, NC (Urian *et al*. 2005). An increase in abundance off Cape Hatteras, NC in winter, reviewed in Torres *et al*. (2005), reinforces this hypothesis. South of Cape Hatteras, NC, where the SAB begins, seasonal trends are less well understood and more difficult to define. Photo-identification of individuals in this study showed regional movements that may aid in this understanding.

Four of the six dolphins from CRNWR matched to individuals from Winyah Bay, SC exhibited site fidelity within the estuary. Petricig (1995), Gubbins (2000), Young and Phillips (2002), and Zolman (2002), documented year round residents found exclusively within the boundaries of estuaries in South Carolina. The ICW and a series of salt marsh creeks connect CRNWR and Winyah Bay, although there is also an ocean entrance to this area 10km north of Cape Romain inlet. North Inlet and Winyah Bay are connected, and all of the dolphins documented by Rob Young in North Inlet also enter Winyah bay on occasion, but not all Winyah Bay animals venture into North Inlet. Three of the dolphins sighted in CRNWR and Winyah Bay were sighted within the estuary in both locations. It is possible these animals may primarily or exclusively use connecting creeks and the ICW for their intra-coastal travels. One dolphin with an extensive year round sighting record in North Inlet and Winyah Bay, SC was sighted within the tidal marsh in CRNWR. Also, the few times Young surveyed outside Winyah Bay in the ocean and on shrimp trawlers, he did not find any of the animals documented in the North Inlet/Winyah Bay groups. However, not all of the dolphins in the aforementioned groups are present in that study area year round, so they must travel either north, south, or offshore. All of the dolphins sighted by Rob Young in Murrell's Inlet were sighted exclusively in the coastal ocean, indicating a pattern similar to that found in this study. That is, some dolphins seem to occur primarily, if not exclusively, within estuaries while others do not seem to enter these systems at all (Young pers. comm. 2006). These animals' movements may represent an extended home range among dolphins living primarily within estuaries. Regardless, these sightings indicate a wider range of estuarine habitat use than was included in this study. It is also clear from this and the aforementioned estuarine studies, that in addition to animals that appear to primarily stay within boundaries of the estuary, there are seasonally resident and transient dolphins that move between the ocean and estuaries. However, it is not clear if year round residents travel outside of estuaries.

Read *et al*. (2004) showed the significance of including bottlenose dolphins living in bays, sounds and estuaries in abundance estimates used for management purposes. There is no sighting information for dolphins within estuaries south of CRNWR to Charleston, SC. Further research south to Charleston may create a better understanding of the abundance, site fidelity, and range of coastal dolphins within estuaries as well as help define differences among these animals and other coastal bottlenose dolphins.

In addition to providing information about movement patterns, the Winyah Bay/CRNWR sightings suggest long-term associations among individuals exhibiting site fidelity. A year round and a seasonal CRNWR resident were seen together in June 2001 in Winyah Bay and February 2005 in CRNWR. In the 2001 sighting another CRNWR dolphin, considered a transient because it was sighted only once in this study, was with them. This transient dolphin was sighted in CRNWR in October 2003 with an animal sighted year round in Winyah Bay and North Inlet. This North Inlet dolphin was also sighted with the seasonally resident CRNWR dolphin in Winyah Bay in July 1999. In addition, three of these dolphins, the CRNWR year round resident and transient, and the North Inlet dolphin, were each seen with the same seasonal CRNWR dolphin, sighted 19 times in this study, on separate occasions. But this seasonal CRNWR resident was never seen in Winyah Bay. The pattern of association among these four dolphins is consistent with other studies of resident dolphins reviewed in Shane (2004), suggesting some long-term, short-term, and fluid associations among animals exhibiting long-term site fidelity. These associations also suggest some of the animals within estuaries from CRNWR to North Inlet may be part of the same community, or members of neighboring communities with overlapping and/or extended home ranges such as found on the Gulf coast of Florida (reviewed in Connor *et al.* 2000).

