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Use of Photo-identification and Mark-recapture Techniques to Identify Characteristics of the Stock Structure of Coastal Bottlenose Dolphins (Tursiops truncatus) Off Northern South Carolina

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Use of photo-identification and mark-recapture techniques to identify characteristics of the stock structure of coastal bottlenose dolphins (*Tursiops truncatus*) off northern South Carolina

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To my father, who taught me that work comes before play, that a job well done only has to be done once, and that life is about following ones heart.
Dad, wherever you are, I hope you are proud of me.

1965-1999

To my mother who has always supported my decisions, even when she disagreed with them, and encouraged me to follow my dreams.
Mom, thank you for all your support and understanding.

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Abstract

National Marine Fisheries Service (NMFS) stock assessment reports describe two coastal and two estuarine bottlenose dolphin stocks that utilize the waters of northern South Carolina (Waring *et al.* 2014), but coastal data from this area are lacking. Photo-ID mark-recapture surveys were conducted from 2013-2015 along two 50 km coastal transects centered on Murrells Inlet, SC; and from 2014-2015 along two 50 km transects covering both coastal and estuarine waters centered on Little River, SC. Capture histories of marked individuals were used to estimate abundance and, in conjunction with neighboring catalog comparisons, infer movements, residency patterns, and stock membership. Local abundance estimates derived from the Markovian Mt model (MARK 6.2) varied seasonally and inter-annually. The most reliable abundance estimates are from the 2013 and 2014 summers (371 and 1441, CV 0.17 and 0.14, respectively). Lack of recaptures and low distinctive rates caused an upward bias for estimates in the other seasons. Decreased winter abundance was reflected in our data by a 2-fold decrease in sightings-per-unit-effort (SPUE) from summer to winter. The fall migratory peak attributed to the Southern Migratory Coastal Stock was reflected by a 2-fold increase in SPUE between summer and fall. A likely shift in stock composition occurred between summer and fall given the lack of recaptures. Members of the Northern South Carolina Estuarine System Stock were sighted in coastal waters as far north as Murrell's Inlet, supporting NMFS definitions; but several members of the Southern North Carolina Estuarine System Stock were sighted in coastal waters 70 km south of their currently defined southern boundary, potentially warranting a revision. Dorsal fin matches among several catalogs indicate that multiple stocks overlap in northern South Carolina and that an undefined coastal stock occurs from southern North Carolina to northern South Carolina, possibly as far north as Cape Lookout, NC and as far south as Charleston, SC in the summer.

Preface

This thesis is divided into three chapters. The first chapter reviews literature on bottlenose dolphins (*Tursiops truncatus*) on the US east coast and mark-recapture methodology. The second chapter discusses bottlenose dolphins off the northern South Carolina coast. Finally, the third chapter expands to an additional survey area on the border with North Carolina.

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Chapter 1 – Literature Review

Coastal Bottlenose Dolphin Stocks

Bottlenose dolphins (*Tursiops truncatus*) are found in tropical and temperate latitudes worldwide (Reeves *et al.* 2002). In the western North Atlantic Ocean, bottlenose dolphins are divided into two morphotypes: offshore and coastal (Blaylock *et al.* 1995, Rosel *et al.* 2011, Waring *et al.* 2015) and are federally protected under the Marine Mammal Protection Act (MMPA, 16 U.S.C. §1361 *et seq.*). The coastal morphotype is considered “depleted” (MMPA, 16 U.S.C. §1362) due to a large die-off in 1987/1988 (Scott *et al.* 1988).

Since the 1987/88 die-off, scientific efforts were focused on examining bottlenose dolphin stock structure and seasonal movements (Hohn 1997, Waring *et al.* 1999, Waring *et al.* 2000, Waring *et al.* 2001). Scott *et al.* (1988) proposed a single stock of coastal migratory bottlenose dolphins ranging from New Jersey to central Florida based on the temporal and geographic pattern of strandings during the 1987/88 epizootic. An alternative hypothesis included the presence of several migratory stocks and/or several resident stocks (Hohn 1997). McLellan *et al.* (2002) suggested the presence of more than one stock based on examinations of long-term stranding records for the entire US east coast. In a genetic study, Rosel *et al.* (2009) found at least 5 distinct populations in the coastal and estuarine waters between New Jersey and northern Florida.

Our understanding of bottlenose dolphin stocks has evolved over recent years. From 2002 to 2007, seven management units were recognized as follows: the Northern Migratory (NMU), the Northern North Carolina (NNCMU), the Southern North Carolina (SNCMU), the South Carolina (SCMU), the Georgia (GAMU), the Northern Florida (NFLMU), and the Central Florida (CFLMU) management units (Waring *et al.* 2002, Waring *et al.* 2007). The SNCMU ranged from Cape Lookout (Waring *et al.* 2007) as far south as Murrell's Inlet, SC and the SCMU ranged from Murrell's Inlet to the Savannah River at the SC/GA border (Urian *et al.* 1999, McFee *et al.* 2006). The proposed management units were listed as depleted due to the lack of baseline data for each management unit and the high mortality rates in fishing gear (Waring *et al.* 2002, Waring *et al.* 2007).

In 2008 and 2009 the management units were listed as stocks (Waring *et al.* 2009a, Waring *et al.* 2009b). The Southern Migratory Coastal Stock (SM) was defined in 2008 as coastal dolphins migrating from North Carolina to central Florida (Waring *et al.* 2009a). The Northern North Carolina and the Southern North Carolina management units were redefined to include only estuarine dolphins and renamed as Northern North Carolina Estuarine System Stock (NNCESS) and Southern North Carolina Estuarine System Stock (SNCESS) respectively (Waring *et al.* 2014). In 2010 the South Carolina and the Georgia management units were redefined and combined into one stock, the South Carolina/Georgia Coastal Stock (SC/GA) (Waring *et al.* 2011).

Currently, the National Marine Fisheries Service (NMFS) recognizes eleven estuarine stocks and five coastal stocks including in the latter: the Northern Migratory (NM), the Southern Migratory (SM), the South Carolina/Georgia (SC/GA), the Northern

Florida (NFL), and the Central Florida (CFL) coastal stocks (Waring *et al.* 2015). These stocks recently suffered from another disease outbreak that killed over 1,800 dolphins between the years of 2013 and 2015 (NMFS 2015) and are still considered depleted under the MMPA (Waring *et al.* 2014). Under the MMPA, depleted stocks are considered strategic and require current information to calculate and report the potential biological removal (PBR) (MMPA, 16 U.S.C. §1386) in the form of stock assessment reports. PBR is based on estimates of abundance, a maximum rate of increase, and a fixed recovery factor (MMPA, 16 U.S.C. §1362).

Stock assessment reports (SARs) prepared for bottlenose dolphins have been typically based on abundance estimates derived from stratified aerial surveys. Sightings from these surveys were attributed to the different stocks based on their geographical location. Yet, according to the latest SAR "[t]he spatial extent of these [coastal] stocks, their potential seasonal movements, and their relationship with estuarine stocks are poorly understood" (Waring *et al.* 2014). Consequently, current abundance estimates for coastal stocks may be biased by the unintentional inclusion of sightings from multiple stocks in their calculations.

Understanding the boundaries of each dolphin stock, along with potential seasonal movements and stock overlap are crucial steps to appropriate management of activities that may incidentally take dolphins such as fishery bycatch and ship strikes. When stock boundaries are defined based on the best available data, survey areas can be properly designated and population parameters can be estimated with less bias. The northern boundary of the Northern Migratory stock is well defined given that their summer range is not shared with any other stock (coastal or otherwise). However, due to the high potential for overlap with estuarine and/or coastal stocks, the boundaries for the other four coastal stocks are rather artificially defined.

Bottlenose dolphin stocks off northern South Carolina

Currently four stocks are described to inhabit coastal water of northern South Carolina for at least part of the year: two estuarine and two coastal (Waring *et al.* 2014). The estuarine stocks are the Northern South Carolina Estuarine System Stock (NSCESS) and the Southern North Carolina Estuarine System Stock (SNCESS), both described to occur in nearshore coastal waters. Coastal stocks include the Southern Migratory Coastal Stock (SM), and the South Carolina/Georgia Coastal Stock (SC/GA).

The Northern South Carolina Estuarine System Stock (NSCESS) was recently described in 2013 as dolphins inhabiting estuarine and nearshore coastal waters (up to 1 km offshore) from Murrell's Inlet to Prince Inlet (SC) (Waring *et al.* 2014). Its northern boundary is separated from the southern boundary of the SNCESS by a 70 km stretch of sandy beaches with no connections to the Intracoastal Waterway. Population size for this entire stock is unknown (Waring *et al.* 2014), however Brusa (2012) estimated a population of 84 dolphins for the North Inlet-Winyah Bay National Estuarine Research Reserve portion of the stock in 2011-2012.

The Southern North Carolina Estuarine System Stock (SNCESS) is defined as dolphins that inhabit both estuarine and nearshore coastal waters (< 3 km from shore) from the southern Pamlico Sound to the Little River Inlet at the North Carolina/South Carolina border (Waring *et al.* 2014). Based on satellite tag telemetry, freeze-brand tags, and long term photo-identification studies, these dolphins undertake small seasonal migrations spending winters south of New River and summers between Cape Fear and

Cape Lookout, including parts of southern Pamlico Sound (Waring *et al.* 2014). According to stock assessment reports, this stock overlaps with the SM coastal stock between late fall and spring in coastal waters (Waring *et al.* 2014).

The Southern Migratory Coastal Stock (SM) has the least understood distribution (Waring *et al.* 2014). Stable isotope data suggest this stock occurs between southern North Carolina and Georgia, overlapping with both estuarine and coastal stocks along its range, including the SC/GA coastal stock (Waring *et al.* 2014). Limited satellite tag data indicate that these dolphins stay in North Carolina during the summer and fall, migrating as far south as northern Florida for the winter and returning to North Carolina in the spring (Waring *et al.* 2014). However, other studies suggest that their southern migration starts in the fall (McFee *et al.* 2006, Speakman *et al.* 2010, Young (unpublished data)).

McFee *et al.* (2006) observed a significant increase in neonate bottlenose dolphin strandings during the fall and spring between the years of 1997 and 2003 in South Carolina. Interestingly, neonate strandings were higher only in the fall for the northern portion of the state from Little River to Murrell's Inlet (McFee *et al.* 2006). This trend is consistent with transect surveys that have shown an influx of dolphins in October and November (1995-1997) for northern SC (Young and Peace 1999) and an influx of transient dolphins in November and December (2005-2006) for the Charleston area (Speakman *et al.* 2010). Limited photo-identification analysis from this influx has revealed matches ranging from Wilmington, NC (Speakman *et al.* 2010, Young (unpublished data)), to Jacksonville, FL (Speakman *et al.* 2010).

The South Carolina/Georgia Coastal Stock (SC/GA) is defined as dolphins occupying coastal waters up to 100 m deep from the North Carolina/South Carolina border to the Georgia/Florida border and it is based on the presence of dolphins in coastal waters both in SC and GA during the summer months when the SM stock is presumably found north of Cape Lookout (Waring *et al.* 2014). The presence of coastal dolphins in South Carolina is supported by summer (Waring *et al.* 2014) and winter (Torres *et al.* 2005) aerial surveys and by long-term photo-identification studies primarily in the Charleston Harbor area.

Zolman *et al.* (2002) identified the presence of transients and seasonal residents that were not part of the estuarine population. Speakman *et al.* (2006) described an estuarine and a coastal dolphin population near the Charleston Harbor. Coastal dolphins were noted to follow shrimp boats and to be restricted to the coastal area or the open areas of the Charleston Harbor associated with shrimp boat traffic (Speakman *et al.* 2006). In a photo-identification study aboard South Carolina Department of Natural Resources (SCDNR) trawlers, no dolphins previously known to associate with shrimp boats were matched to members of the Charleston or the Northern Georgia estuarine stocks (Greenman pers. comm. 2015[1]). Laska *et al.* (2011) described mixed groups of estuarine and coastal dolphins in nearshore coastal waters around Charleston; however the degree of this interaction remains unclear.

The most recent abundance estimates included in the NMFS Stock Assessment Reports (SARs) for both the SM stock and the SC/GA stock were calculated using stratified aerial survey data from the summer (July-August) of 2010 and 2011 (Waring *et al.* 2014). The best abundance estimate for each stock was calculated as the weighted average between these two survey years, with higher weighing given to the year with the

[1] Justin Greenman, December 15th, 2015.

most precise estimate (Waring *et al.* 2014). The precision of each abundance estimate was given by its coefficient of variation (CV), in which values closer to zero are considered most precise. Population size for the SM stock was estimated at 9,173 individuals (CV 0.30), for dolphins sighted in the summer months from the shoreline out to the 20-m isobaths between Cape Lookout, NC and Assateague, VA (Waring *et al.* 2014). SC/GA stock abundance was estimated at 4,377 individuals (CV 0.43) for dolphins found in the summer months from the shoreline to the 40 m isobaths between the NC/SC border and the GA/FL border (Waring *et al.* 2014).

However, abundance estimates carried out using traditional aerial line-transect surveys lack the ability to identify individuals and to designate dolphins to specific stocks. Thus biologically meaningful definitions of stock boundaries are needed in order to estimate unbiased population parameters for each stock, especially in areas of stock overlap. Photo-identification methods are well established for individually identifiable cetaceans such as bottlenose dolphins and can provide insights into temporal-spatial use of the surveyed area, allowing for inferences into stock identity. Moreover, photo-identification surveys can be applied to a mark-recapture framework, allowing for estimates of population parameters that can be more precise than those estimated using aerial line-transects surveys (Fairfield 1990).

Mark-Recapture

Mark-recapture estimates can be calculated most simply using the Lincoln-Petersen model for two-sample surveys (one mark and one recapture) assuming a closed population where: total population abundance ($\hat{N}$) is calculated by assuming the ratio of marked individuals in the first sample (n_1) to the total population ($\hat{N}$) is equal to the ratio of captured individuals in the second sample (n_2) to the number of recaptured individuals (previously marked) in the second sample (m_2) (Nichols 1992, Williams *et al.* 2002, Chao and Huggins 2005). The Schnabel method, an extension to the Lincoln-Petersen method, may be used when population closure is assumed but multiple recapture surveys are conducted (Krebs 1988, Williams *et al.* 2002, Chao and Huggins 2005). The abundance estimate, variance, and confidence interval formulas for both models (Krebs 1988, Williams *et al.* 2002) are found in Chapter 2.

More robust models can be used in long-term studies, in the presence of different residency patterns, and/or when the range of the target species is unknown (Smith *et al.* 2013). Pollock's Robust Design (1982) includes a combination of closed and open population models by creating a sampling scheme with two different temporal scales, namely primary and secondary periods. Each secondary period represents a complete survey of the entire study area. Intervals between secondary periods are kept short to allow for population mixing without violating closure. A primary period is comprised of a set of two or more secondary periods. Primary periods are spaced over longer time scales and the population is assumed to be open between them (see Pollock 1982, Pollock *et al.* 1990).

Models can be fitted to robust design data allowing for estimations of abundance, temporary emigration, and survival (Kendall 2001). Nichols (1992) and Seber (1992) review a variety of models that address different sources of heterogeneity in capture probability. The null model Mo is the simplest model and assumes no variation in capture probability between individuals or sampling occasions (Nichols 1992, Seber 1992, Williams *et al.* 2002). Model Mt (time variation) assumes that individuals have the same capture probability within a sampling occasion, but that this probability varies between sampling occasions (Nichols 1992, Seber 1992, Williams *et al.* 2002). Model Mh (heterogeneity) assumes that individuals have different capture probabilities (Nichols 1992, Seber 1992, Williams *et al.* 2002). Combinations of models may be fitted to the data using statistical programs such as MARK (Cooch and White 2006) or packages for the program R (R Core Team 2015).

When emigration occurs, capture probabilities will be biased downward by those individuals that are not available for capture at the time of sampling. Emigration can be random or follow a first-order Markov process (Kendall *et al.* 1997). Under the random emigration model, the probability of being unavailable for capture is equal to the probability of being available for capture (Kendall *et al.* 1997). Markovian emigration is time dependent with the probability of being available for capture during the current sampling period depending upon whether or not the individual was present in the study area in the previous sampling period (Kendall *et al.* 1997). Models may be constrained for random or Markovian emigration (Kendall *et al.* 1997) using the same statistical programs mentioned above.

Model fitness is tested based on Akaike's information criterion (AICc) (Kendall 2001, Speakman *et al.* 2010). AICc is a procedure corrected for small sample size that is used to select the model that best fits the data and has the fewest parameters (i.e. most parsimonious) (Burnham and Anderson 2002). Abundance estimates using mark-recapture data include only the marked proportion of the population. Thus, abundance estimates of marked individuals are divided by the marked proportion of the samples to estimate total abundance (Nichols 1992, Wilson *et al.* 1999, Read *et al.* 2003, Balmer *et al.* 2008, Speakman *et al.* 2010).

Mark-Recapture Model Assumptions

Abundance estimates generated using mark-recapture models are conditional on a set of model assumptions. For the robust design, these assumptions include a combination of open and closed population model assumptions such as 1) marks are stable, unique, and recognizable over-time; 2) capture does not affect recapture or survival; 3) all individuals have an equal and independent chance of capture and survival; 4) population is demographically and geographically closed within primary periods; and 5) emigration is temporary (Pollock *et al.* 1990, Kendall *et al.* 1995, Read *et al.* 2003, Schwarz 2002, Speakman *et al.* 2010). Violations of these assumptions may bias estimates derived under these models and need to be examined.

Marks are stable, unique, and recognizable over-time – This assumption can be met when good quality photographs and reasonably marked individuals are used (Wilson *et al.* 1999, Read *et al.* 20003, Speakman *et al.* 2010). However, this assumption is violated when marked dolphins acquire heavy loads of the barnacle (*Xenobalanus globicipitis*) on their dorsal fins during the course of the study, temporarily obscuring their natural marks. Individuals with heavy loads of *Xenobalanus sp.* are treated as unmarked, thus potentially falsely reducing the proportion of marked individuals (distinctive rate). Violations of this assumption cause an upward bias in abundance estimates (Williams *et al.* 2002, Rosel *et al.* 2011) and a downward bias in survival rates (Williams *et al.* 2002).

Capture does not affect recapture or survival – The capture of a dolphin consists of taking a picture of its dorsal fin, a photographic ‘capture’, and should not affect survival (Speakman *et al.* 2010) or recapture (Read *et al.* 2003).

All individuals have an equal and independent chance of capture and survival – Young-of-the-year and juveniles dolphins have the highest mortality rates (McFee *et al.* 2006). Adults have low mortality rates (Wells and Scott 1999), thus restricting the dataset to include adults only (Speakman *et al.* 2010) can minimize violations of the assumption of equal survivability.

The assumption of an equal chance of capture among individuals may be violated in the presence of emigration. Pollock’s Robust Design (1982) is robust to violations of equal catchability (Pollock *et al.* 1990) as long as migration occurs at a longer temporal scale than sampling (Kendall 1999). In addition, the equal ‘catchability’ assumption may be violated given that home ranges and site fidelity may vary among individuals (Gubbins 2002a). Individuals with high site fidelity to the study area would cause a negative bias in abundance, conversely individuals that have low site fidelity to the study area would positively bias abundance estimates (Pollock *et al.* 1990, Williams *et al.* 2002).

The ‘independence of capture’ assumption may be violated since bottlenose dolphins are known to have preferred associates (Shane *et al.* 1986, Quintana-Rizzo and Wells 2000, Gubbins 2002b), yet this bias would be reflected in the standard errors rather than in the abundance estimates (Williams *et al.* 2002).

Population is demographically and geographically closed within primary periods – Demographical closure may be obtained by restricting the dataset to adults, since dolphins are long-lived (Wells and Scott 1999). Geographical closure is harder to achieve, especially when the distribution of the target species is unknown. Nonetheless violations of geographical closure would bias estimates of individuals present within the study area at the time of sampling (i.e. individuals exposed to sampling efforts) (Pollock *et al.* 1990, Kendall 1999), but do not bias estimates pertaining to the super-population (Williams *et al.* 2002). In this study, the super-population was defined as the putative stocks that may occur in the survey area at the time of sampling although not necessarily exposed to sampling efforts.

Objectives

Dolphins are found year-round off the northern coast of South Carolina (Young and Peace 1999). Nonetheless, stock membership and residency patterns of these individuals are unclear. An influx of individuals attributed to the SM stock transiting through this area has occurred consistently in the fall (McFee *et al.* 2006, Speakman *et al.* 2010, Young pers. comm.), yet it is unknown if individuals from this fall migratory peak are only moving through or if they remain in the area for any amount of time. Effective conservation and management plans require current and reliable estimates of potential biological removal (PBR) for each bottlenose dolphin stock. Therefore, the use of long-term photo-identification data is crucial to determine stock membership and stock boundaries in areas of stock overlap such as the northern coast of South Carolina.

The overall objective of this study was to describe the stock structure of bottlenose dolphins inhabiting the northern coast of South Carolina. Specifically, I attempted to determine the number of stocks in the area by identifying members of each stock, describe movements for these dolphin stocks, and describe potential stock overlap. Finally, I provided year-round local abundance estimates for dolphins in northern South Carolina.

Chapter 1 provided a literature review on the topics of bottlenose dolphin stocks in the Atlantic US including current descriptions for stocks occurring off the northern South Carolina coast, mark-recapture methodology, and unresolved questions on stock boundaries, residency patterns and stock overlap.

Chapter 2 was written according to the publishing guidelines provided by the journal Marine Mammal Science. This chapter reports on data collected from 2 years of formal transect surveys centered in Murrell's Inlet, South Carolina, with the intent of estimating local abundance during multiple times of the year, describing movements, clarifying the number of stocks that occur in the area, and describing potential stock overlap. It specifically addresses the following hypotheses:

H1: The northern South Carolina coast has two coastal bottlenose dolphin stocks; the South Carolina/Georgia Coastal Stock (SC/GA), found in northern South Carolina year-round, and the Southern Migratory Coastal Stock (SM), found in northern South Carolina in the colder months.

H2: Summer estimates of local abundance will pertain to the SC/GA Coastal Stock, while estimates during other seasons may include members of the SM Coastal Stock.

H3: Members of the Northern South Carolina Estuarine System Stock will be found in coastal waters south and inclusive of Murrell's Inlet, but their contribution to coastal abundance estimates will be negligible.

Chapter 3 introduces an additional survey area for the second year of my study centered at the South Carolina/North Carolina border in Little River. The objectives of these surveys were similar to the ones described for Chapter 2, except these surveys were also focused on clarifying the southern boundary for the Southern North Carolina Estuarine System Stock. Ultimately, this chapter is not meant to stand alone, but it will be incorporated with additional data collected in southern North Carolina for a separate publication. It addresses the additional hypothesis:

H1: Members of the Southern North Carolina Estuarine System Stock will be found in and near Little River Inlet, especially in the colder months.

Chapter 2 – Stock structure of bottlenose dolphins (*Tursiops truncatus*) in coastal waters off northern South Carolina

Introduction

Stock structure of bottlenose dolphins (*Tursiops truncatus*) in the western North Atlantic is described as a complex mosaic of overlapping coastal and estuarine populations (Waring *et al.* 2015). Currently, the National Marine Fisheries Service (NMFS) recognizes eleven estuarine stocks and five coastal stocks along the U.S. Atlantic east coast (Waring *et al.* 2015). Despite our limited knowledge of coastal stocks, NMFS is required to provide definitions of these stocks, estimates of abundance and potential biological removal (PBR) (Wade and Angliss 1997) in the form of Stock Assessment Reports (SARs). These reports are used to assess the need for conservation and management plans for depleted stocks under the Marine Mammal Protection Act (MMPA, U.S.C. 16 §1362). Therefore, current and reliable information for each bottlenose dolphin stock is crucial to the implementation of effective management plans.

According to the most recent SARs, the northern coast of South Carolina is home to two coastal bottlenose dolphin stocks which overlap in the cold season: the South Carolina/Georgia Coastal Stock (SC/GA) and the Southern Migratory Coastal Stock (SM) (Waring *et al.* 2014). In addition, the ranges of two estuarine stocks are described to include coastal waters in the region: the Northern South Carolina Estuarine System Stock (NSCESS) and the Southern North Carolina Estuarine System Stock (SNCESS) (Waring *et al.* 2014). Estuarine stocks are defined based on a combination of long-term photo-identification (photo-ID) studies, satellite tag telemetry, and freeze-brand tags (Waring *et al.* 2014). However, limited data are available on coastal stocks, thus definitions of boundaries and potential stock overlap are rather arbitrary. For example, the SC/GA stock is defined to inhabit coastal waters from the North Carolina/South Carolina border to the Georgia/Florida border. This definition is largely based on the presence of dolphins in coastal waters off both South Carolina and Georgia during the summer months while the SM stock is presumably found north of Cape Lookout (Waring *et al.* 2014).

Seasonal movements for the SM stock are based on satellite tags from two individuals that were tagged near Cape Fear in November (Waring *et al.* 2014). While one dolphin moved as far south as northern Florida in the winter, the other remained in South Carolina and southern North Carolina; both individuals returned to North Carolina in the spring (Waring *et al.* 2014). The tags did not last through the summer, nevertheless Cape Lookout, NC is presumed to be the southern boundary for this stock during the summer months (Waring *et al.* 2014).

The most recent abundance estimates for the SM and the SC/GA stocks included in the SARs are based on stratified aerial surveys during the summer (July-August) of 2010 and 2011(Waring *et al.* 2014). Groups of dolphins observed during these surveys were assigned to different stocks based on their geographical location. Yet, the summer range of the SM stock is not well understood and the geographical extent of the SC/GA stock is artificially defined. Current abundance estimates for these stocks may be biased by the probable overlap of sightings from multiple stocks during surveys.

Balmer *et al.* (2014) suggested that a combination of health assessment and satellite tagging would provide the most cost effective baseline data on health and boundaries for data-deficient stocks. However, as health assessments are not feasible for many studies, photo-ID coupled with comparison of catalogs among study areas can provide baseline data on distribution, movements, and potential stock membership (Balmer *et al.* 2014).

Long-term photo-ID studies have been used to define bottlenose dolphin distribution, residency patterns (Quintana-Rizzo and Wells 2000, Gubbins 2002a, Zolman 2002), as well as to support definitions of stock boundaries for estuarine dolphins along the US east coast (Waring *et al.* 2014, Waring *et al.* 2015). In South Carolina, photo-ID studies in coastal waters have mainly focused on the Charleston area.

Speakman *et al.* (2006) noted coastal dolphins following shrimp boats and remaining in the coastal area or the open areas of the Charleston Harbor associated with shrimp boat traffic. Laska *et al.* (2011) described mixed groups of estuarine and coastal dolphins in nearshore coastal waters around Charleston; however the degree of this interaction remains unclear. Greenman (2012) identified coastal bottlenose dolphins during a study examining fisheries interaction in coastal waters from North Carolina to Florida during 2010-2011, and though comparisons with other catalogs are underway, dolphins previously known to associate with shrimp boats were not matched to members of the Charleston or the Northern Georgia estuarine stocks (Greenman pers. comm. 2015[2]).

An influx of dolphins into coastal waters in South Carolina has been documented in a number of studies. McFee *et al.* (2006) observed a significant increase in strandings of neonate bottlenose dolphins during the fall between the years of 1997 and 2003 in northern South Carolina. This trend is consistent with small boat-based transect surveys that have also shown an influx of dolphins in October and November (1995-1997) for northern SC (Young and Peace 1999) and an influx of transient dolphins in November and December (2005-2006) for the Charleston area (Speakman *et al.* 2010). Limited photo-ID analysis from this influx has revealed matches ranging from Wilmington, NC (Speakman *et al.* 2010, Young pers. comm.), to Jacksonville, FL (Speakman *et al.* 2010). Moreover, northern South Carolina historical catalog comparisons (1997-1999) produced more matches with southern North Carolina (18/73) then South Carolina (2/73) (Urian pers. comm.).

Estimates of population size and changes throughout the year can be obtained from photo-ID surveys conducted within a mark-recapture framework. Mark-recapture photo-ID surveys have been used extensively to estimate bottlenose dolphin abundance (Read *et al.* 2003, Balmer *et al.* 2008, Speakman *et al.* 2010, Urian *et al.* 2013). Closed population models are conventionally used to estimate abundance, however, the assumptions of geographical and demographical closure and equal probability of capture are challenging to meet when the target population's range or residency patterns are unknown (Pollock *et al.* 1990). Open population models do not require closure and allow

[2] Justin Greenman, December 15th, 2015.

for emigration but these models do not include the presence of seasonal residents (emigration is permanent) (Pollock *et al.* 1990).

Pollock's Robust Design (1982) combines both open population and closed population models allowing for temporary migration (Pollock *et al.* 1990), and it is robust to the violation of equal probability of capture (Kendall 2001). It includes two temporal scales: primary periods in which the population is assumed to be open and secondary periods in which the population is assumed to be closed (Pollock 1982, Nichols 1992, Rosel *et al.* 2011). Secondary periods, nested within primary periods, are used to estimate abundance from two or more closely spaced sampling sessions, while primary periods are used to estimate survival and emigration rates over longer periods (Pollock 1982, Kendall 2001, Speakman *et al.* 2010, Rosel *et al.* 2011).

Northern South Carolina is described to include the ranges of two coastal stocks (Waring *et al.* 2014), but this definition is data deficient. Bottlenose dolphins are found year-round off the northern South Carolina coast (Young and Peace 1999), and an influx of individuals attributed to the SM stock has occurred consistently in the fall (McFee *et al.* 2006, Young pers. comm.). Yet stock membership, seasonal movements and stock overlap are not well understood. I used a combination of year-round mark-recapture photo-identification surveys and comparisons of photo-ID images with neighboring catalogs to describe dolphin movements, infer stock membership and stock overlap, and estimate local abundance. Changes in population size throughout the year will most likely reflect changes in the stock structure of dolphins utilizing the study area and will not reflect fluctuations in the true population size of the putative stocks.

Methods

Mark-Recapture Photo-Identification Surveys

The northern South Carolina coast is characterized by a long stretch of sandy beaches with little estuarine influence, contrasting with surrounding areas dominated by barrier islands, large estuaries and continuous connections to the Intracoastal Waterway (Schwab *et al.* 2009). The continental shelf has a gentle slope, with the 10-m contour less than 5 km from shore and the 15-m contour beyond 10 km from shore (Taylor *et al.* 2008).

During onshore-offshore aerial surveys off the US east coast from Savannah, GA to the mouth of the Chesapeake Bay, VA, Torres *et al.* (2005) found most bottlenose dolphins were sighted within 2 km from shore. Thus our mark-recapture surveys followed pre-defined 50 km tracks parallel to the coast at 0.5 km and 1.5 km from shore, assuming a visibility of 500 m on either side of the research vessel. Transects ranged from 10th Avenue North (N 33.694429, W 78.878216) in central Myrtle Beach to the North Inlet entrance and were logistically divided into north and south of our coastal access point in Murrell's Inlet (Fig. 1).

Following Pollock's Robust Design (1982), I considered one secondary period completed when both 50 km track-lines were run once (100 km total). I aimed to run one mark and two recapture surveys (three secondary periods) within three weeks for every primary period. Primary periods were temporally spaced by an eight week interval between the last survey of the previous period and first survey of the following period for three reasons: 1) baseline data for the northern South Carolina coast are lacking, thus timeframes that would best describe the dynamics of bottlenose dolphins stocks in the area are unknown; 2) to ensure the population was open between primary periods; and 3) to investigate the degree of immigration/emigration to and from the study area over relatively short intervals.

Secondary periods were completed in the shortest possible timeframe within primary periods to avoid violating the assumption of demographic closure. One survey of the entire area (one secondary period) could be accomplished in one day if the sea state remained calm and the total number of dolphins sighted remained relatively low. Due to weather and/or daylight constrains, it was not possible to complete all secondary periods in the same timeframe nor was it possible to keep the same timeframe interval between secondary periods. During the second year of surveys, we seldom achieved the goal of sampling the area three times for each primary period due to extended windy conditions.

Surveys were carried out on days with good visibility and Beaufort Sea State (BSS) of 3 or less using a 5.5 m rigid-hull inflatable outboard-powered vessel at the slowest plane speed (10-14 knots). The vessel crew included 2-4 researchers: a captain, a photographer, and a data recorder. When dolphins were sighted, geographical coordinates were recorded and the vessel left the track-line.

The dolphin group, defined as dolphins within 100 m of each other heading in the same direction and engaged in similar behavior (Urian and Wells 1996), was approached off-effort. Geographical coordinates were recorded when the individuals were within photographical range. The crew attempted to photograph every group member from a perpendicular angle independent of visible marks on the dorsal fin (Wursig and Jefferson 1988) using Canon Digital SLR cameras equipped with either a 75-300 mm or a 100-400 mm adjustable lens. The sighting was terminated if 1) all individuals were photographed, 2) 45 minutes have elapsed, or 3) group displayed erratic behavior and/or disappeared. However, when the group size was large (> 30 dolphins), the group was photographed systematically as subgroups and the 45 minutes time restriction was observed separately for each subgroup. At the end of each sighting, geographical coordinates, environmental conditions, group size and composition, as well as overall behavior and heading were recorded.

Photographic data, survey tracks and associated geographical coordinates were downloaded into a computer and organized by survey date. Dorsal fin photos were compared within each sighting and the best right and/or left image of each dolphin was placed in a separate folder. 'Best' images were then cropped to include only the dorsal fin of one individual and image elements such as exposure, lighting, and contrast were enhanced using the tools available in Microsoft® Photo Gallery 2012. FinBase (Adams *et al.* 2006), a modified Microsoft® Access database for dolphin sighting data, was used to manage the dorsal fin images and the associated survey/sighting information.

The 'best' images of each dolphin were scored for photographic quality (PQ) using the score scale built into FinBase. Images with a PQ score greater than 11 were considered unsuitable and excluded from subsequent analysis. Suitable images were used to create a dorsal fin catalog. At the time of entry, dorsal fins were scored for distinctiveness following the methods of Urian *et al.* (2013), in which D1 fins are highly marked, D2 fins have at least 2 distinguishable features and D3 fins have little to no features. We considered D1 and D2 fins as marked and D3 fins as unmarked. Every catalog entry was verified by a second researcher.

Capture histories, a string of 1s and 0s indicating whether each marked individual was captured (i.e. photographed) (Williams *et al.* 2002), were compiled using queries built in FinBase. Capture histories were then used to estimate population parameters in the program R (R Core Team 2015) using the package Rcapture (Baillargeon and Rivest 2007) and the program MARK 6.2 (Cooch and White 2006).

Mark-Recapture Data Analysis

Several closed and robust models were fitted to the data. First, closed population models were fitted to each primary period. The Chapman modification of the Lincoln-Petersen model (Seber 1982, Williams *et al.* 2002, Chao and Huggins 2005) was applied to two-sample surveys and calculated as:

$$\hat{N} = \frac{(n_1 + 1) * (n_2 + 1)}{(m_2 + 1)} - 1$$

$$Var\hat{N} = \frac{(n_1 + 1) * (n_2 + 1) * (n_1 - m_2) * (n_2 - m_2)}{(m_2 + 1)^2 * (m_2 + 2)}$$

$$95\ \%\ Confidence\ Interval = \hat{N} \pm 1.96 * \sqrt{Var\hat{N}}$$

Where n_1 represents the number of identified dolphins in the 'mark' survey, n_2 represents the number of identified dolphins in the 'recapture' survey, and m_2 represents the number of recaptured (previously identified) dolphins (Seber 1982, Williams *et al.* 2002).

The Schnabel method (Krebs 1988, Williams *et al.* 2002) was applied to three sample surveys and calculated as follows:

$$\hat{N} = \left(\frac{\sum(C * M)}{\sum(R) + 1}\right)$$

95 % Confidence Interval:

$$\text{upper endpoint} = \frac{\sum(C * M)}{(\sum(R) Lower\ Limit)}, \text{lower endpoint} = \frac{\sum(C * M)}{(\sum(R) Upper\ Limit)}$$

Where C = number of captured dolphins in each sample, M = number of marked dolphin in the population at large, and R = number of recaptured dolphins in each sample (Krebs 1988). Confidence intervals were calculated using the Poisson frequency distribution table since the data did not follow a normal distribution (see Krebs 1988). Given the number of recaptures, the Poisson frequency distribution table provides upper and lower limits for 95% or 99% confidence intervals. To get the upper confidence interval endpoint, the sum of recaptures was substituted by the value corresponding to the lower 95% limit on the Poisson table. Similarly, the lower confidence interval endpoint was obtained by substituting the sum of R by its upper limit corresponding value on the Poisson table.

Package Rcapture (Baillargeon and Rivest 2007) in program R (R Core Team 2015) was used to fit a combination of closed and robust population models that relaxed the ‘equal catchability assumption’. Model Mh accounts for individual heterogeneity in capture probability, model Mt accounts for temporal variation in capture probability, and model Mth includes a combination of the latter (Nichols 1992, Seber 1992, Williams *et al.* 2002). The behavioral response model (Mb) was not applied to the data given the non-invasive nature of photo-identification.

The program MARK 6.2 (Cooch and White 2006) was used to fit 12 robust models that included variation in capture probability under either random or Markovian emigration. These models were tested against four null models of ‘no emigration’ and ‘no movement’. The ‘set time intervals’ option in program MARK was used to adjust the time interval between primary periods given these were uneven across samples (Cooch and White 2006). Models were run under the ‘logit link function’ since most models included constraints (Cooch 2001).

Model derived estimates included only distinctively marked dolphins, thus total population abundance ($\tilde{N}$) was adjusted to include both marked and unmarked individuals by dividing the ‘marked’ ($\hat{N}$) dolphin abundance by the distinctive rate (θ) as follows (Urian *et al.* 2015):

$$\tilde{N} = \frac{\hat{N}}{\theta} \qquad \text{and} \qquad Var\tilde{N} = \hat{N}^2\left(\frac{Var\,\hat{N}}{\hat{N}^2}\right) + \left(\frac{Var\,\hat{\theta}}{\hat{\theta}^2}\right)$$

The distinctive rate (θ) is the number of marked individuals in a sighting divided by the total number of individuals in the sighting. It was calculated for each primary period from a compilation of all on-effort sightings where all individuals in the group were photographed (Wilson *et al.* 1999). Neonates and calves were excluded from this estimate given their lack of independence (Nicholson *et al.* 2012).

The coefficient of variation (CV) was calculated for abundance estimates derived from the best fitted model under different methodologies for each primary period. The estimation method with the lowest CV was selected as the best (most precise) method.

Statistical Tests

A Mann-Whitney U test was used to compare median sightings-per-unit-effort (SPUE) between two independent variables and test whether or not the medians were significantly different. Kruskal-Wallis X^2 test was employed to test whether or not the SPUE medians were significantly different when three or more independent variables were under investigation. Both tests were performed using program R (R Core Team 2015).

Movements, Distribution, and Potential Stock Membership

A subset of the catalog, including all D1 dorsal fins (n = 78) and D2 dorsal fins sighted 3 or more times (n = 45) was selected for comparisons among well-established dorsal fin catalogs. Due to time constraints, full catalog comparisons were not possible. This selected subset of dorsal fin images was compared internally with the Coastal Carolina University's dorsal fin catalog to investigate individual sighting history, movements, and seasonal patterns. In addition to the current study, the Coastal Carolina University dorsal fin catalog dates back to 1997, including sightings from 18 years of coastal and estuarine surveys from various locations in South Carolina. Recent catalog entries included formal mark-recapture surveys centered in Little River and in southern North Carolina.

The same subset of dorsal fin photographs (n = 123) was compared among adjacent survey areas in the Carolinas via the Mid-Atlantic Bottlenose Dolphin catalog (MABDC, Urian *et al.* 1999), specifically with the National Ocean Service-Charleston (NOS) and the Duke Marine Lab/University of North Carolina Wilmington (DUML/UNCW) catalogs to determine individual movements and stock membership. The MABDC has over 14,000 dorsal fin images from 18 survey areas and 28 different contributors, dating back to 1979 (Urian pers. comm.).

Rather than classifying individuals in different residency categories, I described when individual dolphins were resighted. Movements were defined based on sighting dates from matches with other areas. Similarly, stock membership was inferred based on the combined sighting history of matches (internal and via MABDC), consultations with other researches, and published stock descriptions.

Results

Mark-Recapture Photo-Identification Surveys

I planned to conducted mark-recapture surveys over 12 primary periods from July 2013 through June 2015. The December 2014 primary period was postponed to January 2015 due to logistical limitations. However, weather conditions in 2015 also hindered survey efforts until mid-April/May. Consequentially the primary periods planned for January and March 2015 were not completed and were supplemented with the addition of a primary period in July/August 2015.

Each primary period included 2-3 secondary periods. Due to weather constraints and/or high number of individual dolphins sighted, it took between 1 and 4 survey days to complete a secondary period, with an interval of 0-10 days between surveys. A total of 43 survey days yielded 27 secondary periods within 10 primary periods (Table 1).

Over this 2 year study, 262 hours were spent on the water surveying a total of 2,653 km on-effort. We sighted 211 dolphin groups (195 on-effort) and identified 532 marked individuals from on-effort sightings. The marked proportion (θ) varied from 0.69 in August 2013 to 0.09 in October 2014 (Table 2). The low θ in October was due to heavy coverage of the barnacle *Xenobalanus globicipitis*, which obscured the outline of the dorsal fins for dolphins sighted during the fall migratory peak.

Sighting frequency of marked dolphins ranged from 1 to 6, and only 132 of 580 dolphins were sighted more than once (Fig. 2). The rate of discovery of new individuals increased between July/August and October (2013), plateaued between December 2013 and April 2014, increased steeply between April and August (2014), and kept increasing at a slower rate during year 2 (August 2014 – August 2015) (Fig. 3).