Movement of some coastal dolphins may be connected to commercial fisheries and associated opportunistic feeding (Chilvers and Corkeron 2002). Four of the five dolphins sighted in coastal nearshore waters of CRNWR and matched to individuals in the Charleston catalog were seen in association with shrimp trawlers. Two of these dolphins were sighted in Charleston on separate occasions with trawlers. Three were sighted together in July 2004 in CRNWR. There are no sightings of these animals together in Charleston. Chilvers and Corkeron (2002) and

Fleming (2004) suggest dolphins feeding in association with shrimp trawlers have different habitat preferences and group sizes than overlapping groups of animals that do not associate with these vessels. They recommend comparison studies of dolphin social structure and ranging patterns where trawling occurs. Sightings in the CRNWR extended the range north of all five dolphins sighted in Charleston, including the only match to CRNWR not seen in either area associated with a trawler. Further examination of dolphins associated with trawlers in this area may provide insight into how this fishery impacts seasonal and/or regional movements.

Regional movements discussed here provide information that may prove useful in describing stocks of bottlenose dolphins for management purposes. Photo-identification information provides data critical for defining and evaluating stock descriptions. For example, photo-identification information led to the description of a northern migratory stock of coastal dolphins (Urian *et al.* 2005). NMFS placed these animals into a discrete management unit defined as the "Northern Migratory Management Unit" (Fig. 2). These animals are managed as a separate stock in the summer, north of Cape Hatteras, NC, and as a mixed stock overlapping with the Northern North Carolina Management Unit and the Southern North Carolina Management Unit in the winter (Fig. 2). The existence of a mixed stock consisting of year round residents in Pamlico Sound, NC and the Northern Migratory Management Unit off Cape Hatteras, NC in winter is reviewed in Urian *et al*. (2005) and supported by fin comparisons. Data supporting mixing between the Northern Migratory Management Unit and the Southern North Carolina Management Unit includes only two matched fins between Beaufort, NC and Wilmington, NC. To date there have been no matches between fin catalogs north and south of Beaufort, N.C., suggesting dolphin movement south of Beaufort may not include stocks from farther north (Urian *et al.* 2005). Based on fin comparisons, dolphins identified in the ocean in CRNWR were present from Charleston, SC to Wilmington, NC in all seasons over several years. These sightings include all of the Charleston matches as well as Winyah Bay, SC, Murrells Inlet, SC and Wilmington, NC. Two of the Charleston dolphins were sighted in winter in Charleston and summer in CRNWR. While this may show some seasonal movement, given the relatively short distance (50km), this more likely represents large home ranges. The dolphin matched between CRNWR, Winyah Bay, and Wilmington, NC, moved between the South Carolina Management Unit and the Southern North Carolina Management Unit. Given the distance between CRNWR, Charleston and Wilmington, approximately 200km, this animal may also have an extended range that varies seasonally. Shane *et al*. (1986), in a review of ranging patterns for bottlenose dolphins, cite an example of distinctly marked animals sighted up to 300km from the area where they were considered resident. These animals did not exhibit strong site fidelity in an estuarine environment, but rather an extended range in coastal waters. Continued research focusing on accurate stock descriptions based on photo-identification efforts and biopsy data are required to properly describe coastal bottlenose dolphin stocks in the SAB.

Considering that the SAB begins just south of Cape Hatteras, and includes nearshore waters influenced more consistently by the productivity of coastal estuaries and the Gulf Stream, it is not surprising that dolphins south of Cape Hatteras are present year round. Some may exhibit strong site fidelity, as evidenced by animals residing year round within estuaries, and some may primarily travel in nearshore waters in association with migratory fishes, and possibly commercial fisheries. If this scenario exists, then management units in the SAB may need some adjustment to more accurately reflect overlapping dolphin stocks as well as dolphins living primarily in estuaries.

Conclusion

Cape Romain National Wildlife Refuge is a dynamic, highly productive estuarine system. Efforts are currently underway to protect threatened species living within the refuge, such as loggerhead sea turtles and a variety of colonial nesting shore birds. Research in progress includes the monitoring of fish populations, and quantifying the biological, physical and chemical characteristics of this environment (Kracker 2003). Prior to this study no information existed to inform researchers and/or managers interested in CRNWR about the presence or habitat preferences of one of the system's top predators -- bottlenose dolphins. Bottlenose dolphins may seriously impact fish populations (Young and Phillips 2002), and an understanding of their seasonal abundance and year round presence may help fisheries managers. Adding bottlenose dolphins to the inventory of species studied in CRNWR is a critical step towards better understanding the system.