Mean sightings-per-unit-effort (SPUE) was 1.4 dolphins/km for the inner track (0.5 km from shore) and 1.1 dolphins/km for the outer track (1.5 km from shore), but the difference was not significant (Mann-Whitney U = 1712, n = 27 survey tracks at each distance from shore, p = 0.2231). A comparison of SPUE per primary period did not meet the homogeneity of variance assumption (Levene's test p = 0.0087) due to small sample size; thus, the Kruskal-Wallis test was not employed to test the differences between primary periods. Nonetheless, SPUE was generally higher for primary periods between June and early November and lower for primary periods between December and April. Moreover, the October/November primary period in 2014 had the highest number of daily sightings (≥ 10) and the highest mean SPUE (4.57 dolphins per km) (Appendix A). Seasonal SPUE was significantly different (Kruskal-Wallis $X^2_{(3)} = 13.73$, p = 0.0033), with the late fall (Oct/Nov 2014) SPUE being significantly higher than all other seasons (Dunn's test p < 0.000 spring, p < 0.000 summer, p < 0.000 winter, and p = 0.02 early fall). Early fall (Oct 2013) SPUE was also significantly higher than winter (December 2013/ February 2014) (Dunn's test p = 0.02).

Model Selection and Model Derived Estimates

Several primary periods yielded low (n = 1 or n = 2) or no (n = 0) recaptures and required modified analysis. The December 2013 (n = 1) and the February 2014 (n = 0) primary periods were combined to increase recapture sample size (n = 1) given that one match was found between them and that mean water temperatures (MWT) were below 15 °C. Likewise, June (n = 0) and August 2014 (n = 14) primary periods were combined to increase recapture sample size (n = 27) given the presence of matches between these primary periods and the similar MWT. When primary periods were combined, they were analyzed as a series of samples in which the first secondary period represented the 'mark' survey and the subsequent secondary periods represented 'recapture' surveys.

The April 2014 primary period had no recaptures (n = 0) and no matches with preceding or succeeding primary periods. Similarly, April/May (n = 1) and July/August (n =1) of 2015 had low recaptures and no matches between them. Combining these periods did not increase recapture sample size, thus they were treated separately.

The October/November primary periods also had low recaptures (n = 2 for 2013, and n = 0 for 2014), however given that the fall represents a unique time of the year when dolphins are migrating through the area (Young pers. comm.), these periods were not combined with either preceding or succeeding primary periods. An artificial recapture was added to each of the primary periods mentioned above to correct for small sample size.

Package Rcapture (Baillargeon and Rivest 2007) in program R (R Core Team 2015) was used to fit closed population models to each primary period. Best fitting models were selected based on the lowest AICc value. These models were then compared to the null model estimates derived from either the Lincoln-Petersen method or the Schnabel method. Both best fitting R models and 'manual' estimation methods yielded similar trends with highest abundance in the fall of 2014 ($\hat{N}$ = 5,314; 95% C.I. = 674-12,199 and $\hat{N}$ = 8,488; 95% C.I. = 674-19,783, respectively) and lowest abundance in the spring 2014 ($\hat{N}$= 80; 95% C.I. = 40-164 and $\hat{N}$ = 84; 95% C.I. = 16-1647, respectively (Fig. 4).

Program MARK 6.2 (Cooch and White 2006) was used to fit 12 robust models that included variations in capture probability under either random or Markovian emigration. These models were tested against four null models of 'no emigration' and 'no movement'. Markovian Model Mt with time variation in apparent survival (S), time variation in emigration (γ''), time variation in immigration (1-γ'), and different capture probability for each sampling occasion (p(t)) was the best fitted model (Table 3).

Estimates from all models followed the same general annual trend with increased number of dolphins in the fall and decreased number of dolphins in the spring of 2014. Abundance estimates from the Mt model with Markovian emigration varied from 19 (95% CI 11-84, CV = 0.68) in spring 2014 to 1,382 (95% CI 572-3464, CV = 0.49) in fall 2014. The total population abundance (after adjusting for θ) varied from 76 (95% CI 44-336, CV = 0.68) in the spring 2014 to 16,070 (95% CI 6,651-40,279, CV = 0.49) in the fall of 2014 (Table 2).

The apparent survival probability (S) varied between primary periods with the lowest estimates between winter and spring, and between spring and summer (Table 2). The emigration probability (γ'') was estimated at 1.00 from October 2013 until June 2014, when it dropped to 0.45 and increased again between October 2014 and May 2015 (Table 2). The immigration probability (1-γ') was high in most primary periods except between winter and spring (Table 2).

Movements, Distribution, and Stock Membership

During the current study, 108 dolphins were sighted in more than one primary period or during off-effort photo-ID surveys. Most resightings occurred between July and October 2013, June through October 2014, and/or April through August 2015, during which sampled mean water temperatures were above 19 °C. Two dolphins were resighted while sampled mean water temperature was below 14 °C, one in December 2013 and February 2014 (7.9-13.6 °C) and the other in February 2014 and March 2015 (7.9-11 °C).

Even though winter and spring months had less effort due to weather conditions, there appears to be a stock(s) transition during October/November and again during April/May. Historical (2005-2013) water temperature averages also show a transition from semi-tropical (above 19 °C) to temperate (below 15 °C) in November and again from temperate to semi-tropical in April (Armstrong, 2014). These transitions suggest the presence of a ‘warm’ season (April/May –mid-November) assemblage and a ‘cold’ season (mid-November–March/April) assemblage. Dolphins photographed during the warm season were not photographed during the cold season.

Dorsal fins photographs were compared to photo-ID studies off Little River, SC (June 2014-August 2015) and off southern North Carolina (June-August 2014 and December 2014) carried out by CCU. Catalog comparisons yielded 10 matches with Little River and four matches with southern NC (Fig. 5), all within the warm season. Five dolphins were photographed in Murrell’s Inlet between June and September 2014 and in Little River in October 2014. Inter-annual matches included four dolphins seen in August-October 2014 in Murrell’s Inlet and in May 2015 in Little River, three dolphins sighted in Murrell’s Inlet in July-September 2013 and in southern North Carolina in July 2014, and one dolphin sighted in Murrell’s Inlet in August 2013 and in Little River in August 2015.

Comparisons using a subset of the catalog (n = 123) with CCU's historical catalog and with adjacent areas via the MABDC catalog yielded a total of 15 matches dating as far back as 1996 (Fig. 6). Eight dolphins were matched with the NOS Charleston, SC catalog dating back to 2003. Three individual dolphins were photographed in Charleston in May and June (2003-2009) and photographed in northern South Carolina within the warm season (May-October). Another five individuals were photographed in November (2006) and December (2007) in the Charleston area and photographed in northern SC in the warm season (May-October).

Matches with southern North Carolina included five dolphins, of which two were historical matches between the CCU and the UNCW catalogs (Urian pers. comm.). Dolphins 3003 and 3006 were sighted in southern North Carolina in the summer (July-Sept) of 1998 and in northern South Carolina in the fall transition period (mid-October-mid-November). Both of these individuals were sighted in the summer during the present study.

Dolphins 3026 and 3027 were sighted in northern SC during the cold months and in southern North Carolina during the warm months. These two individuals have a history of sightings in inshore waters of southern NC, thus they are defined as members of the SNCESS based on the definitions in the SARs. The remaining three dolphins had only coastal sightings within the warm season and thus potentially belong to a coastal stock. However, coastal dolphins ranging between southern North Carolina and northern South Carolina during the warm months are not described in any SARs to date.

Discussion

Abundance estimates (after adjusting for θ) varied substantially from 76 dolphins (CV = 0.68) in the spring of 2014 to 16,070 dolphins (CV = 0.49) in the fall of 2014 (Table 2). These differences are indicative of the number of individuals using the study area and do not reflect fluctuations in the true population size of the putative stocks. These are the only estimates of bottlenose dolphin abundance available for coastal South Carolina.

Estimates of abundance were highest in the fall of both years. Though survey effort was limited during the cold months due to weather constraints, winter estimates were generally lower than summer estimates. The same general trend was observed in coastal waters of North Carolina, where bottlenose dolphins were most abundant during late fall (October/November) and less abundant during winter/spring (January/March) (Torres *et al.* 2005). Abundance estimates for the inshore waters of South Carolina, including the Charleston Estuary (Speakman *et al.* 2010) and the North Inlet/Winyah Bay Estuarine Reserve (Brusa 2012), follow a different trend with the highest estimates of abundance in the summer and lowest in the winter.

The current best abundance estimates for the SC/GA and the SM stocks in the SARs are 4,377 and 9,173 dolphins respectively. Summer abundance estimates for northern South Carolina were 371 (CV 0.17) dolphins in 2013 and 1,441 (CV 0.14) dolphins in 2014. Abundance estimates using photographic mark-recapture methods applied to coastal areas of similar size along the Atlantic seaboard are not available at this time. Speakman *et al.* (2010) surveyed 33 km of nearshore coastal waters near the

Charleston harbor, yet abundance estimates for this particular survey area were not reported. Toth *et al.* (2011) identified 205 marked bottlenose dolphins in a 70 km stretch of coastline off New Jersey during a 3-year study. In comparison, the present study identified 532 marked dolphins along a 50 km stretch of coastline in 2 years.

The summers of 2013 and 2014 were the only primary periods with sufficient recaptures rates (R>7) to provide reliable abundance estimates (Krebs 1988). Primary periods with low recaptures (0-2) caused an upward bias in the abundance estimates and created wide confidence intervals. Even when primary periods were combined (e.g. winter 2013-2014), only one recapture was achieved. Moreover, the prevalence of the barnacle *Xenobalanus globicipitis* during the colder months may have caused an artificial decrease in the distinctive rates, given that individuals with heavy loads of *Xenobalanus sp.* are treated as unmarked. In turn, abundance estimates during the colder months potentially suffered from an additional bias.

The fall primary periods were not combined with any other season given that they represent a unique time of the year when dolphins are migrating through the area. Even though the fall of 2013 (early October surveys) had low recaptures (2 out of 108 marked dolphins), this sampling period had relatively high proportion of marked individuals with a distinctive rate of 0.56 and estimates are likely not biased. Conversely, the fall of 2014 (late October/early November surveys) had no recaptures and very low distinctive rates (0.09). One artificial recapture was added to allow for estimation, which resulted in an upward bias in abundance. Nevertheless, this primary period had the highest number of daily sightings (≥ 10 in every survey day) and highest mean sightings-per-unit-effort. Thus, it appears the 2014 fall surveys captured the annual fall migratory peak in northern

South Carolina (Young pers. comm.); while the 2013 fall surveys were carried out earlier in the season and did not capture the peak.

In addition to low recapture rates, abundance estimates may be biased by violations of model assumptions. For the robust design, these assumptions include a combination of model assumptions such as: 1) marks are stable, unique, and recognizable over-time; 2) capture does not affect recapture or survival; 3) all individuals have an equal and independent chance of capture and survival; 4) population is demographically and geographically closed within primary periods; and 5) emigration is temporary (Pollock *et al.* 1990, Kendall *et al.* 1995, Read *et al.* 2003, Schwarz 2002, Speakman *et al.* 2010). These assumptions were reviewed by Read *et al.* (2003) and Speakman *et al.* (2010), and only potential violations are discussed here.

<u>Marks are stable, unique, and recognizable over-time</u> – This assumption is violated when potentially marked dolphins acquire heavy loads of the barnacle (*Xenobalanus globicipitis*) on their dorsal fins, temporarily obscuring their natural marks. Estimates derived from the October 2013, December 2013/February 2014, and October/November 2014 primary periods are likely positively biased due to a high proportion of individuals with heavy loads of *Xenobalanus*, which reduces recapture rates and violates the assumption that marks are not lost or gained during the study.

<u>Population is geographically closed within primary periods</u> – In this study, logistical restrictions and weather conditions hindered survey efforts, and the interval between secondary periods was as long as 21 days, possibly violating assumption of geographic closure. Violations of the assumption that the population is geographically closed may cause an upward bias in the abundance estimates for the population present

within the study area at the time of sampling (i.e. individuals exposed to sampling efforts) (Pollock *et al.* 1990, Kendall 1999), but do not bias estimates pertaining to the super-population (Williams *et al.* 2002). In this study, the super-population was defined as the putative stocks that may occur in the survey area at the time of sampling although not necessarily exposed to sampling efforts.

All individuals have an equal and independent chance of capture and survival – The chance that all individuals have equal probability of capture may be violated if emigration occurs during the study. The Robust Design (1982) is robust to violations of equal catchability (Pollock *et al.* 1990) as long as migration occurs at a longer temporal scale than sampling (Kendall 1999). Previous studies in this area strongly suggest a migratory peak into the study area and differences in capture probability were incorporated into the Markovian emigration model. Markovian models that included heterogeneity in capture probabilities (Mth) were too parametrized and provided a poor fit to the data.

Population is demographically closed within primary periods – The assumption that there is demographic closure may be met by restricting the dataset to adult individuals, since bottlenose dolphins are long-lived (Wells and Scott 1999). However, bottlenose dolphins in the study area were impacted by an unusual mortality event during the span of the present study (NMFS 2015). To date, no dolphins identified during this study were matched to dolphins that stranded in South Carolina during the epizootic and one dolphin identified during this study was matched to an individual that stranded off the southern North Carolina coast (Urian pers. comm.).

Management Implications

This study highlights the importance of photo-identification as a tool to describe stock boundaries and movements. For example, the northern boundary for the NSCESS was defined based on habitat characteristics and the southern boundary abuts the northern boundary for the Charleston Estuarine System Stock. However, these boundaries have not been systematically investigated to date. The present study supported the definitions for the northern boundary of the NSCESS given that members of this stock were never sighted in coastal waters north of Murrell's Inlet, SC.

In the absence of definitive data for coastal stocks, stock assessment reports describe the SM stock summer distribution to be north of Cape Lookout and the SC/GA stock to be restricted to waters of coastal South Carolina and Georgia (Waring *et al.* 2014). Interestingly, summer dolphins occurring between Cape Lookout, NC and the South Carolina border are not included in any stock assessment report to date. However, dorsal fin matching efforts among several catalogs during the present study indicate that coastal dolphins routinely range from Cape Fear, NC to Winyah Bay, SC during the warm season of May through October. Historical efforts to match dorsal fin catalogs found 25% of dorsal fins photographed in northern South Carolina were also photographed in southern North Carolina, mostly in the Wilmington area (Urian pers. comm.).

Long-term stranding data support the hypothesis that northern South Carolina dolphins are related to southern North Carolina coastal dolphins. McFee *et al.* (2006) found different stranding patterns for neonate dolphins in the northern and southern portion of South Carolina. Neonate strandings were significantly higher in the fall from

Little River to Murrell's Inlet, contrasting with the bi-modal peak in the spring and fall for the rest of the state (McFee *et al.* 2006). Moreover, stranding patterns described for the northern portion of South Carolina are similar to those described for the southern portion of North Carolina (Thayer *et al.* 2003), possibly representing a single stock. Whether these dolphins belong to the SM stock or are part of a stock of their own needs to be further investigated.

Alternatively, the SC/GA stock could extend into southern North Carolina during the warm months, given that dorsal fin matches with both southern North Carolina and Charleston, SC were found during the warm months in the present study. Sighting histories of those dolphins matched with the Charleston catalog suggest these individuals belong to coastal stocks given that none of them were sighted within the Charleston Harbor, but were rather sighted in nearshore coastal waters (Speakman, pers. comm.[3]). Matches within the warm season most likely include members of the SC/GA stock and matches between warm and cold seasons could belong to the SC/GA or the SM stock (Appendix B). However, the SM stock is not described to be present in northern SC during the warm months. Thus, these between-season matches could also represent a separate coastal stock. The lack of year-round resightings in the present study also suggests a seasonal migratory pattern for the study area.

The present study supports that multiple stocks overlap in northern South Carolina and that an undefined coastal stock occurs from southern North Carolina to northern South Carolina, possibly as far south as Charleston in the summer (Appendix C). Dolphins found between Cape Lookout and the North Carolina/South Carolina

[3] Todd Speakman, March 4th, 2015

border during the summer months are currently not included in any stock descriptions. Moreover, the northern boundary for the SC/GA coastal stock is artificially defined at the North Carolina/South Carolina state boundary; and the seasonal movements of the SM stock are defined based on limited data from only 2 satellite tags that did not last a whole year.

Previous coastal stock descriptions included a Southern North Carolina Coastal Stock ranging from Cape Lookout, NC to Murrell's Inlet, SC and distinct South Carolina and Georgia coastal stocks (Waring *et al.* 2008). Data from the present study support this previous description over the current descriptions of stocks occupying the northern South Carolina coast. Additional survey and matching effort is needed to better define the boundaries and distribution of coastal stocks.

Chapter 3 – Is there a bottlenose dolphin (*Tursiops truncatus)* stock boundary at Little River Inlet, SC?

Introduction

Bottlenose dolphin stocks off the northern South Carolina coast are poorly defined due to the lack of baseline data. The North Carolina/South Carolina state border is defined as the geographical boundary for at least two stocks: the Southern North Carolina Estuarine System Stock (SNCESS) and the South Carolina/Georgia Coastal Stock (SC/GA). In addition, the Southern Migratory Coastal Stock (SM) is believed to migrate to northern South Carolina in the winter (Waring *et al*. 2014). However, the legitimacy of this boundary has not been investigated through systematic photo-identification surveys.

Photo-identification survey data from southern North Carolina (1995-2003) were used to examine the relationship between dolphins and shrimp boats. Fleming (2004) found different temporal and spatial variability in the sightings of shrimp trawler-associated and non-shrimp trawler-associated dolphins. Non-trawler dolphin sightings occurred only in the fall and winter in the Southport area; but the same individuals were sighted year-round in northern estuarine waters near Wilmington, NC (Fleming 2004). This sighting pattern supports the National Marine Fisheries Service (NMFS) definition for the SNCESS, thus non-trawler dolphins potentially represent the latter.

Most trawler-dolphin sightings occurred in the summer and fall (Fleming 2004). Trawler-associated dolphins are potentially members of a coastal stock. Five of 45 trawler-associated dolphins from the Southport area (southern North Carolina) have been matched with Coastal Carolina University's (CCU) historical catalog (1998-1999) from coastal surveys of Murrell's Inlet (Urian pers. comm.) indicating that at least some of these dolphins move into coastal South Carolina.

In an attempt to further investigate the stock membership of dolphins found off northern South Carolina, Dunn *et al.* (2014) created a partnership with two dolphin tour groups, one in Little River and one in Murrell's Inlet. They compared photographs taken during dolphin tours to those taken during systematic surveys in Murrell's Inlet from June through December 2013 (described in Chapter 2). Comparisons were also made with Coastal Carolina University's historical catalog, and the National Ocean Service-Charleston catalog via the Mid-Atlantic Bottlenose Dolphin Catalog (MADBC) (Urian *et al.* 1999). Photographic data included 463 dolphins photographed during formal transect surveys off Murrell's Inlet, 44 dolphins photographed during dolphin tours off Murrell's Inlet, and 122 dolphins photographed during dolphin tours off Little River and yielded 16 matches, including one match with Charleston, SC. Moreover, results showed temporal and spatial variability among individuals; while some dolphins were repeatedly found in one survey area, others moved between survey areas.

Systematic mark-recapture surveys were ongoing on two 50 km transects centered in Murrell's Inlet, SC (described in Chapter 2). Dunn's *et al.* (2014) findings were compelling enough to initiate mark-recapture systematic surveys off of Little River to further investigate the degree of movement within northern South Carolina and between adjacent areas in the Carolinas. The objectives of these surveys were to investigate whether Little River Inlet is a geographical boundary for dolphin stocks, define which stocks are present in the survey area, describe seasonal movements and potential stock overlap, and estimate local abundance at various times of the year. I hypothesized that: 1) members of the SNCESS will be found in inshore and near-shore coastal waters off Little River during the colder months, as proposed by Fleming (2004) and Waring *et al.* (2014), and 2) dolphins found in coastal waters off Little River will include members of the SC/GA and/or the SM coastal stocks.

Methods

Mark-Recapture Photo-Identification Surveys

The northern South Carolina coast is characterized by a long stretch of sandy beaches with little estuarine influence, contrasting with surrounding areas dominated by barrier islands, large estuaries and continuous connections to the Intracoastal Waterway (Schwab *et al.* 2009). The only connection to the Intracoastal Waterway is via the Little River Inlet Estuary, a 4 km long stretch from the Intracoastal Waterway to the jetties found at the border with North Carolina. The study area included a 28 km stretch of estuarine waters from Holden Beach, NC to Little River, SC and a 50 km stretch of coastal waters from Holden Beach, NC to northern Myrtle Beach, SC, hereafter referred to as Little River surveys (Fig. 7).

In South Carolina, mark-recapture surveys followed two 25 km pre-defined tracks parallel to the coast at 0.5 km and 1.5 km from shore from Little River Inlet to approximately 82nd Ave in Myrtle Beach. In North Carolina, the 25 km coastal track was run at 0.3 km from shore and the 28 km inshore track was comprised of the Intracoastal Waterway (ICW) from the Lockwood-Folly Inlet in Holden Beach, NC to the Johnny Causeway landing in Little River.

Following Pollock's Robust Design (1982), I considered one secondary period completed when all track-lines were run once (103 km). I aimed to run one mark and two recapture surveys (three secondary periods) within 3 weeks for every primary period. Primary periods were temporally spaced by an 8-week interval between the last survey of the previous period and first survey of the following period for three reasons: 1) baseline data for the northern South Carolina coast are lacking, thus timeframes that would best describe the dynamics of bottlenose dolphins stocks in the area are unknown; 2) to ensure the population was open between primary periods; and 3) to investigate the degree of immigration/emigration to and from the study area over relatively short intervals. There were 5 primary periods and 11 secondary periods (16 survey days) in this study.

Secondary periods were carried out in the shortest possible timeframe within primary periods to avoid violating the assumption of demographic closure. One survey of the entire area (one secondary period) could be accomplished in one day if the sea state remained calm and the total number of dolphins sighted remained relatively low. Due to weather and/or daylight constraints, it was not possible to complete all secondary periods in the same timeframe nor was it possible to keep the same timeframe interval between secondary periods.

Robust design survey procedures, photographic treatment, and data analysis followed the same protocols as described in Chapter 2. In addition, data from concurrent surveys centered in Murrell's Inlet (Chapter 2) and Little River were combined and re-analyzed. Herein, I focus on the Little River data and the combined dataset.

Results

Little River Mark-Recapture Photo-Identification Surveys

Surveys in Little River were conducted from August 2014 through August 2015, during which 5 primary periods were completed (Table 4). Primary periods included 2-3 secondary periods with a total of 16 survey days and 11 secondary periods. We were only able to sample the area three times in August 2014. Thereafter, only one mark and one recapture survey were completed for each primary period. The time to complete each secondary period ranged from 1- 2 days with an interval of 0-2 days between surveys. The interval between secondary periods ranged from 1 to 11 days.

Over this study, we spent 125 hours on the water off Little River, surveying a total of 1,296 km on effort (Table 4). We sighted 75 dolphin groups in Little River (69 on-effort) and identified 141 individuals. The marked proportion ranged from 0.62 in August 2015 to 0.17 in October of 2014. Sighting frequency of marked dolphins ranged from 1 to 4, and only 28 dolphins were sighted more than once (Fig. 8). The Little River discovery curve increased steeply between late August/early September and late October/early November 2014 and had a gentler slope thereafter (Fig. 9).

Mean Sightings-per-unit-effort (SPUE) were similar for the LR 1.5 km track (1.57) and the NC 0.3 km track (1.37). The 0.5 km track had a mean SPUE of 0.59 dolphins/km and the ICW had the lowest SPUE of 0.03 dolphins/km. These differences were only significant (Kruskal-Wallis $X^2_{(3)} = 9.252$, $p = 0.026$) for the ICW track (Dunn's test p= 0.0358 0.5 km track, p = 0.0023 1.5 km track, and p = 0.0077 0.3 km track). Mean SPUE did not significantly differ between primary periods (Kruskal-Wallis $X^2_{(3)} = 3.382$, p =

0.496) or between survey seasons (Kruskal-Wallis $X^2_{(3)} = 3.247$, $p = 0.355$). August surveys were defined as summer, mid-October-mid-November surveys were defined as fall, March surveys were defined as winter, and May surveys were defined as spring.

Model Selection and Model Derived Estimates

Most primary periods had no recaptures, except for August 2014 (n = 4) and August 2015 (n = 12), thus an artificial recapture was added to correct for small sample size and allow for parameter estimation. Package Rcapture (Baillargeon and Rivest 2007) in program R (R Core Team 2015) was used to fit six classical closed population models to each primary period. Best fitting models were selected based on the lowest AICc value. These models were then compared to the null model estimates derived from either the Lincoln-Petersen method or the Schnabel method. Both best fitting R models and 'manual' estimation methods yielded similar trends with highest abundance in the fall (late October/early November) of 2014 ($\hat{N}$= 675, 95% C.I. = 71-885 and $\hat{N}$ = 504, 95% C.I. = 95-9,882 respectively) and lowest abundance in the winter (early March) of 2014 ($\hat{N}$= 30, 95% C.I. = 13-61 and $\hat{N}$ = 22, 95% C.I. = 4-431, respectively). When adjusted for the proportion of marked individuals, the 2015 winter and summer surveys had similarly low abundance estimates (Fig. 10).

Program MARK 6.2 (Cooch and White 2006) was used to fit 12 robust models that included variation in capture probability under either random or Markovian emigration. These models were tested against four null models of 'no emigration' and 'no movement'. Three different Markovian models had similar AICc values and thus estimates from these models were averaged to account for model uncertainty (Burnham and Anderson 2002) (Table 5). Averaged abundance estimates varied from 27 (95% CI

26-119, CV = 0.72) in March 2014 to 826 (95% CI 253-3,136, CV = 0.74) in the fall 2014. The total population abundance (after adjusting for θ) varied from 69 (95% CI 61-98, CV = 0.11) in the summer 2015 to 4,820 (95% CI 1,547-18,447, CV = 0.74) in the fall of 2014 (Table 4).

Estimates of apparent survival probability (S), emigration (γ”) and immigration (1-γ’) were also averaged between the best 3 models and between primary periods (Table 6). Apparent survival probability had the lowest estimate between March and May (0.50). The emigration probability (γ”) was lowest between August and November and highest between November and March and March and May, decreasing again between May and August. The immigration probability (1-γ’) varied from 0.81 between March and May and 1.00 for the other primary periods.

Murrell’s Inlet and Little River Combined Mark-Recapture Photo-Identification Surveys

There were four primary periods during which we were able to survey both Murrell’s Inlet (Chapter 2) and Little River (August 2014, October/November 2014, April/May 2015, and August 2015) (Table 7). Primary periods included 2-3 secondary periods with a total of 27 survey days and 9 secondary periods. The time to complete each secondary period (when all tracks in both areas were surveyed once) ranged from 2-4 days with an interval of 0-10 days between surveys. The interval between secondary periods ranged from 1-16 days.

A total of 174 hours were spent on the water, surveying a total of 1,901.6 km on-effort for the combined dataset. We sighted 157 dolphins groups (146 on-effort) and identified 392 individuals. The proportion of marked individuals ranged from 0.52 in

August 2015 to 0.13 in October of 2014. Sighting frequency of marked dolphins ranged from 1 to 5, and only 68 dolphins were sighted more than once; 15 of those were seen in both areas (Fig. 11). An additional six dolphins photographed off Little River were matched to individuals photographed off Murrell's Inlet during the previous year.

The discovery curve from the combined surveys increased at a higher rate between August and October/November 2014 (primary periods I and II) and had a slower rate thereafter (Fig. 12). Mean SPUE was not significantly different between transects (Kruskal-Wallis $X^2(5) = 10.273$, $p = 0.0678$) or between survey areas (Mann-Whitney U = 745, $p = 0.087$). Mean SPUE per primary period and per season failed the homogeneity of variances test (Levene's test $p = 0.0113$ and $p = 0.01103$ respectively), thus Kruskal-Wallis was not performed on this dataset.

Model Selection and Model Derived Estimates

Most primary periods had no recaptures, except for August 2014 (n = 19) and August 2015 (n = 13), thus an artificial recapture was added to correct for small sample size and allow for parameter estimation. Package Rcapture (Baillargeon and Rivest 2007) in program R (R Core Team 2015) was used to fit 6 classical closed population models to each primary period. Best fitting models were selected based on the lowest AICc value. These models were then compared to the null model estimates derived from either the Lincoln-Petersen method or the Schnabel method. Both best fitting R models and 'manual' estimation methods yielded similar trends with highest abundance in the fall of 2014 ($\widehat{N}$ = 1,141, 95% C.I. = 128-2,997; and $\widehat{N}$ = 1,260, 95% C.I. = 377-7,099, respectively) and lowest abundance in the summer of 2015 ($\widehat{N}$ = 136, 95% C.I. = 100-213; and $\widehat{N}$= 129, 95% C.I. = 84-270, respectively).

Program MARK (Cooch and White 2006) was used to fit 12 robust models that included variation in capture probability under either random or Markovian emigration. These models were tested against four null models of 'no emigration' and 'no movement'. Three different Markovian models had similar AICc values and thus estimates from these models were average to account for model uncertainty (Burnham and Anderson 2002) (Table 8). Estimates from all models followed the same general trend with increased number of dolphins in the fall and decreased number of dolphins in the 2015 summer (Fig. 13). Averaged abundance estimates varied from 142 (95% CI 105-219) in August 2015 to 928 (95% CI 464-2044) in the fall 2014. The total population abundance (after adjusting for θ) varied from 274 (95% CI 203-423) in the summer 2015 to 7,401 (95% CI 1,291-16,302) in the fall of 2014 (Table 9).

Estimates of apparent survival probability (S), emigration (γ") and immigration (1-γ') were also averaged between the best three models and between primary periods (Table 9). Apparent survival probability was only less than 1 between May and July. The emigration probability (γ") varied from 0.69 to 0.82 and the immigration probability (1-γ') was lowest between October and April and highest between April and July, contrary to field observations.

Movement, Distribution, and Stock Membership

In Little River, we encountered 30 individuals in more than one primary period. Most of those (14) were resighted inter-annually in August. The combined dataset of concurrent surveys yielded 7 additional resightings between August 2014 and May 2015 (Fig. 14). The majority of dolphins resighted in Little River and in concurrent surveys off Murrell's Inlet occurred within the warm season, indicating a seasonal shift in stock composition. Mean water temperature for northern South Carolina is described to be semi-tropical (above 19 °C) between April and late November, when it shifts to temperate (below 15 °C) (Armstrong, 2014).

Comparisons of the combined dataset against CCU's southern North Carolina catalog resulted in 23 dolphins that were sighted in more than one month in at least 2 survey areas (Fig. 15). Of those, 14 dolphins were sighted in inshore waters of southern North Carolina and were designated as members of the SNCESS. Most of the SNCESS dolphins were observed during the summer of 2014 in estuarine and nearshore waters off southern North Carolina and during the winter and spring in coastal waters off of Little River and/or Murrells Inlet. The remaining 9 dolphins were sighted during the warm months between March and October.

Catalog comparisons on a subset of D1 (n = 17) and D2 dolphins sighted 3 or more times (n = 21) off Little River with CCU's historical catalog and with adjacent areas via the MABDC yielded eight matches (Fig. 16). Four dolphins were matched to the Charleston catalog, two were sighted in both areas within the warm season and the other two were sighted during the warm season in northern South Carolina and in Charleston in mid-November. Dorsal fin matches with southern North Carolina included three dolphins with estuarine sightings and one dolphin with a historical match between CCU's catalog and the UNCW catalog (Urian pers. comm.); potentially a coastal dolphin. Historical matches followed the same trend described above for southern North Carolina with members of the SNCESS seen during the warm season in southern North Carolina and in the cold season of northern South Carolina.

Discussion

In Little River, abundance estimates were consistently fewer than 100 dolphins year-round, except during late October/early November when abundance was estimated at 4,724 individuals. The combined dataset showed a different trend with lowest abundance estimates in August 2015 (Ñ = 268), similar estimates between August 2014 and May 2015 (Ñ ~ 1,200) and highest estimates in late October/early November (Ñ = 10,240 dolphins). Abundance estimates from the Murrell's Inlet area showed a more consistent trend with lowest estimates during the cold months (December – April) and highest estimates during the fall, and especially during late fall (late October/early November) when estimates are believed to represent the migratory peak attributed to the SM stock (Chapter 2).

As previously discussed in Chapter 2, the small number of recaptures within a primary period can result in a strong bias in the estimates of population parameters (Krebs 1988, Williams *et al.* 2002). Individuals were only recaptured during the summer primary periods in both the Little River dataset and the combined dataset and thus focus will be given to those population parameters. Similarly, Murrell's Inlet surveys achieved enough recaptures only during the summer (Chapter 2) and thus provide a basis for comparisons.

In Murrell's Inlet, summer estimates were lowest in July/August 2013 (Ñ =371, CV 0.17) and higher in both June-September 2014 (Ñ = 1,441, CV 0.14) and July/August 2015, although the latter was not precise (Ñ = 1,149, CV 0.95). Moreover, the summer 2014 estimate included the combination of two primary periods; however, the

August/September primary period alone yielded a similar estimate of 1,063 dolphins. Concurrent surveys off Little River occurred in both August/September 2014 and July/August 2015. Estimates from Little River alone were similar for both of summers (Ñ = 77, CV 0.34 and Ñ = 69, CV 0.62 respectively) given the overlapping confidence intervals (Table 6). Estimates for the combined dataset were highest in the summer of 2014 (Ñ = 1,193, CV 0.19) and lowest in the summer of 2015 (Ñ = 268, CV 0.19), following the same trend as the Murrell's Inlet estimates alone. Independent of survey area or calculation methods, estimates of abundance were consistently higher in late October/early November, supporting that dolphins do migrate to northern South Carolina during that time.

Little River Inlet is described as the boundary for the South Carolina/Georgia coastal stock and the Southern North Carolina Estuarine System Stock (SNCESS). If this boundary is correct, we would expect to find SNCESS dolphins in Little River but not off of Murrell's inlet, as well as limited matches between the North Carolina and the South Carolina portion of Little River surveys. Moreover, matches with adjacent areas should reveal movement between northern South Carolina and the Charleston area and limited movement, perhaps only during the fall migratory peak, with southern North Carolina.

Data from this study suggest just the opposite as several members of the SNCESS were observed in Little River and in coastal waters 70 km south of their proposed southern boundary during the colder months (Chapter 2). These results support the seasonal shift in stock distribution described by NMFS but suggest a boundary revision (Appendix C). Moreover, these data suggest a potential winter overlap between the SNCESS and the NSCESS in coastal waters during the colder months.

Additionally, dorsal fin matching efforts among several catalogs during the present study indicate that coastal dolphins routinely range from Cape Fear, NC to Winyah Bay, SC during the warm months. Interestingly, summer dolphins occurring between Cape Lookout, NC and the South Carolina border are not included in any stock assessment report to date. Historical efforts to match dorsal fin catalogs found 25% of dorsal fins photographed in northern South Carolina were also photographed in southern North Carolina, mostly in the Wilmington area (Urian pers. comm.).

Long-term stranding data support the hypothesis that northern South Carolina dolphins are related to southern North Carolina stocks. McFee *et al.* (2006) found different stranding patterns for neonate dolphins in the northern and southern portion of South Carolina. Neonate strandings were significantly higher in the fall from Little River to Murrell's Inlet, contrasting with the bi-modal peak in the spring and fall for the rest of the state (McFee *et al.* 2006). Moreover, stranding patterns described for the northern portion of South Carolina are similar to those described for the southern portion of North Carolina (Thayer *et al.* 2003), possibly representing a single stock. Whether these dolphins belong to the SM stock or are part of a stock of their own needs to be further investigated.

Alternatively, the SC/GA stock could extend into southern North Carolina during the warm months, given that dorsal fin matches with both southern North Carolina and Charleston, SC were found during the warm months in the present study. Sighting histories of those dolphins matched with the Charleston catalog suggest these individuals belong to coastal stocks given that none of them were sighted within the Charleston

Harbor, but were rather sighted in nearshore coastal waters (Speakman, pers. comm.[4]). Matches within the warm season most likely include members of the SC/GA stock and matches between warm and cold seasons could belong to the SC/GA or the SM stock (Appendix B). However, the SM stock is not described to be present in northern SC during the warm months. Thus, these between-season matches could also represent a separate coastal stock. The lack of year-round resightings in the present study also suggests a seasonal migratory pattern for the study area.

The present study supports that multiple stocks overlap in northern South Carolina and that an undefined coastal stock occurs from southern North Carolina to northern South Carolina, possibly as far south as Charleston in the summer (Appendix C). Dolphins found between Cape Lookout and the North Carolina/South Carolina border during the summer months are currently not included in any stock descriptions. Moreover, the northern boundary for the SC/GA coastal stock is artificially defined at the North Carolina/South Carolina state boundary; and the seasonal movements of the SM stock are defined based on limited data from only 2 satellite tags that did not last a whole year.

Previous coastal stock descriptions included a Southern North Carolina Coastal Stock ranging from Cape Lookout, NC to Murrell's Inlet, SC and distinct South Carolina and Georgia coastal stocks (Waring *et al.* 2008). Data from the present study support this previous description over the current descriptions of stocks occupying the northern South Carolina coast. Additional survey and matching effort is needed to better define the boundaries and distribution of coastal stocks.

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[4] Todd Speakman, March 4th, 2015

Conclusion

Chapter 2

H1: The northern South Carolina coast has two coastal bottlenose dolphin stocks; the South Carolina/Georgia Coastal Stock (SC/GA), found in northern South Carolina year-round, and the Southern Migratory Coastal Stock (SM), found in northern South Carolina in the colder months.

Hypothesis 1 is supported with potential revisions to stock boundaries and seasonal movements. Dorsal fin matches with adjacent areas in the Carolinas support the presence of at least two, potentially three coastal dolphin stocks off the northern South Carolina coast. Matches between southern North Carolina and northern South Carolina during the summer suggest that either the SM ranges as far south as northern SC during the summer, or the SC/GA range extends into southern NC, or that another coastal stock occupies the area during the summer. However, the fall migratory peak attributed to the SM stock was reflected in the 2014 late October/early November primary period during which sighting frequency was highest and there were no recaptures.

During the colder months, dolphin sightings were scarce reflecting seasonal movement of both coastal stocks. Dolphins identified during the colder months (December-March) were not photographed during any other season, thus the SM stock appears to occupy the study area only during late fall. These data suggest that coastal stock overlap occurs in the fall rather than in the winter. The lack of year-round sightings in the study area suggests seasonal movements of all coastal stocks within the study area. Individually identified dolphins did return to the study area during the spring and summer, however spring migration possibly includes both coastal stocks.

H2: Summer estimates of local abundance will pertain to the SC/GA Coastal Stock, while estimates during other seasons may include members of the SM Coastal Stock.

Hypothesis 2 is not supported. Dolphins photographed off Murrells Inlet during the summer months were also photographed in southern North Carolina and in Charleston, SC during the warm months. Dolphins ranging from southern NC to northern SC are not described in any stock assessment report to date. Whether these summer dolphins are members of the SC/GA coastal stock or members of an unidentified coastal stock needs further investigation.

H3: Members of the Northern South Carolina Estuarine System Stock will be found in coastal waters south and inclusive of Murrell's Inlet, but their contribution to coastal abundance estimates will be negligible.

Hypothesis 3 is supported. Three members of the NSCESS were photographed in coastal waters off Murrell's Inlet and/or near the mouth of North Inlet. Given the small number of individuals sighted in coastal waters, the NSCESS is not thought to contribute to the estimates of abundance in coastal waters.

Chapter 3

H1: Members of the Southern North Carolina Estuarine System Stock will be found in and near Little River Inlet, especially in the colder months.

Hypothesis 1 is supported with revision of stock boundaries. There was a clear southern range expansion for SNCESS dolphins in the winter. During the warm months (May-October), no estuarine sightings were recorded between Lockwood-Folly and Little River Inlet. In contrast, sightings occurred not only in the Intracoastal Waterway but also in coastal waters as far south as Pawley's Island during the colder months (December-March).

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Table 1. Summary of mark-recapture field efforts during 2013-2015 in coastal waters along northern South Carolina.

Year	Primary	Secondary	km on-effort	n° of sightings	Best Field Estimate	Mean Water Temp (range °C)
2013	I	July 29-30	100.86	12	426	27.9 (26.8-28.7)
2013	I	Aug 3-4	101.85	14	125	27.4 (26.5-28.4)
2013	I	Aug 9-10	105.86	8	107	27.6 (27.2-27.8)
2013	II	Oct 4-5	94.69	6	186	24.8 (23.6-25.5)
2013	II	Oct 11-12	102.79	6	143	23.3 (23.6-25.5)
2013	II	Oct 18	103.15	6	167	22.7 (22.0-24.1)
2013	III	Dec 13	107.04	8	109	11.9 (10.6-12.4)
2013	III	Dec 16 and 19	96.95	13	120	12.8 (12.1-13.6)
2014	IV	Feb 16	100.12	2	7	8.1 (7.9-8.3)
2014	IV	Feb 18 and 23	97.03	3	27	10.3 (10.2-10.5)
2014	IV	March 2	100.05	0	0	14.6
2014	V	April 12-13	93.70	11	57	18.8 (16.2-20.8)
2014	V	April 22 and 26	97.90	1	2	17.3
2014	V	April 27	98.73	3	49	19.6 (19.0-20.3)
2014	VI	June 14	98.99	4	30	29.5 (27.1-35.7)
2014	VI	June 19 and 26	98.41	11	187	28.8 (26.0-32.2)
2014	VI	July 1	101.29	7	33	28.3 (27.0-29.0)
2014	VII	Aug 17	99.30	2	92	27.0
2014	VII	Aug 23	101.09	7	179	28.6 (27.0-29.5)
2014	VII	Aug 31 Sept 2 and 11	97.94	6	91	28.0 (27.0-29.0)
2014	VIII	Oct 21 and 24	90.44	26	546	20.4 (18.0-22.5)
2014	VIII	Nov 4-5	93.55	21	260	19.0 (18.0-19.0)
2015	IX	Apr 22 and May 3	91.63	19	300	19.5 (18.4-20.8)
2015	IX	May 20 and 28	93.21	9	72	24.1(23.5-24.5)
2015	X	July 30	94.77	2	85	29.5
2015	X	Aug 21	99.05	3	37	29.9 (29.4-30.2)
2015	X	Aug 23	92.53	1	15	29.1
Total	**10**	**27**	**2,652.92**	**211**		**$\bar{x}$ = 21.9**

Table 2. Summary of population parameters estimated under Pollock's Robust Design Markovian model Mt for each primary period.