In the context of this study, in relation to questions originally set forth, several things can be said about bottlenose dolphins in CRNWR. The refuge provides habitat for bottlenose dolphins year round. Some of the same dolphins reside within the refuge year round and others inhabit the area seasonally. In winter months relative abundance of dolphins, and their likely prey, is lowest. There are areas within CRNWR where dolphins are more consistently observed. Finally, some of the same dolphins found within CRNWR move north up to 180km and south up to 50km along the coast within the SAB.

In a broader context, information about individual dolphins in and around CRNWR informs those assessing movements and defining stocks of coastal bottlenose dolphins in the mid-Atlantic. Continuing to narrow the data gap between CRNWR and Charleston, SC will help create an even clearer picture, and tell a more complete story, of coastal and estuarine dolphins in the mid-Atlantic.

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APPENDIX A

DUML Sighting Form

Photo Grade: ☐

Field Hours ________ to ______

Effort [S O C] High Tide: ________

Date & initial when complete:
Photo-analysis:
Data entry:

Date: __/__/__

Sighting No: ____

Platform ____________________

Recorder/Observers ________________________________ Time: ____ to ____

Location ________________________________ LOC ____

Begin: Latitude ____ Longitude ____ Beaufort Scale: ____

End: Latitude ____ Longitude ____

Depth: ____ ft. Water Temp: ____ °F Tide: IN 1 OUT 2 HI 3 LOW 4 Salinity: ____ ‰

Activity: Mill 1, Feed 2, Prob. Feed 3, Travel 4, Play 5, Rest 6, Leap Tailslap Chuff 7, Social 8, w/Boat 9, Other 0 ____

FIELD ESTIMATES	MIN	MAX	BEST	PHOTO ANALYSIS Pos IDs	Min not IDed	Max not IDed	Revised MIN	Revised MAX	Final BEST
TOTAL DOLPHINS									
TOTAL CALVES									
YOUNG OF YEAR									

Comments: ________________________________

Dolphins Sighted: ID confirmation: P= photograph V= visual O = other (explain)

Name	Code	Conf.	Name	Code	Conf.	Name	Code	Conf.

Photos: (roll: frame->frame) ________________________________

Tape: (reference number) ________________________________

APPENDIX B

Measurement of Photographic Quality and Dolphin Distinctiveness for the Mid-Atlantic Bottlenose Dolphin Photo-ID Catalog
Kim Urian, Curator

Section 1.01 OVERALL PHOTOGRAPHIC QUALITY
Overall Photographic Quality is based on the quality of the photograph **independent** of the distinctiveness of the fin.

The Overall Photographic Quality score is based on an evaluation and sum of the following characteristics (these scores are absolute values, not a sliding scale):

- **Focus/Clarity**
  Crispness or sharpness of the image. Lack of clarity may be caused by poor focus, excessive enlargement, or motion blur; for digital images, poor resolution resulting in large pixels.

  2 = excellent focus 4 = moderate focus 9 = poor focus, very blurry
- **Contrast**
  Range of tones in the image. Images may display too much contrast or too little. Photographs with too much contrast lose detail as small features wash out to white. Images with too little contrast lose the fin into the background and features lack definition.

  1 = ideal contrast 3= either excessive contrast or minimal contrast
- **Angle**
  Angle of the fin to the camera.

  1 = perpendicular to camera 2 = slight angle 8 = oblique angle
- **Partial**
  A partial rating is given if so little of the fin is visible that the likelihood of re-identifying the dolphin is compromised on that basis alone. Fins obscured by waves, *Xenobalanus*, or other dolphins, would be evaluated using this rating.

  1 = the fin is fully visible, leading & trailing edge 8= the fin is partially obscured
- **Proportion of the frame filled by the fin**

An estimate of the percentage area the fin occupies relative to the total area of the frame.

1 = greater than 5%; subtle features are visible 5 = less than 1%; fin is very distant
To score Overall Photographic Quality, sum the scores for each characteristic:

6 - 9:	Excellent quality	=> **Q-1**
10–12:	Average quality	=> **Q-2**
>12 :	Poor quality	=> **Q-3**

Section 1.02 OVERALL DISTINCTIVENESS
Overall Distinctiveness is based on the amount of information contained on the fin; information content is drawn from leading and trailing edge features, and pattern, marks, and scars.