Year	Primary	$\hat{N}$	θ	$\tilde{N}$	C.I.	CV	MWT (°C)	S	γ''	1-γ'
2013	Jul 29-Aug 10	254	0.69	371	285-531	0.17	27.6			
2013	Oct 4-18	1306	0.56	2,332	1,380-4,039	0.28	23.3	1.00	>0.00	N/A
2013	Dec 13-19	57	0.32	178	84-584	0.60	12.5	1.00	1.00	1.00
2014	Feb 16-Mar 2						9.4			
2014	April 12-27	19	0.25	76	44-336	0.68	19.0	0.59	1.00	0.00
2014	June 14-July 1	418	0.29	1,441	1,128-1,938	0.14	28.8	0.76	1.00	0.70
2014	Aug 17-Sept 11						28.2			
2014	Oct 21-Nov 5	1382	0.09	16,070	6,651-40,279	0.49	19.8	0.99	0.45	1.00
2015	Apr 22-May 28	482	0.32	1,492	820-3,043	0.36	21.0	0.99	0.80	1.00
2015	Jul 30-Aug 23	362	0.32	1,149	308-5,752	0.95	29.6	0.68	N/A	N/A

Table 3. Program MARK output summarizing model fitness under Pollock's robust design full likelihood with closed captures. The 'Constrains' column was added to the table to clarify the differences between each model. Notation (.) denotes constant over time and (t) denotes time variation between primary periods. Capture and recapture probability were assumed to be equal within each primary period since photographic capture minimizes behavioral responses to capture (c=p), but these probabilities were allowed to vary between primary periods.

Model	Constrains	AICc	Delta AICc	AICc Weights	Num. Par	Deviance
{Markovian S(t), g"(t), g'(t), c=p(t)}	***$\gamma''_k = \gamma''_{k-1}, \gamma'_k = \gamma'_{k-1}$***	***-2219.2188***	***0***	***0.68947***	***39***	***-1484.3051***
{Random S(t), g"(t)= g'(t), c=p(t)}	γ" = γ'	-2215.6331	3.5857	0.11479	37	-1476.2213
{Markovian S(.), g"(t), g'(t), c=p(t)}	constant φ	-2215.3208	3.898	0.09819	37	-1475.909
{Markovian S(t), g"(t), g'(.), c=p(t)}	constant γ'	-2215.3039	3.9149	0.09737	37	-1475.8921
{Markovian S(t), g"(.), g'(t), c=p(t)}	constant γ"	-2200.7519	18.4669	0.00007	38	-1463.5857
{Random S(.), g"(t)= g'(t), c=p(t)}	constant φ, γ" = γ'	-2200.5861	18.6327	0.00006	37	-1461.1743
{Markovian S(.), g"(t), g'(.), c=p(t)}	constant φ and γ'	-2200.2487	18.9701	0.00005	38	-1463.0825
{Markovian S(t), g"(.), g'(.), c=p(t)}	constant γ" and γ'	-2194.9279	24.2909	0	37	-1455.5161
{No_Movement S(t), g"(.), g'(.), c=p(t)}	γ" = 0, γ" = 1	-2191.3052	27.9136	0	36	-1449.6549
{No_Emigration S(t), g"(.), g'(.), c=p(t)}	γ" = γ' =0	-2191.3052	27.9136	0	36	-1449.6549
{Markovian S(.), g"(.), g'(t), c=p(t)}	constant φ and γ"	-2189.753	29.4658	0	37	-1450.3412
{Random S(t), g"(.)= g'(.), c=p(t)}	constant φ and γ" = γ'	-2189.5129	29.7059	0	37	-1450.1011
{Markovian S(.), g"(.), g'(.), c=p(t)}	constant φ, γ" and γ'	-2185.94	33.2788	0	35	-1442.0582
{Random S(.), g"(.)= g'(.), c=p(t)}	constant φ, γ" = γ'	-2178.5627	40.6561	0	35	-1434.6809
{No_Movement S(.), g"(.), g'(.), c=p(t)}	constant φ, γ" = 0, γ" = 1	-2172.7484	46.4704	0	34	-1426.642
{No_Emigration S(.), g"(.), g'(.), c=p(t)}	constant φ, γ" = γ' = 0	-2172.7484	46.4704	0	34	-1426.642

Table 4. Summary of mark-recapture field efforts in 2014-2015 centered in Little River, northern South Carolina.

Year	Primary	Secondary	km on-effort	n° of sightings	Best Field Estimate	Mean Water Temp (range °C)
2014	I	Aug 21	105.01	2	17	
2014	I	Aug 28-29	98.46	2	18	26.3 (26.0-26.5)
2014	I	Sept 2 and 10	93.38	5	151	27.7 (27.0-28.0)
2014	II	Oct 25 and 27	120.91	22	327	21.7 (20.0-23.0)
2014	II	Nov 3-4	127.0	14	206	19.0
2015	III	March 9	127.89	8	59	10.5 (9.3-11.6)
2015	III	March 16	127.27	4	20	13.4 (11.9-16.1)
2015	IV	May 2	118.84	5	12	18.7 (18.1-19.5)
2015	IV	May 4	127.42	8	49	21.0 (20.2-21.3)
2015	V	Aug 9 and 13	123.76	1	19	29.1
2015	V	Aug 16	125.84	4	49	29.0 (28.8-29.1)
Total	**5**	**11**	**1,295.78**	**75**	**927**	**$\bar{x}$ = 21.7**

Table 5. Program MARK output summarizing model fitness under Pollock's robust design full likelihood with closed captures. The 'Constrains' column was added to the table to clarify the differences between each model. Notation (.) denotes constant over time, (t) denotes time variation between primary periods. Capture and recapture probability were assumed to be equal since photographic capture minimizes behavioral responses to capture. Population parameters estimated under the top three models (in bold) were average to account for model uncertainty.

Model	Constrains	AICc	Delta AICc	AICc Weights	Num. Par	Deviance
{Markovian S(.) gamma"(t) gamma'(t) c=p(t)}	**constant φ**	**-494.64**	**0**	**0.44924**	**19**	**-298.5685**
{Markovian S(.) gamma"(t) gamma'(.) c=p(t)}	**constant φ and γ'**	**-493.63**	**1.0081**	**0.27138**	**18**	**-295.0686**
{Markovian S(t) gamma"(t) gamma'(.) c=p(t)}	**constant γ'**	**-493.11**	**1.5328**	**0.20875**	**19**	**-297.0358**
{Random S(t) gamma"(t)=gamma'(t) c=p(t)}	γ" = γ'	-488.94	5.6963	0.02603	20	-295.3948
{Markovian S(t) gamma"(.) gamma'(t) c=p(t)}	constant γ"	-488.06	6.5795	0.01674	19	-291.989
{Random S(t) gamma"(.)=gamma'(.) c=p(t)}	constant γ" = γ'	-486.74	7.8981	0.00866	18	-288.1785
{Markovian S(t) gamma"(t) gamma'(t) c=p(t)}	γ"k = γ"k-1, γ'k = γ'k-1	-486.6	8.0391	0.00807	21	-295.606
{No_Movement S(t) gamma"(.) gamma'(.) c=p(t)}	γ" = 0, γ" = 1	-484.88	9.7623	0.00341	18	-286.3143
{No_Emigration S(t) gamma"(.)= gamma'(.) c=p(t)}	γ" = γ' = 0	-484.88	9.7623	0.00341	18	-286.3144
{Markovian S(t) gamma"(.) gamma'(.) c=p(t)}	constant γ", γ'	-484.28	10.3571	0.00253	19	-288.2114
{Markovian S(.) gamma"(.) gamma'(t) c=p(t)}	constant φ, γ"	-483.44	11.2052	0.00166	18	-284.8715
{Markovian S(.) gamma"(.) gamma'(.) c=p(t)}	constant φ, γ", γ'	-477.26	17.3783	0.00008	18	-278.6984
{Random S(.) gamma"(t)=gamma'(t) c=p(t)}	constant φ, γ" = γ'	-474.21	20.4347	0.00002	20	-280.6564
{No_Movement S(.) gamma"(.) gamma'(.) c=p(t)}	constant φ, γ" = 0, γ" = 1	-473.38	21.2615	0.00001	17	-272.3536
{No_Emigration S(.) gamma"(.)=gamma'(.) c=p(t)}	constant φ, γ" = γ' = 0	-473.38	21.2615	0.00001	17	-272.3536
{Random S(.) gamma"(.)=gamma'(.) c=p(t)}	constant φ, γ" = γ'	-473.26	21.3825	0.00001	18	-274.6941

Table 6. Summary of population parameters estimated under Pollock's Robust Design Markovian model Mt for each primary period off Little River.

Year	Primary	$\hat{N}$	θ	$\tilde{N}$	C.I.	CV	MWT (°C)	S	γ''	1-γ'
2014	Aug 21-Sept 10	34	0.44	77	100-175	0.34	27.1	N/A	N/A	N/A
2014	Oct 25-Nov 4	826	0.17	4,820	8,110-18,289	0.74	20.7	1.00	0.21	N/A
2015	March 3-16	27	0.29	92	134-411	0.72	11.5	1.00	1.00	1.00
2015	May 2-4	33	0.41	82	102-193	0.31	20.1	0.50	1.00	0.81
2015	Aug 9-16	43	0.62	69	77-98	0.62	29.0	0.72	0.32	1.00

Table 7. Summary of mark-recapture field efforts in 2014-2015 for the combined dataset of concurrent surveys off Murrell's Inlet and Little River, northern South Carolina.

Year	Area	Primary	Secondary	km on-effort	n° of sightings	Best Field Estimate	Mean Water Temp (range °C)
2014	MI	I	Aug 17	99.30	2	92	27.0
2014	LR	I	Aug 21	105.01	2	17	
2014	MI	I	Aug 23	101.09	7	179	28.6 (27.0-29.5)
2014	LR	I	Aug 28-29	98.46	2	18	26.3 (26.0-26.5)
2014	LR	I	Sept 2 and 10	93.38	5	90	27.7 (27.0-28.0)
2014	MI	I	Aug 31 Sept 2 and 11	97.94	6	151	28.0 (27.0-29.0)
2014	MI	II	Oct 21 and 24	90.44	26	546	20.4 (18.0-22.5)
2014	LR	II	Oct 25 and 27	120.91	22	327	21.7 (20.0-23.0)
2014	LR	II	Nov 3-4	127.0	14	206	19.0
2014	MI	II	Nov 4-5	93.55	21	260	19.0 (18.0-19.0)
2015	MI	III	Apr 22 and May 3	91.63	19	300	19.5 (18.4-20.8)
2015	LR	III	May 2	118.84	5	12	18.7 (18.1-19.5)
2015	LR	III	May 4	127.42	7	49	21.0 (20.2-21.3)
2015	MI	III	May 20 and 28	93.21	9	72	24.1(23.5-24.5)
2015	MI	IV	July 30	94.77	2	85	29.5
2015	LR	IV	Aug 9 and 13	123.76	1	19	29.1
2015	LR	IV	Aug 16	125.84	4	49	29.0 (28.8-29.1)
2015	MI	IV	Aug 21	99.05	3	37	29.9 (29.4-30.2)
Total		**4**	**9**	**1901.60**	**157**		

Table 8. Program MARK output summarizing model fitness under Pollock's robust design full likelihood with closed captures. The 'Constrains' column was added to the table to clarify the differences between each model. Notation (.) denotes constant over time, (t) denotes time variation between primary periods. Capture and recapture probability were assumed to be equal since photographic capture minimizes behavioral responses to capture. Population parameters estimated under the top three models (in bold) were average to account for model uncertainty.

Model	Constrains	AICc	Delta AICc	AICc Weights	Num. Par	Deviance
{Markovian S(.) gamma"(.) gamma'(t) p=c(t)}	**constant φ and γ"**	***-2156.69***	***0***	***0.47098***	***14***	***-855.1624***
{Markovian S(t) gamma"(.) gamma'(t) p=c(t)}	**constant γ"**	***-2156.3***	***0.3878***	***0.38796***	***15***	***-856.9034***
{Markovian S(.) gamma"(t) gamma'(t) p=c(t)}	**constant φ**	***-2154.17***	***2.5219***	***0.13347***	***16***	***-856.9069***
{Markovian S(t) gamma"(t) gamma'(.) p=c(t)}	constant γ'	-2147.297	9.3954	0.00429	17	-852.1803
{Markovian S(t) gamma"(.) gamma'(.) p=c(t)}	constant γ"and γ'	-2143.996	12.6963	0.00082	16	-846.7325
{No Emigration S(t) gamma"(.)=gamma'(.) p=c(t)}	γ" = γ' =0	-2143.488	13.2047	0.00064	15	-844.0864
{No Movement S(t) gamma"(.)=gamma'(.) p=c(t)}	γ" = 0, γ" = 1	-2143.488	13.2047	0.00064	15	-844.0864
{Markovian S(t) gamma"(t) gamma'(t) p=c(t)}	$\gamma''_k = \gamma''_{k-1}$, $\gamma'_k = \gamma'_{k-1}$	-2142.863	13.8294	0.00047	17	-847.7463
{Random S(t) gamma"(t)=gamma'(t) p=c(t)}	γ" = γ'	-2142.25	14.4422	0.00034	16	-844.9866
{Random S(t) gamma"(.)=gamma'(.) p=c(t)}	constant γ" = γ'	-2141.591	15.1017	0.00025	16	-844.3271
{Markovian S(.) gamma"(t) gamma'(.) p=c(t)}	constant φ and γ'	-2139.074	17.6182	0.00007	17	-843.9575
{Random S(.) gamma"(t)=gamma'(t) p=c(t)}	constant φ and γ" = γ'	-2138.869	17.8239	0.00006	17	-843.7518
{Markovian S(.) gamma"(.) gamma'(.) p=c(t)}	constant φ, γ" and γ'	-2130.635	26.0572	0	16	-833.3717
{Random S(.) gamma"(.)=gamma'(.) p=c(t)}	constant φ and γ" = γ'	-2129.391	27.3017	0	15	-829.9894
{No Emigration S(.) gamma"(.)=gamma'(.) p=c(t)}	constant φ, γ" = γ' = 0	-2121.421	35.2712	0	14	-819.8913
{No Movement S(t) gamma"(.)=gamma'(.) p=c(t)}	γ" = 0, γ" = 1	-2121.421	35.2712	0	14	-819.8913

Table 9. Summary of population parameters estimated under Pollock's Robust Design Markovian model Mt for each primary period during concurrent surveys off Murrell's Inlet and Little River.

Year	Primary	N̂	θ	Ñ	C.I.	CV	MWT (°C)	S	γ"	1-γ'
2014	Aug 17-Sept 11	331	0.44	1,039	876 1,773	0.19	27.65	N/A	N/A	N/A
2014	Oct 21-Nov 5	928	0.17	10,049	3,597 13,821	0.40	20.25	1.00	0.70	N/A
2015	Apr 22-May 28	552	0.41	1,521	1,099 2,139	0.19	20.55	1.00	0.69	0.67
2015	Jul 30 – Aug 23	142	0.62	249	216 461	0.19	29.30	0.75	0.82	0.00

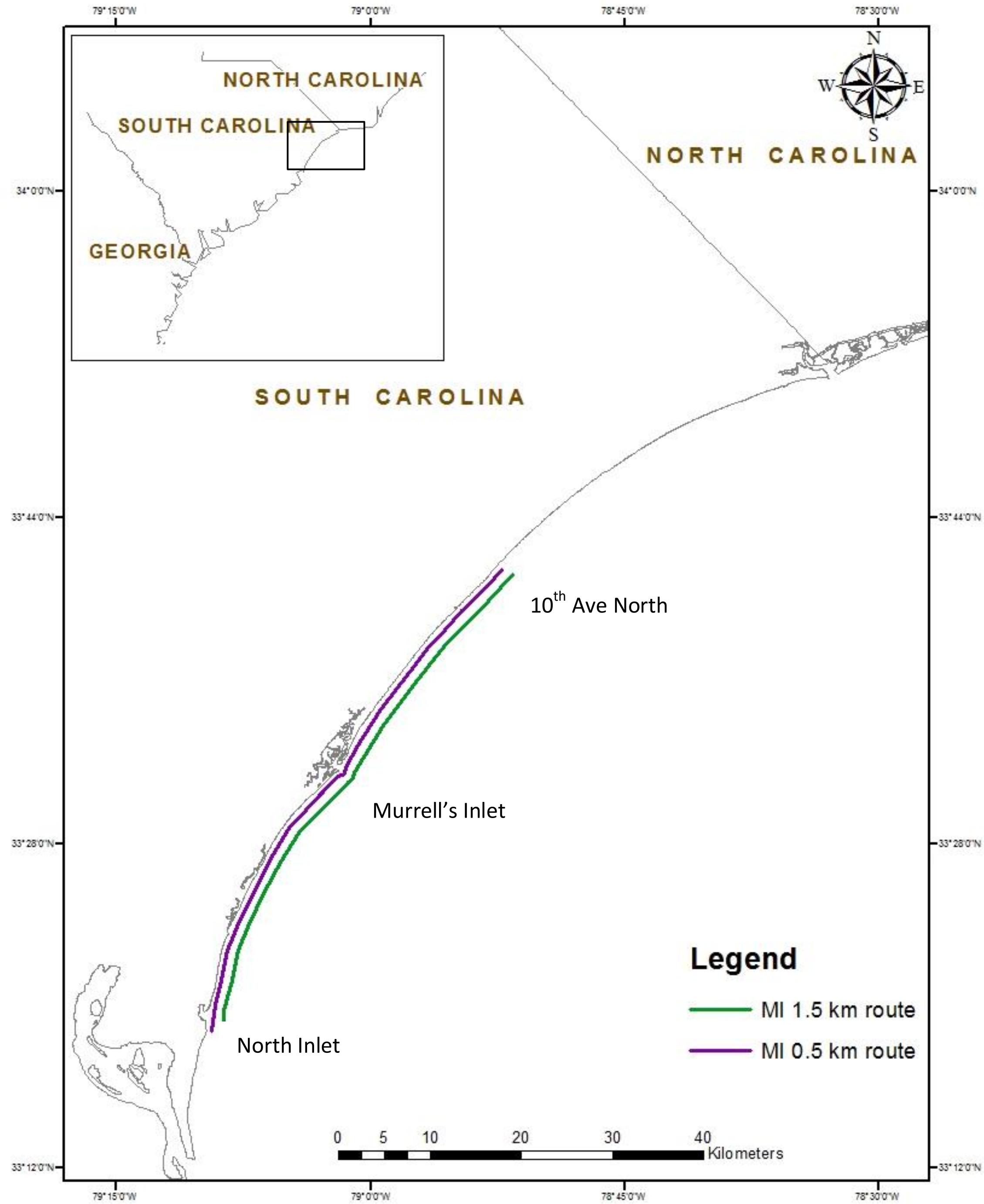


Figure 1. Study Area including survey routes.

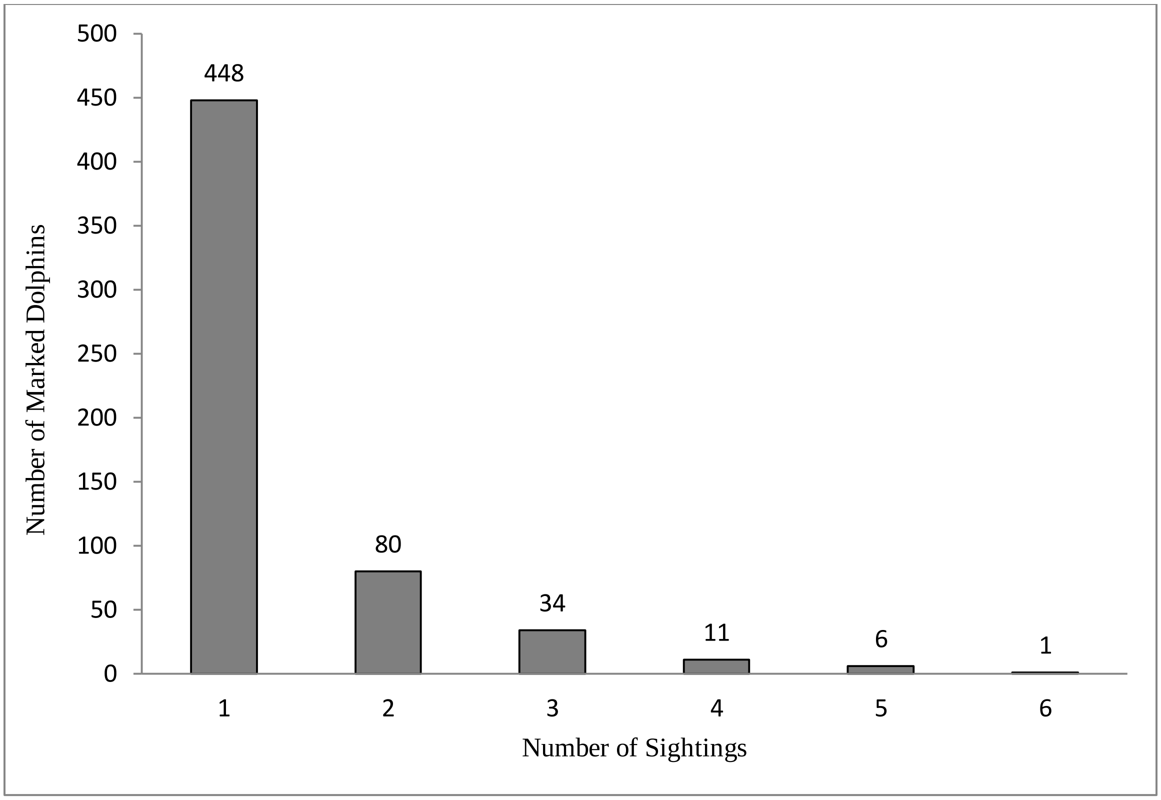


Figure 2. Sighting frequency of marked individual dolphins seen during Murrell's Inlet surveys from 2013-2015. It includes on and off effort sightings. Note most marked individuals were only sighted once.

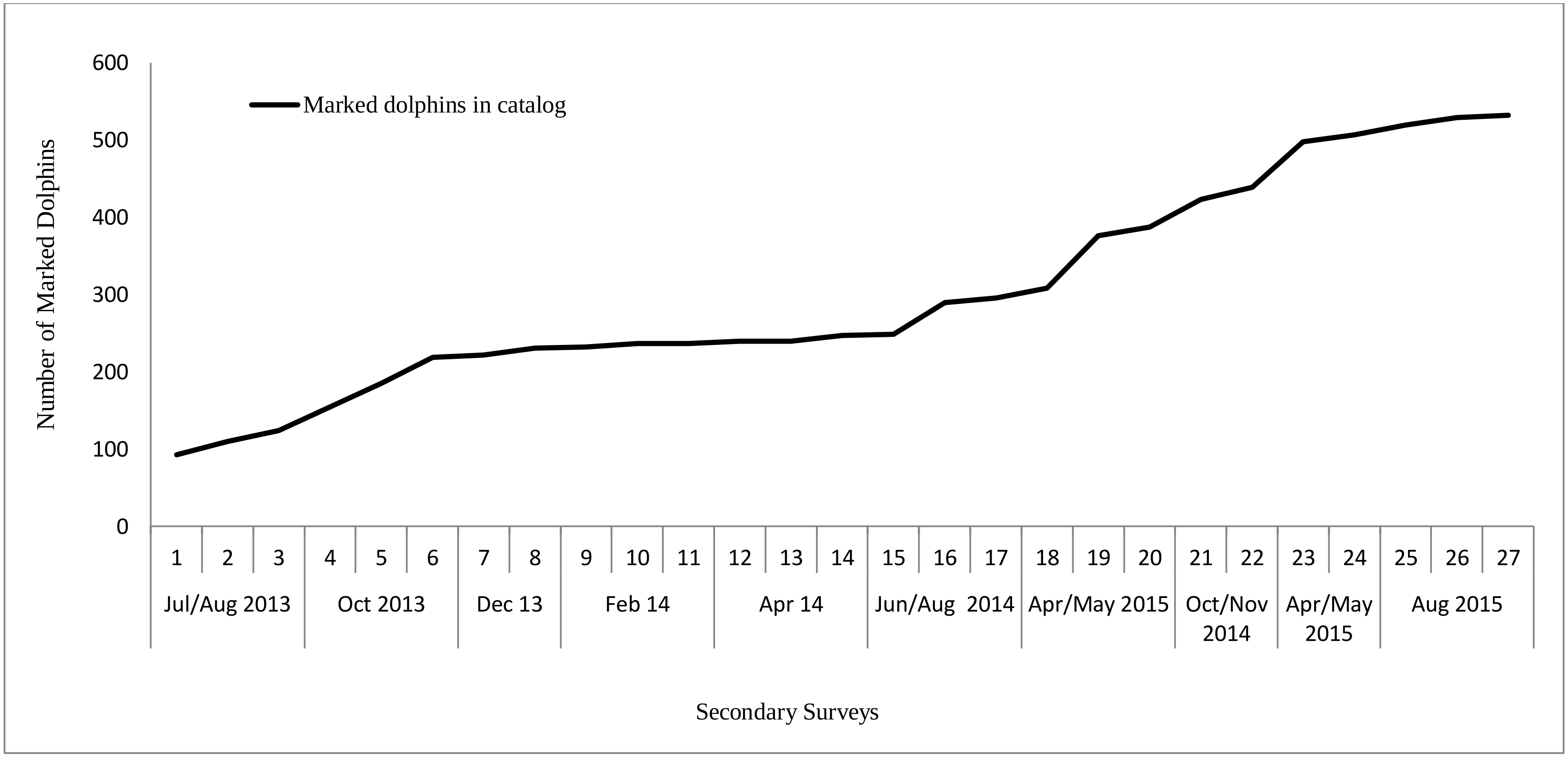


Figure 3. Discovery Curve of marked dolphins sighted during Murrell's Inlet surveys from 2013-2015. The rate of discovery of new individuals increased between summer and fall plateaued during winter and spring, increased steeply between spring and summer, and kept increasing at a slower rate during Year 2.

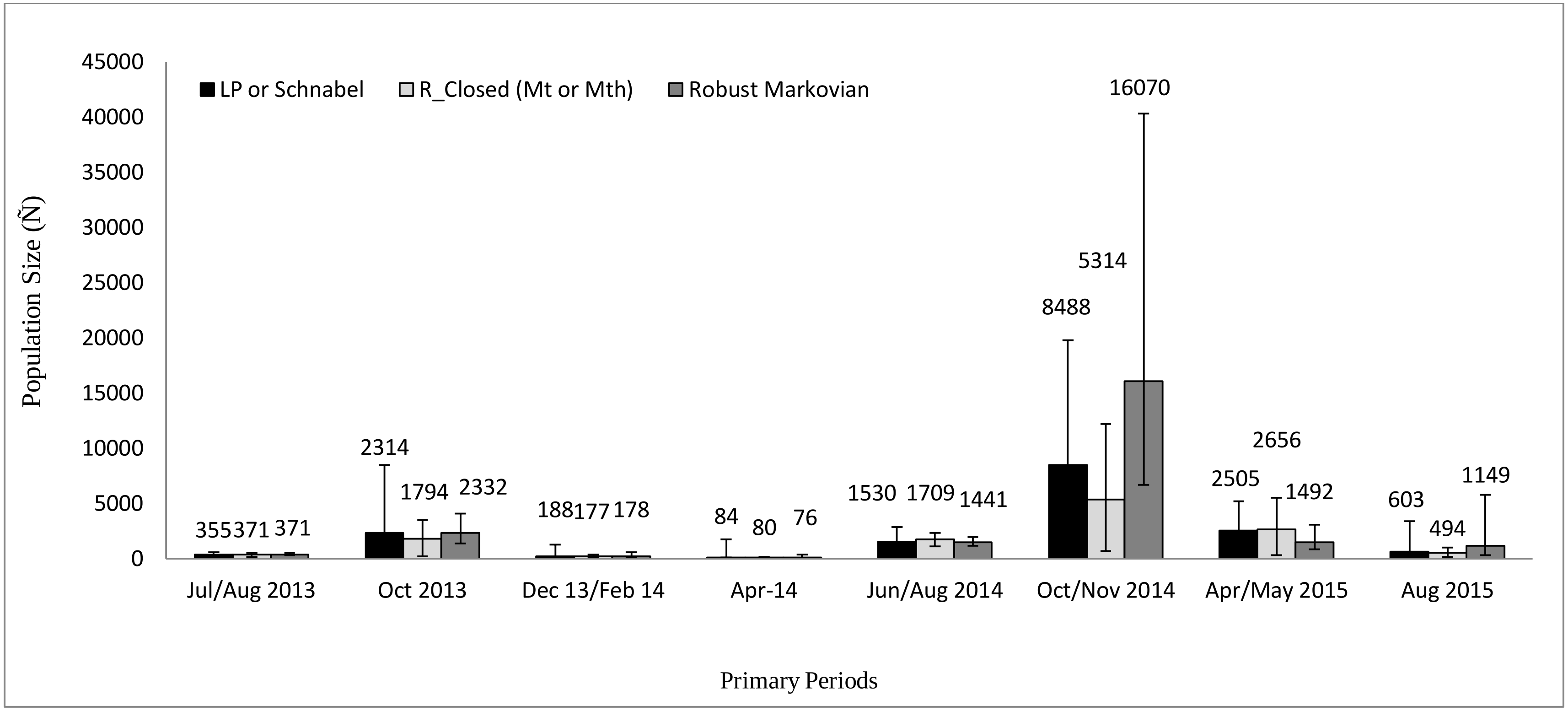


Figure 4. Population size and corresponding 95% confidence intervals estimated using the Lincoln-Petersen method or the Schnabel method, best fitting models in Rcapture (R), and the robust design with Markovian emigration model (MARK 6.2).

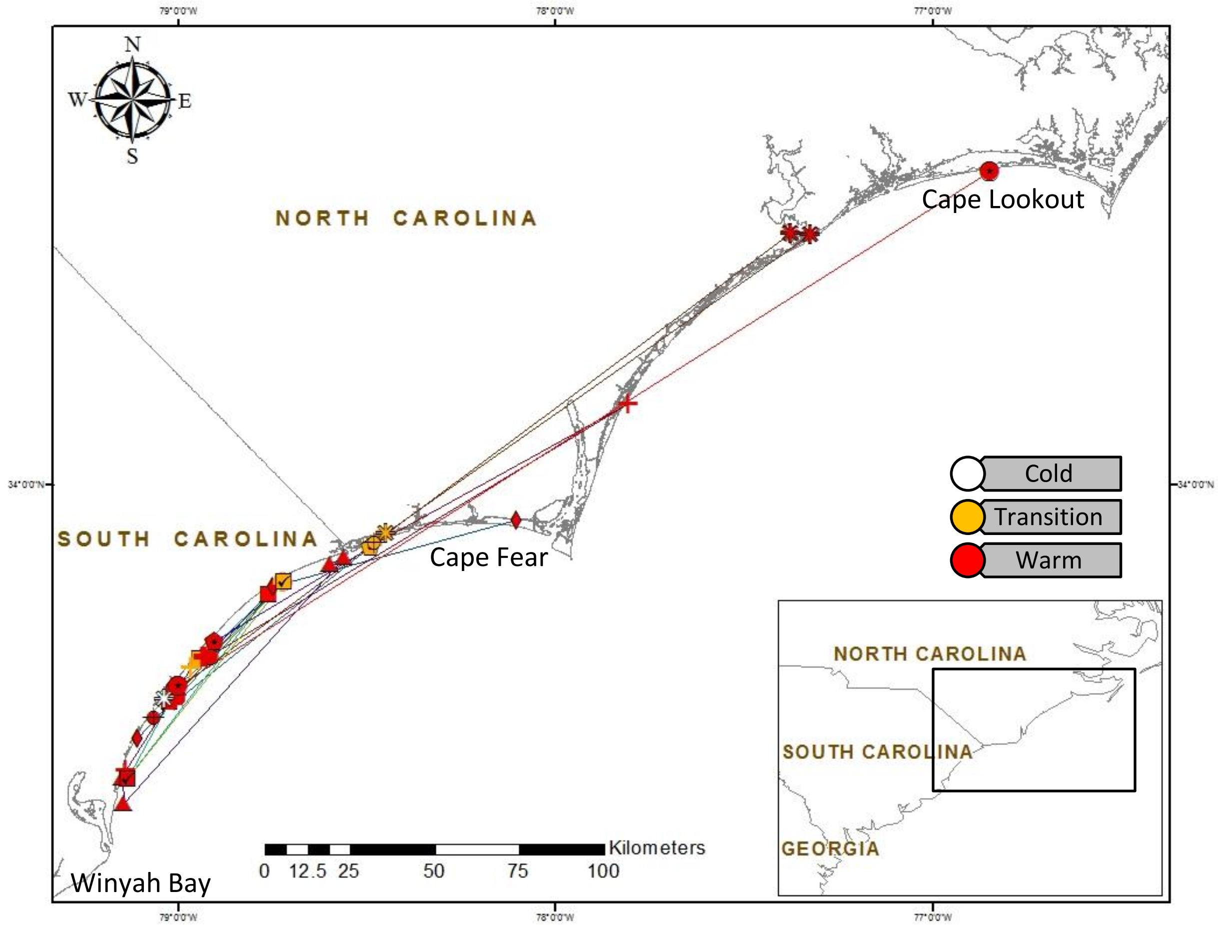


Figure 5. Dorsal fin matches photographed during the present study and photo-ID studies off Little River (August 2014-August 2015) and southern North Carolina (June-August 2014 and December 2014). Each shape represents an individual dolphin. Mid-November-mid-April were considered cold, mid-April-mid-May and mid-October-mid-November were considered transition, and mid-May-mid-October were considered warm months.

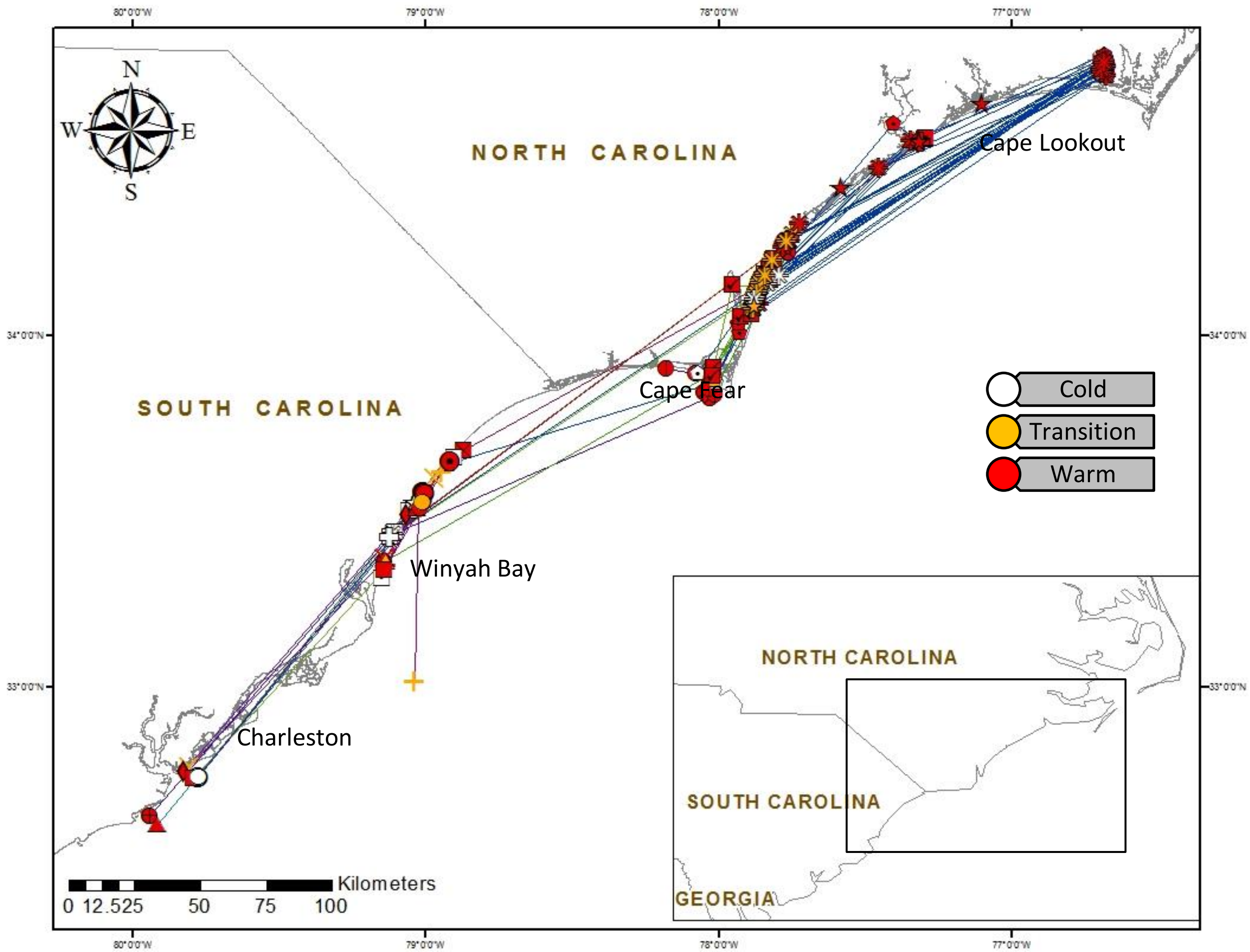


Figure 6. Dorsal fin matches photographed during the present study and historical photo-ID studies off the Carolinas. Each shape represents an individual dolphin. Mid-November-mid-April were considered cold, mid-April-mid-May and mid-October-mid-November were considered transition, and mid-May-mid-October were considered warm months.

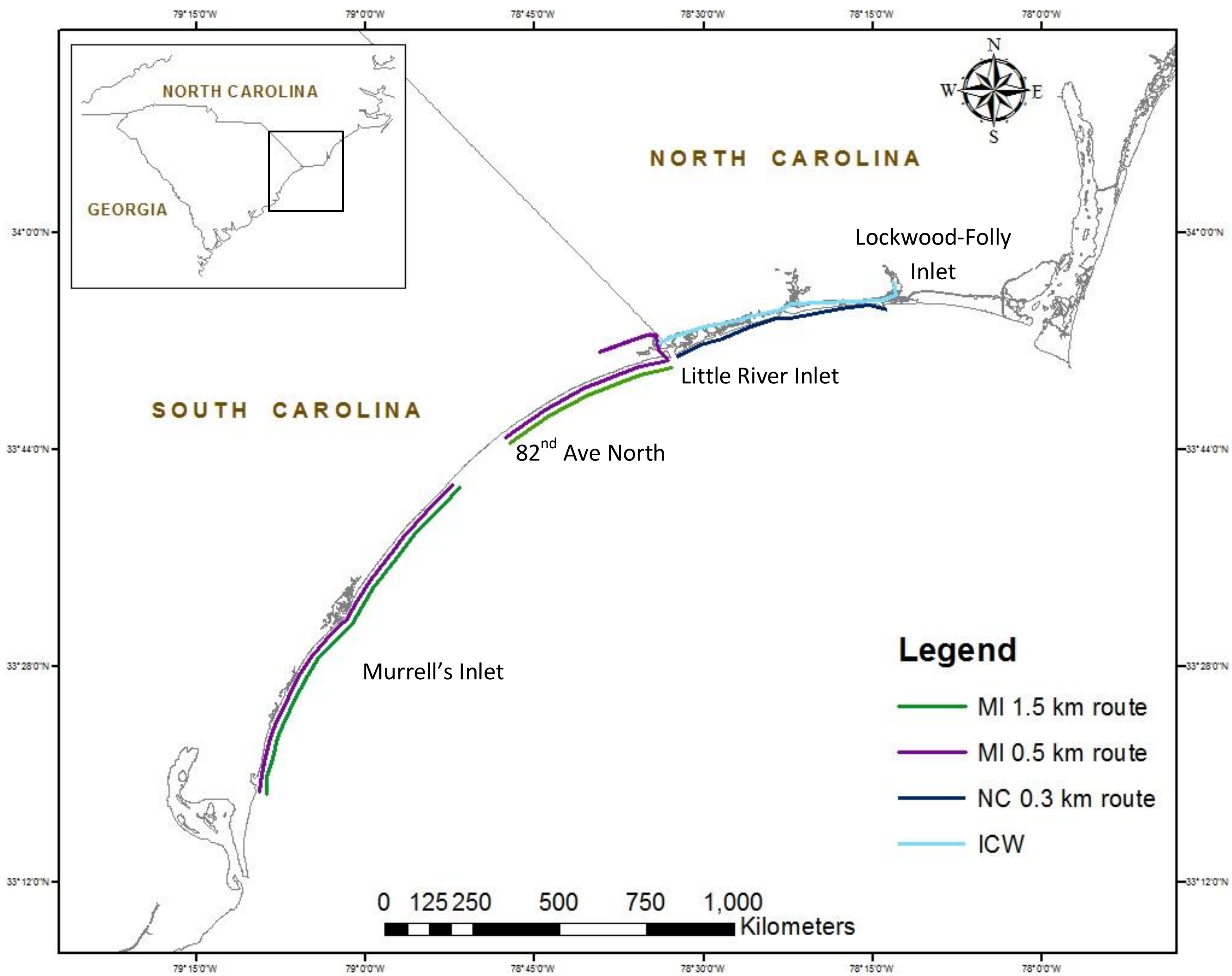


Figure 7. Study areas including survey routes.