D-1 - Very distinctive; features evident even in distant or poor quality photograph

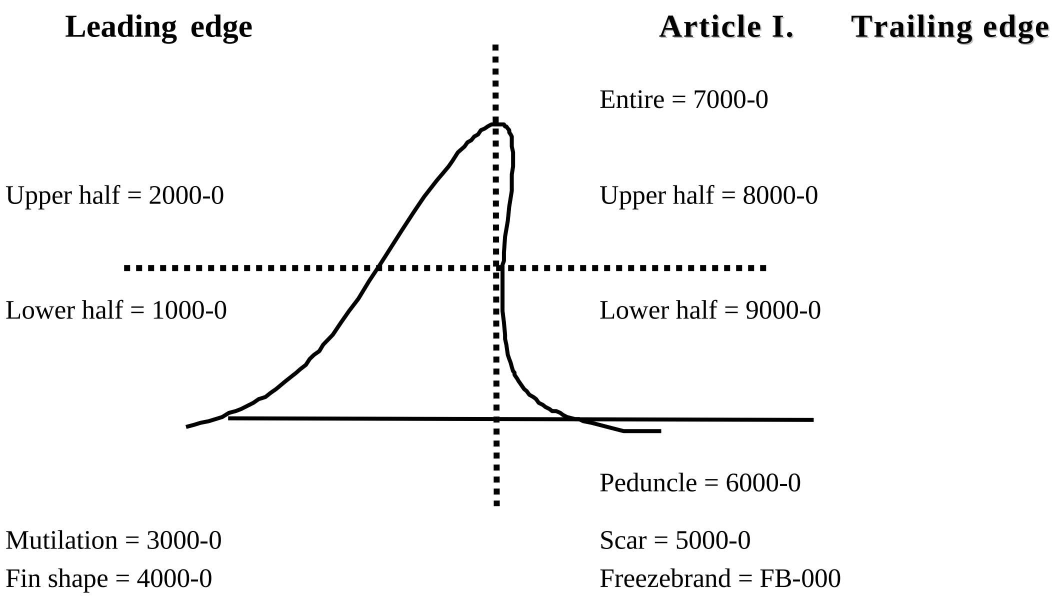
D-2 - Average amount of information content: 2 features or 1 major feature are visible on the fin

D-3 - Not distinctive; very little information content in pattern, markings or leading and trailing edge features

These measurements are derived from: Friday et al. 2000. Measurement of photographic quality and individual distinctiveness for the photographic identification of humpback whales, *Megaptera novaeangliae*. Marine Mammal Science 16: 355-374.

APPENDIX C

Mid-Atlantic Bottlenose Dolphin Photo-ID Catalog (MABDC) Dorsal Fin Categories (Developed by Kim Urian)



The categories are based on the location of the most prominent feature on the dorsal fin. Location is determined by examining the fin, beginning at the anterior insertion of the dorsal fin and following along the fin contour to the posterior insertion of the fin, and using the following key:

<u>MABDC Category</u>

1. a) Dolphin has a freezebrand on dorsal fin and/or body **Freezebrand** **[FB-000]**
2. a) The most prominent feature is located on the dorsal fin............3
   b) The most prominent feature is located on the peduncle **Peduncle** **[6000-0]**
3. a) Dorsal fin is intact, with "typical" shape.................................4
   b) Dorsal fin is not intact or does not have "typical" shape:…….A
   - A. Fin has notch, nick or slice on lower half of leading edge **Lead**, **lower half** **[1000-0]**
   - B. Fin has notch, nick or slice on upper half of leading edge **Lead**, **upper half** **[2000-0]**
   - C. Fin is cut off, top or tip of fin is missing **Mutilation** **[3000-**

0]

D. Fin has unique shape or is canted/bent/curled **Left/Right Bend**
[4000-0]

4. a) Dorsal fin has scarring, pigmentation pattern, healed wound **Scarring**
[5000-0]
   b) Dorsal fin does not have scarring..5

5. a) Fin has most prominent feature on trailing edge:……………..A

A. equally distinctive features in upper & lower half of fin **Entire**
[7000-0]

B. distinctive features in upper half of fin **Upper half**
[8000-0]

C. distinctive features in lower half of fin **Lower half**
[9000-0]

APPENDIX D

Sighting histories of identifiable individuals from Sept. 2003 – August 2005, including April – Sept. 2002. *Dolphins identified first by Laura Engleby in 2002. Year round residents are indicated by an abbreviated superscript ‘yr’.