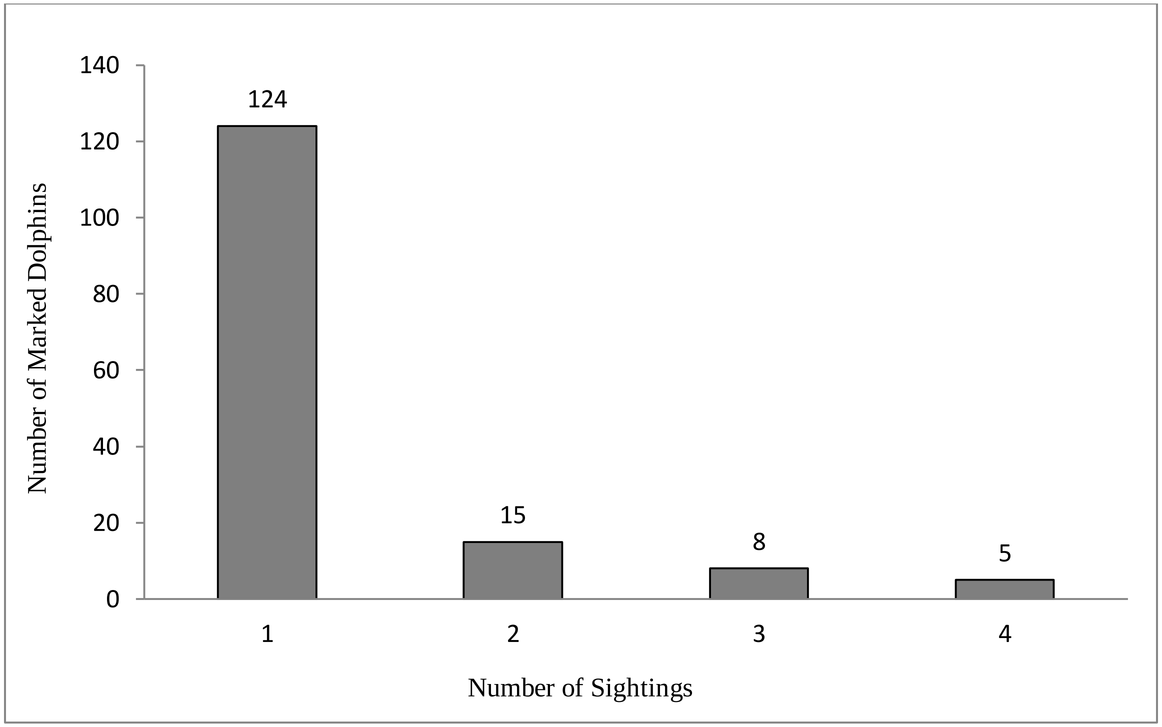


Figure 8. Sighting frequency of marked individual dolphins photographed during Little River surveys from 2014-2015. It includes on and off effort sightings. Note most marked individuals were only sighted once.

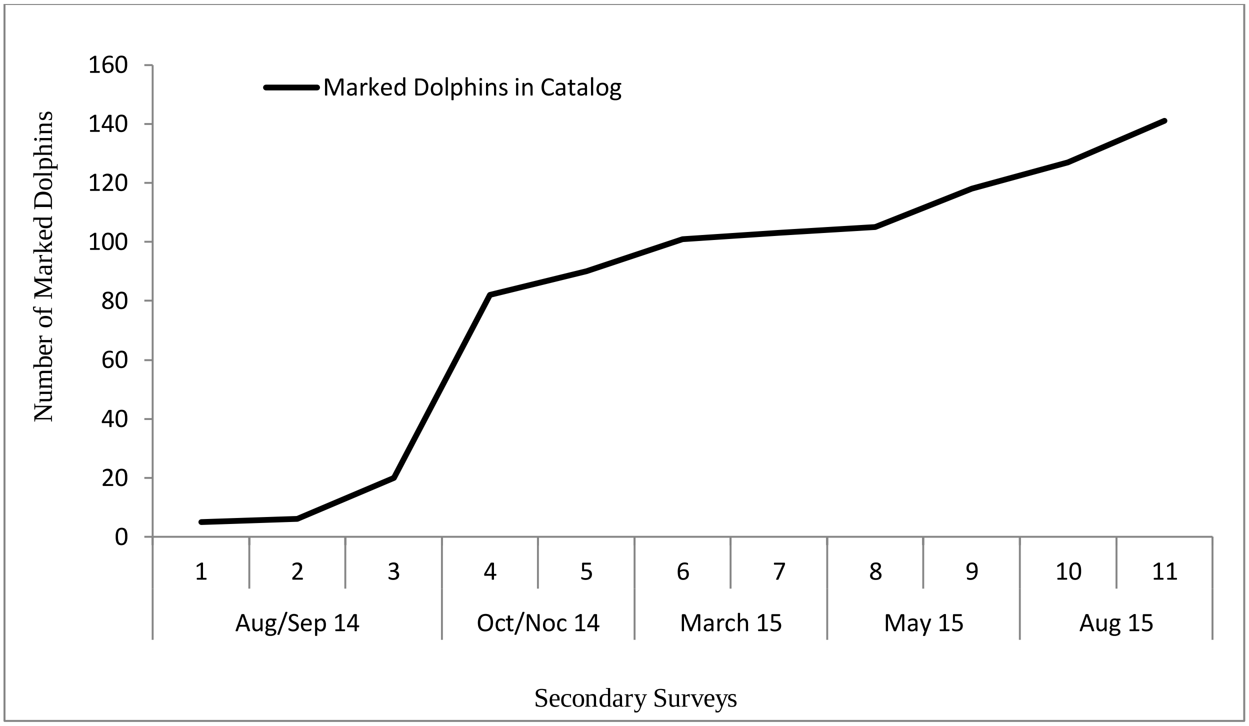


Figure 9. Discovery Curve of marked dolphins sighted during Little River surveys from 2014-20015. Note the steep increase between summer and fall and the gentle increase thereafter.

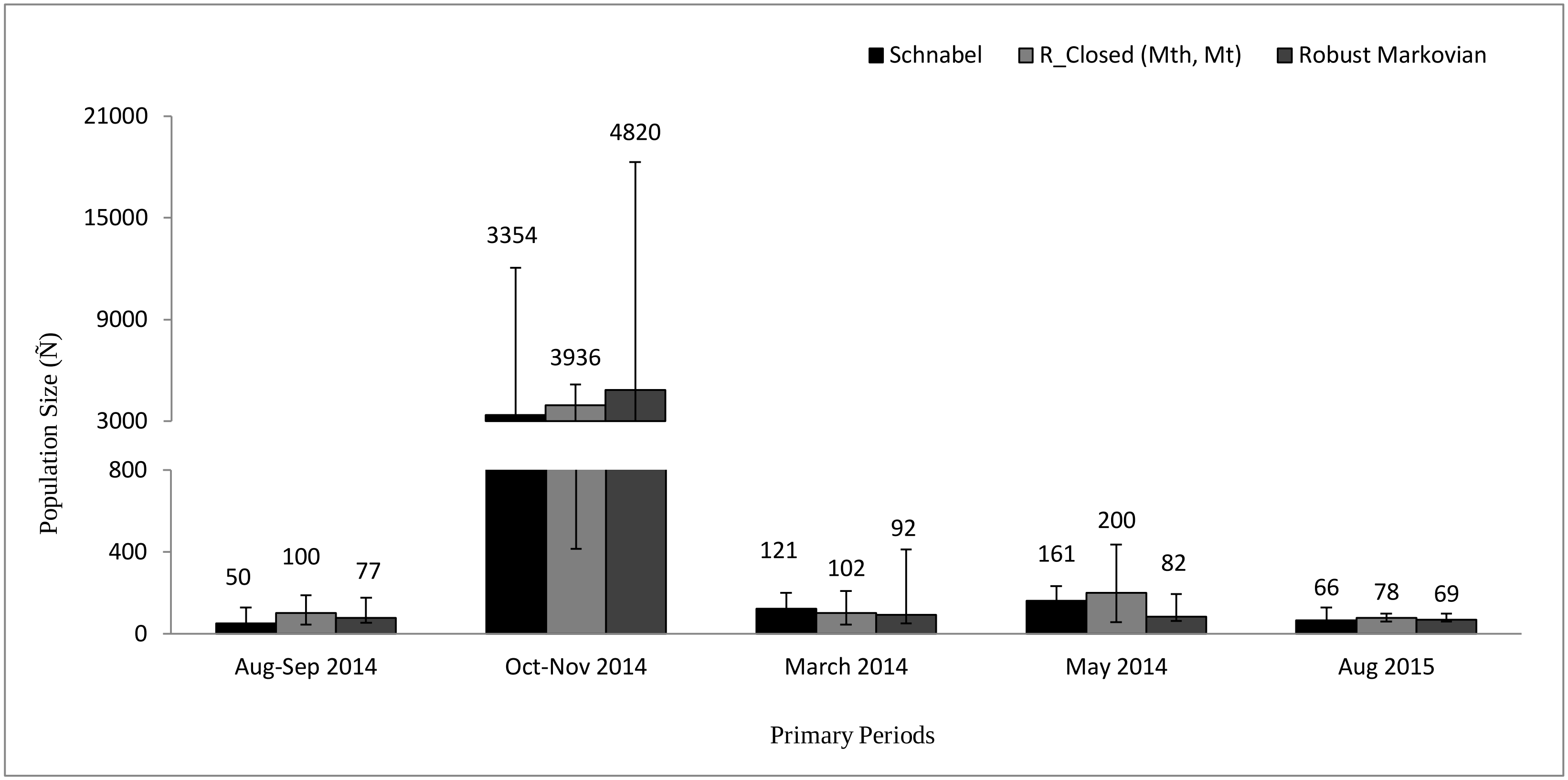


Figure 10. Population size and corresponding 95% confidence intervals estimated using the Schnabel method, best fitting model in Rcapture (R), and the robust design with Markovian emigration model (MARK 6.2).

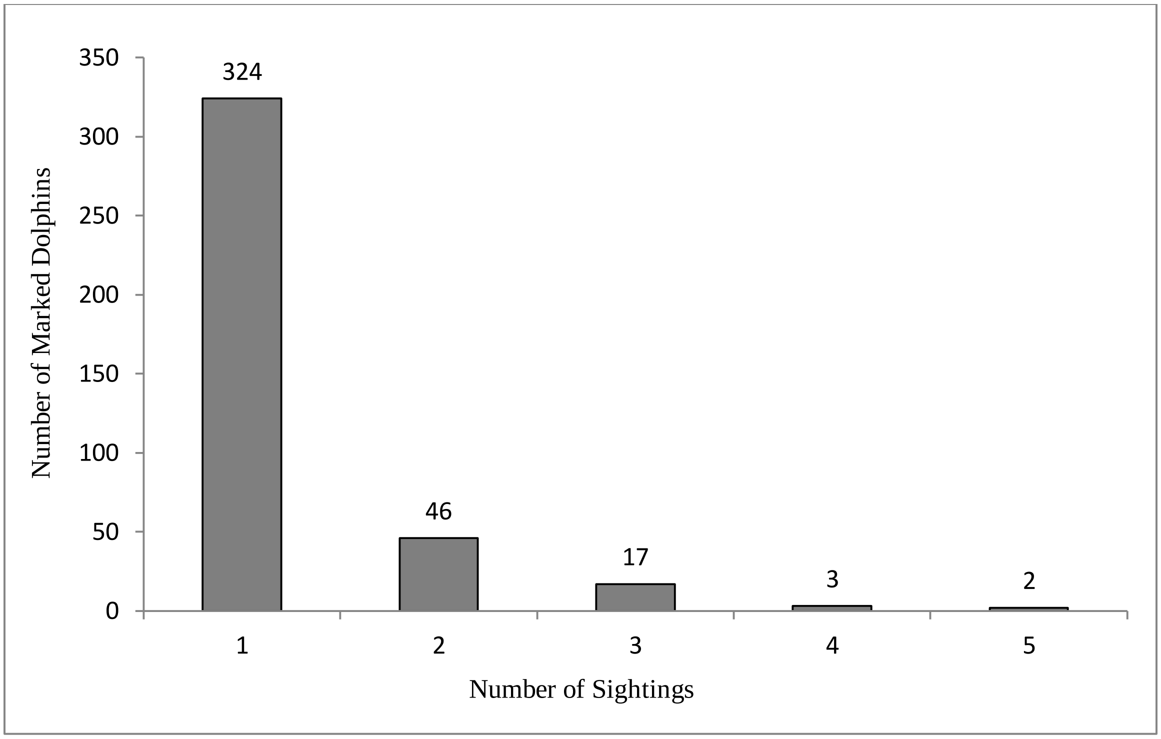


Figure 11. Sighting frequency of marked individual dolphins photographed during Murrell's Inlet and Little River surveys from 2014-2015. It includes on and off effort sightings. Note most marked individuals were only sighted once.

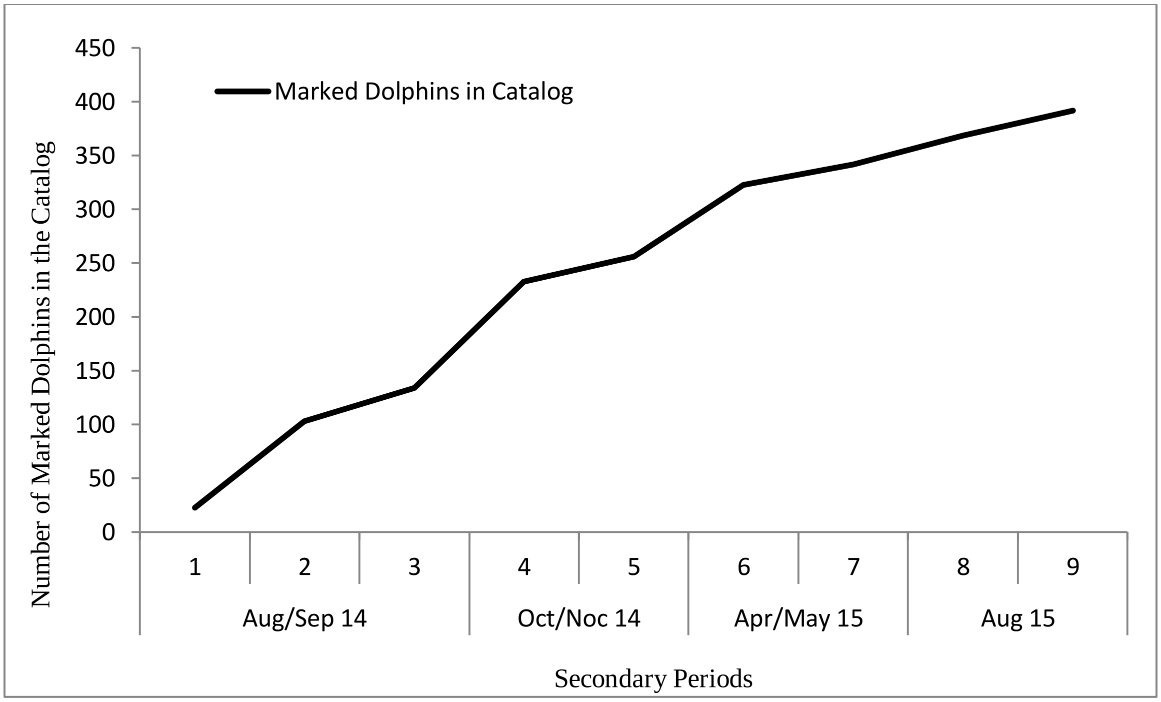


Figure 12. Discovery Curve of marked dolphins sighted during Murrell's Inlet and Little River surveys from 2014-20015. The discovery curve from the combined surveys increased at a higher rate between summer and fall and had a slower rate thereafter.

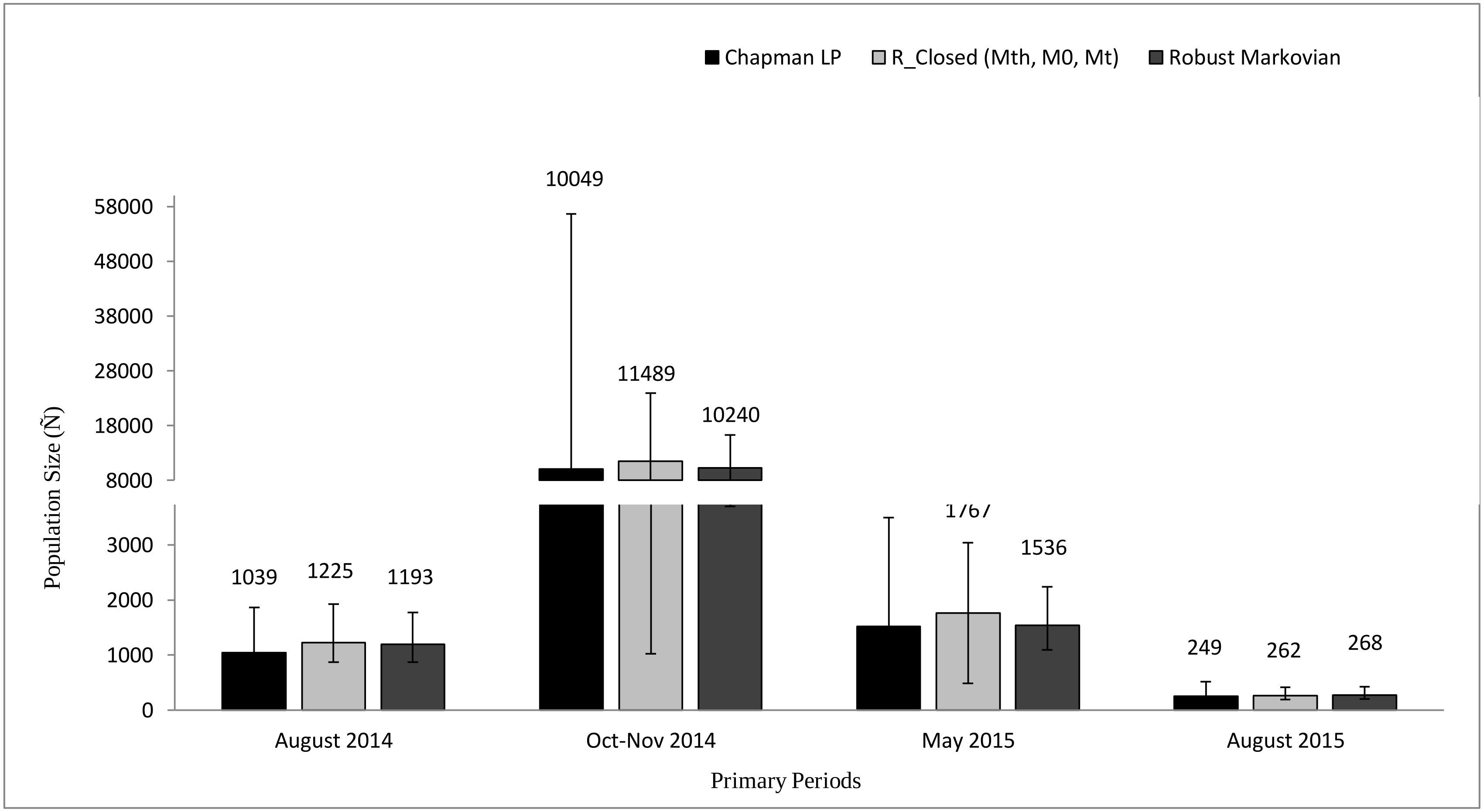


Figure 13. Population size and corresponding 95% confidence intervals estimated using the LP method (Schnabel method was used for August surveys), best fitting model in Rcapture (R), and the robust design with Markovian emigration model (MARK 6.2).