Dolphin ID	**6-12 degrees**	**13-19 degrees**	**20-26 degrees**	**27-33 degrees**	**Total # of Sightings**	**# of years sighted**
90004^{yr}	3	2	4	11	20	3
70003^{yr}*	6	2	2	9	19	4
80003*		2	7	10	19	4
80001^{yr}	3	6	3	6	18	3
70009^{yr}	1	3	3	10	17	3
20001^{yr}*	1	4	4	7	16	4
80014^{yr}	1	5	2	8	16	2
90002^{yr}	3	2	4	6	15	3
70010^{yr}	1	2	1	10	14	3
80021^{yr}*	1	4	4	5	14	3
80000*		2	2	7	11	4
20003	1		2	7	10	2
40000^{yr}	2	5	2	1	10	3
70012^{yr}	1	2	3	4	10	3
90008^{yr}	2	4	1	3	10	3
80005^{yr}	1	2	3	3	9	3
80022^{yr}	1	1	2	5	9	2
90011*			1	8	9	3
70007			1	7	8	2
70013		2		6	8	3
80006^{yr}	1	3	2	2	8	3
80007^{yr}*	1	2	3	2	8	4
80011		2	1	5	8	3
80020		1	2	5	8	2
70016^{yr}	1	2	2	2	7	2
70017	1	2		4	7	2
70024			2	5	7	2
80004^{yr}	1	3	1	2	7	3
80019				7	7	2
80023			1	6	7	2

Appendix D Cont'd.

90009	1	3		3	7	2
90010[yr]	2	2	1	2	7	2
20002*		1	1	3	6	3
70021			1	5	6	2
70022*			1	5	6	3
70026			1	5	6	2
70027		2		4	6	2
80033[yr]	2	2	1	1	6	1
70014[yr]	1	2	1	1	5	3
70037				5	5	1
80010		3	1	1	5	2
80012		1		4	5	3
80013		2		3	5	2
80016		2		3	5	2
80025			1	4	5	2
90007		1	1	3	5	3
70035		1	1	2	4	1
80009	2	1	1		4	2
80029	1	2		1	4	2
80030[yr]	1	1	1	1	4	1
20004				3	3	2
30003				3	3	2
70002		1		2	3	2
70004	1		2		3	2
70015		1		2	3	3
70018	1	2			3	2
70023			1	2	3	2
70025*	1	1		1	3	2
70033	1	1		1	3	1
70048				3	3	2
80002			1	2	3	2
80032	1	1	1		3	1
90001		2	1		3	2
90005		3			3	2
90018		1		2	3	1
70011*	1		1		2	2
70032			1	1	2	2

Appendix D Cont’d.

80024				2	2	2
80028	1	1			2	2
80037			1	1	2	1
80041				2	2	1
90006		2			2	1
90012*			1	1	2	3
90013			1	1	2	2
90016			1	1	2	1
20005				1	1	1
20006				1	1	1
20007			1		1	1
20008				1	1	1
20009				1	1	1
30000		1			1	1
30001			1		1	1
30004*					1	2
30005				1	1	1
30006				1	1	1
70005			1		1	1
70006			1		1	1
70008				1	1	1
70019			1		1	1
70028				1	1	1
70029				1	1	1
70031				1	1	1
70034	1				1	1
70036		1			1	1
70038				1	1	1
70039				1	1	1
70040				1	1	1
70041				1	1	1
70042				1	1	1
70043				1	1	1
70044				1	1	1
70045				1	1	1
70046				1	1	1
70047				1	1	1

Appendix D Cont'd.

80008			1		1	1
80015		1			1	1
80017		1			1	1
80026				1	1	1
80027				1	1	1
80034		1			1	1
80035		1			1	1
80038				1	1	1
80039				1	1	1
80040*				1	1	2
80042		1			1	1
90003			1		1	1
90014				1	1	1
90015		1			1	1
90017				1	1	1
90019				1	1	1
80031*	1				1	2