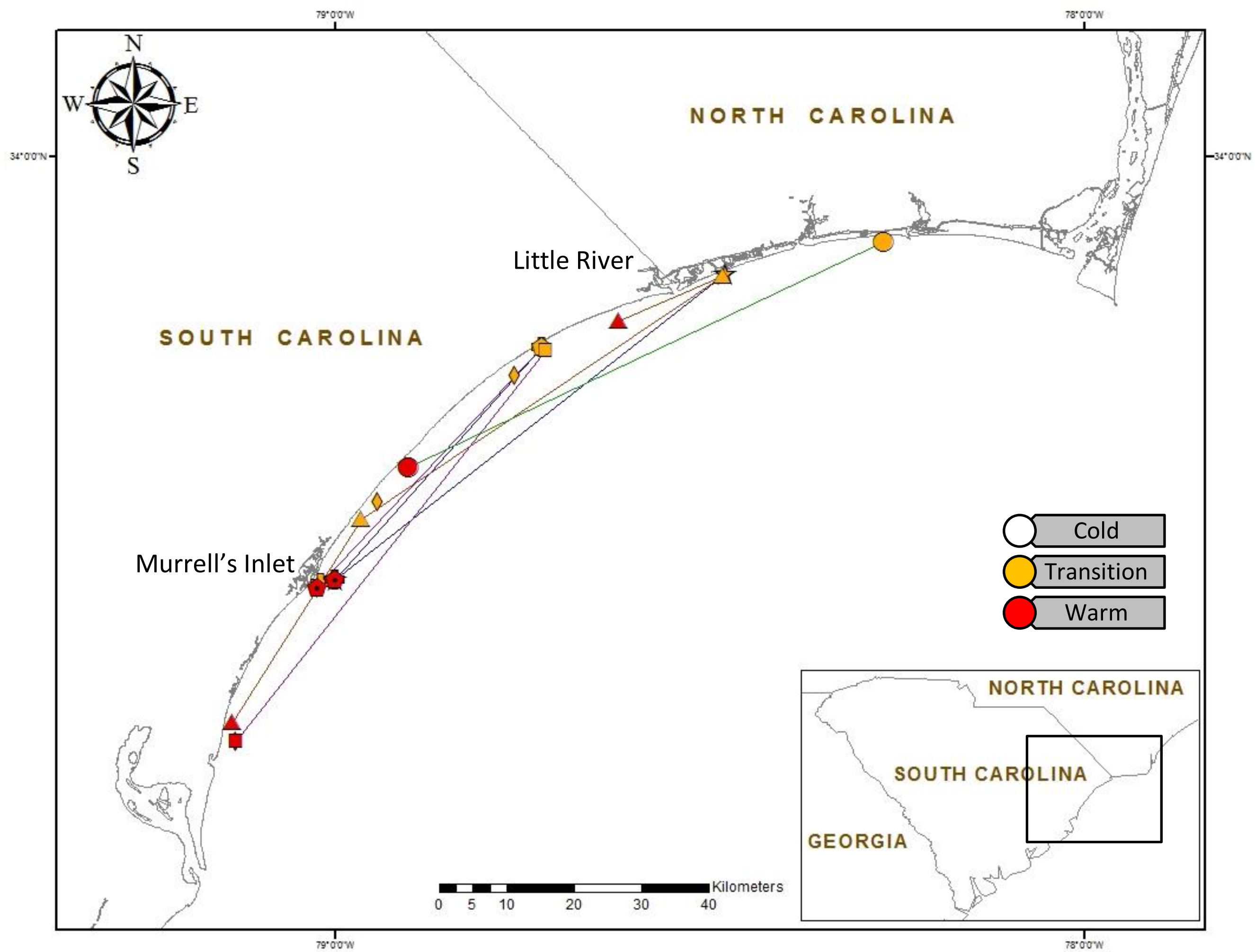


Figure 14. Dorsal fin matches photographed during concurrent surveys off Murrell's Inlet and Little River (August 2014-August 2015). Each shape represents an individual dolphin. Mid-November-mid-April were considered cold, mid-April-mid-May and mid-October-mid-November were considered transition, and mid-May-mid-October were considered warm months.

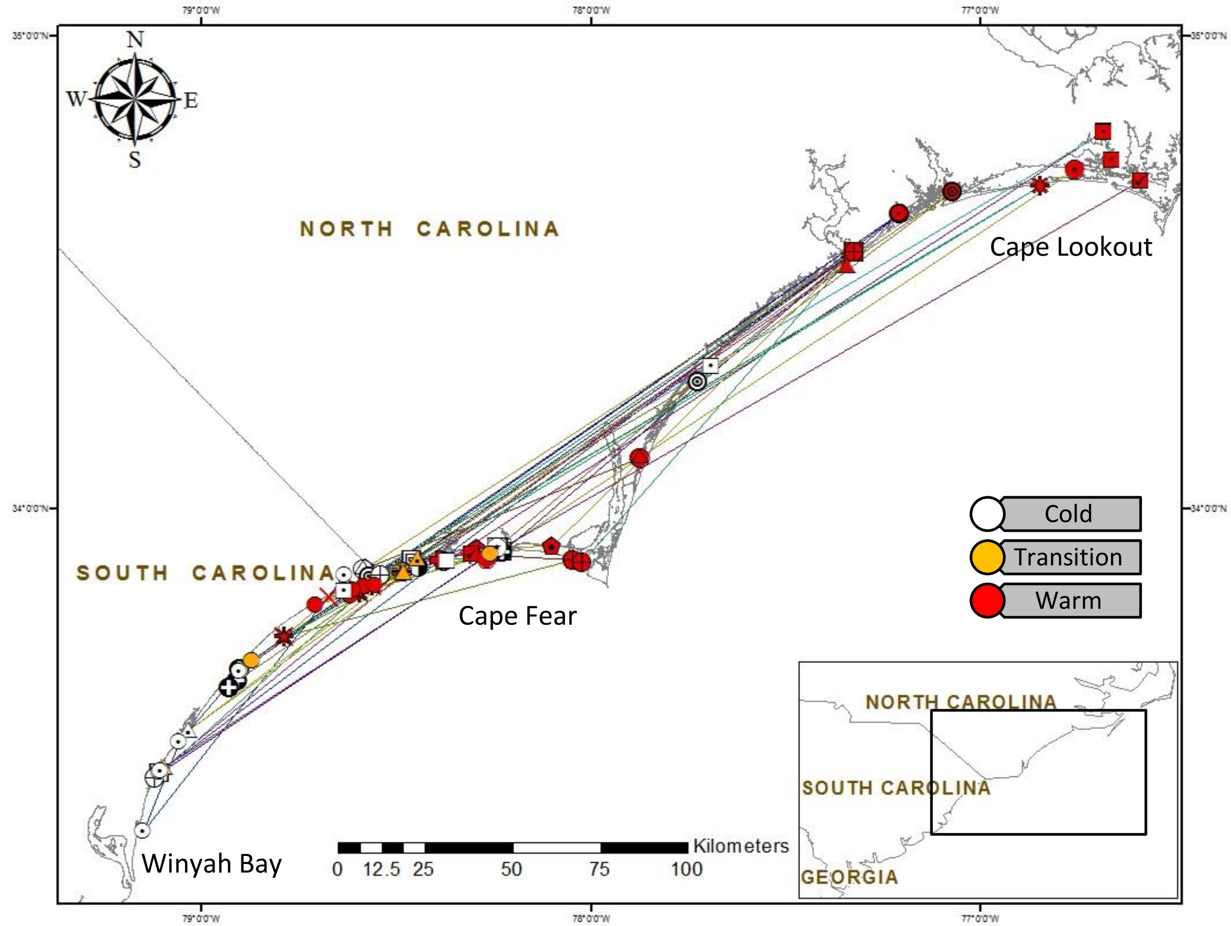


Figure 15. Dorsal fin matches photographed during concurrent surveys off Murrell's Inlet and Little River (August 2014-August 2015) and during photo-ID surveys off southern North Carolina. Each shape represents an individual dolphin. Mid-November-mid-April were considered cold, mid-April-mid-May and mid-October-mid-November were considered transition, and mid-May-mid-October were considered warm months. Shapes containing marks represent members of the SNCESS.

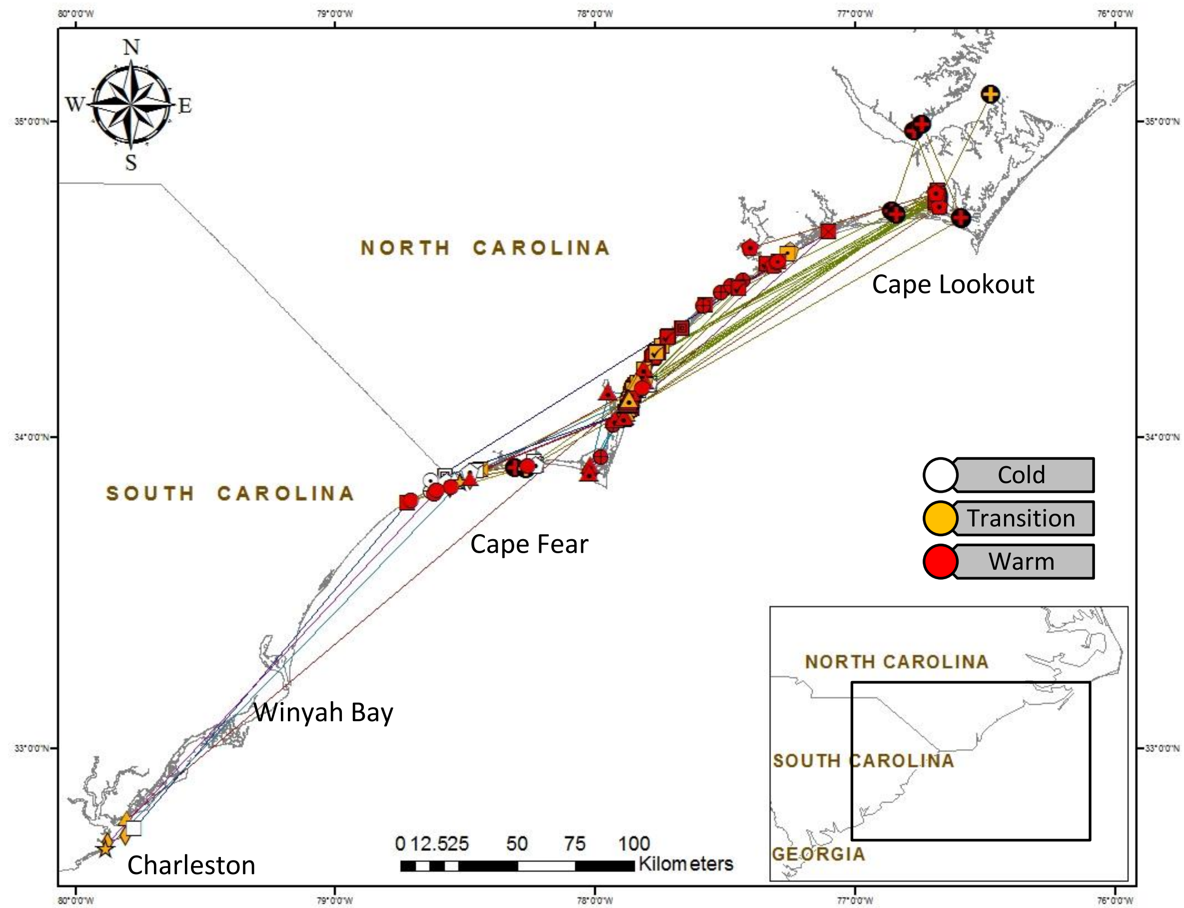


Figure 16. Dorsal fin matches photographed during concurrent surveys off Murrell's Inlet and Little River (August 2014-August 2015) and during photo-ID surveys off the Carolinas. Each shape represents an individual dolphin. Mid-November-mid-April were considered cold, mid-April-mid-May and mid-October-mid-November were considered transition, and mid-May-mid-October were considered warm months. Shapes with internal marks represent members of the SNCESS.

Appendix A: Summary of bottlenose dolphin group sightings.

Appendix A, Table 1. Summary of group sightings of bottlenose dolphins during Murrell's Inlet surveys between July 2013 and August 2015.

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
7/29/2013	1	2	28.4	6.7	25	0	0
7/29/2013	2	2	28.3	6.6	20	4	0
7/29/2013	3	3	28.7	8.2	20	3	0
7/29/2013	4	3	28.6	7.5	32	2	0
7/30/2013	1	2	28.0	4.6	2	1	0
7/30/2013	2	2	26.8	5.6	120	15	4
7/30/2013	3	2	27.9	6.8	120	15	4
7/30/2013	4	2	27.2	5.2	35	8	0
7/30/2013	5	2	27.8	6.9	12	1	0
7/30/2013	6	2	28.1	8.0	23	2	0
7/30/2013	7	3	28.0	6.4	8	0	0
7/30/2013	8	3	27.1	5.7	9	2	1
8/3/2013	1	3	26.7	7.4	20	1	0
8/3/2013	2	2	26.7	7.8	14	2	0
8/3/2013	3	2	26.9	7.2			
8/3/2013	4	2	27.6	5.3	25	2	0
8/3/2013	5	3	27.7	3.2	5	1	0
8/3/2013	6						
8/3/2013	7	3	27.6	6.2	2	0	0
8/3/2013	8	3	28.4	4.6	2	0	0
8/4/2013	1	2.5	26.5	8.6	2	0	0
8/4/2013	2	2	26.8	7.2	2	0	0
8/4/2013	3	1	27.6	6.8	12	0	0
8/4/2013	4	1	28.1	6.1	9	0	0
8/4/2013	5	1	27.7	6.6	30	0	0
8/4/2013	6	1	27.6	4.8	2	0	0
8/9/2013	1	2.5	27.7	7.5	1	0	0
8/9/2013	2	2.5	27.7	7.9	1	0	0
8/9/2013	3	3	27.2	8.8	45	6	0
8/9/2013	4	3	27.8		15	0	0
8/9/2013	5	3	27.4	7.7	6	1	0
8/9/2013	6	3	27.8	6.2	8	2	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
8/10/2013	1	1.5	27.7	4.9	23	0	0
8/10/2013	2	3	27.5	8.5	8	1	0
10/4/2013	1	2	24.1	7.5	60	12	2
10/4/2013	2	1.5	24.9	6.1	22	1	1
10/5/2013	1	1.5	23.6	9.0	50	10	5
10/5/2013	2	1	25.1	8.3	50	12	5
10/5/2013	3	1.5	25.5	6.1	1	0	0
10/5/2013	4	1.5	25.3	5.0	3	0	0
10/11/2013	1	1.5	22.0	8.3	54	15	2
10/11/2013	2	2	22.7	10.5	1	0	0
10/12/2013	1	2	22.0	4.5	32	12	5
10/12/2013	2	1.5	22.4	8.1	40	8	4
10/12/2013	3	1.5	22.3	8.3	9	0	0
10/12/2013	4	1.5			7	0	0
10/18/2013	1	1.5	22.2	5.4	18	3	0
10/18/2013	2	1	22.0	6.1	5	0	0
10/18/2013	3	0.5	22.0	6.8	40	0	0
10/18/2013	4	0.5	22.3	7.5	100	3	2
10/18/2013	5	1	23.4	7.8	2	0	0
10/18/2013	6	1	24.1	4.1	2	0	0
12/13/2013	1	2			1		
12/13/2013	2	2	10.6	2.4	7	1	0
12/13/2013	3	2	12.4	6.2	4	0	0
12/13/2013	4	1.5	12.4	6.0	18		
12/13/2013	5	1	12.1	7.7	2	0	0
12/13/2013	6	1	11.9	7.5	4	0	0
12/13/2013	7	1	12.1	9.2	65		
12/13/2013	8	1	11.8	8.2	8	0	0
12/16/2013	3	3	12.5	7.8	10	0	0
12/16/2013	1	1	13.0	8.0	2	0	0
12/16/2013	2	1.5	12.6	4.0	2	0	0
12/19/2013	1	1	12.3	8.2	3	0	0
12/19/2013	2	0.5	12.1	8.0	10	0	0
12/19/2013	3	0.5	13.2	9.6	27		
12/19/2013	4	0.5	13.0	8.9	3	0	0
12/19/2013	5	0	13.1	9.2	8	0	1
12/19/2013	6	0	12.4	7.8	2	0	0
12/19/2013	7	0	13.6	8.8	13	3	0
12/19/2013	8	0	13.6	6.5	4	0	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
12/19/2013	9	0.5	12.7	6.9	30		
12/19/2013	10	1	12.4	7.0	6	0	0
2/16/2014	1	3	8.3	1.5	2	0	0
2/16/2014	2	1	7.9	3.8	5	0	0
2/23/214	1	1	10.2	6.9	17	4	0
2/23/214	2	0.5	10.3	8.3	8	0	0
2/23/214	3	0.5	10.5	9.0	2	0	0
4/12/2014	1				4		
4/12/2014	2	1.5	16.2		2		
4/12/2014	3	1.5	16.2		28	3	0
4/12/2014	4	3			4	0	0
4/12/2014	5	3			5	0	0
4/12/2014	6	4			1	0	0
4/13/2014	1	0.5	19.3	7.0	4	0	0
4/13/2014	2	0.5	20.6	8.0	3	0	0
4/13/2014	3	0.5	20.8	8.0	2	0	0
4/13/2014	4	0	18.6	3.6	2	0	0
4/13/2014	5	0	19.6	3.9	2	0	0
4/26/2014	1			4.4	2	0	0
4/27/2014	1	1	19.0	10.0	1	0	0
4/27/2014	2	1	19.6	5.1	47	1	1
4/27/2014	3	3	20.3		1	0	0
6/14/2014	1	1.5	27.1	8.0	4	0	0
6/14/2014	2	1	27.7	8.0	8	0	0
6/14/2014	3	1	27.6	5.2	3	0	0
6/14/2014	4	3	35.7	7.6	15	1	0
6/19/2014	1	2	26.0	5.4	1	0	0
6/19/2014	2	3	26.0	6.8	3	0	0
6/19/2014	3	2	27.0	8.3	45	1	0
6/19/2014	4	2	26.0	8.4	15	0	0
6/19/2014	5	3	27.0	7.3	1	0	0
6/26/2014	1	2	32.2	4.0	3	1	0
6/26/2014	2	2	32.2	6.7	6	1	0
6/26/2014	3	1.5	32.2	7.1	3	0	0
6/26/2014	4	2	31.8	6.8	8	0	0
6/26/2014	5	1	28.3	6.1	70	7	0
6/26/2014	6	1	28.3	5.6	32	0	0
7/1/2014	1	0.5	27.0		4	0	0
7/1/2014	2	0.5	28.0		7	0	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
7/1/2014	3	0.5	28.0		6	0	0
7/1/2014	4	0.5	28.0		12	1	0
7/1/2014	5	0.5	29.0		1	0	0
7/1/2014	6	1	29.0		1	0	0
7/1/2014	7	1	29.0		2	0	0
8/17/2014	1	3.0	27.0	7.0	7	1	0
8/17/2014	2	3.0		3.7	85	10	3
8/23/2014	1	0.5	27.0	7.8	1	0	0
8/23/2014	2	0.0	29.0	7.4	1	0	0
8/23/2014	3	0.0	29.0	7.1	1	0	0
8/23/2014	4	0.0	29.5	7.7	20	0	0
8/23/2014	5	0.0			5	0	0
8/23/2014	6	1.0		7.2	150	10	1
8/23/2014	7	3.0		5.7	1	0	0
8/31/2014	1	1.5	29.0	3.8	27	3	0
9/2/2014	1	1.0	29.0	7.6	1	0	0
9/11/2014	1	0.5		4.5	15	1	1
9/11/2014	2	0.5			5	0	0
9/11/2014	3	0.5	27.0	8.6	3	0	0
9/11/2014	4	0.5	27.0	8.9	40	1	1
10/21/2014	1	1.5	20.1		65	10	0
10/21/2014	2	1.5	20.0	7.2	20	0	0
10/21/2014	3	3.0	20.0	9.2	2	0	0
10/21/2014	4	1.0	20.0	3.8	1	0	0
10/21/2014	5	1.0	22.5	4.0	20	5	0
10/21/2014	6	1.0	22.5	7.1	42	12	1
10/21/2014	7	1.0	22.5	6.7	20	0	0
10/21/2014	8	1.0	22.0	7.2	20	0	0
10/21/2014	9	1.0	21.0	6.3	32	0	0
10/21/2014	10	1.0	22.0	6.6	20	3	0
10/21/2014	11	0.0		1.3	1	0	0
10/24/2014	1	2.0	18.0	6.0	60	0	1
10/24/2014	2	2.0	18.0	7.2	5	0	0
10/24/2014	3	3.0	19.0	8.2	30	0	0
10/24/2014	4	1.5	19.5	6.7	65	7	0
10/24/2014	5	1.0	20.0	7.4	40	7	0
10/24/2014	6	1.0	20.0	7.4	8	0	0
10/24/2014	7	1.0	19.5	7.5	8	0	0
10/24/2014	8	1.0	20.5	7.2	4	0	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
10/24/2014	9	1.0	21.5	7.8	10	0	0
10/24/2014	10	1.0	22.5	8.2	4	0	0
10/24/2014	11	1.0	20.0	7.4	35	5	2
10/24/2014	12	1.0	20.0	7.6	4	0	0
10/24/2014	13	1.0	20.0	6.5	14	0	1
10/24/2014	14	1.0	20.0	6.0	45	0	2
10/24/2014	15	1.0	20.0		3	0	0
11/4/2014	5	1.0	19.0	7.5	1	0	0
11/4/2014	6	0.5	19.0		25	1	1
11/4/2014	7	1.0	19.0	7.2	2	0	0
11/4/2014	8	1.0	19.0		1	0	0
11/4/2014	9	0.5	19.0	7.0	2	0	0
11/4/2014	10	1.0	19.0	7.0	28	3	0
11/4/2014	11	1.0	19.0	7.0	3	0	0
11/4/2014	12	1.0	19.0	7.6	7	1	0
11/4/2014	13	1.0	19.0		20	2	0
11/4/2014	14	0.5	19.0		15	1	0
11/5/2014	1	0.0	18.0	6.8	42	1	0
11/5/2014	2	0.0	19.0	6.6	2	0	0
11/5/2014	3	0.5	19.0	7.5	3	0	0
11/5/2014	4	0.5	19.0	6.9	10	0	0
11/5/2014	5	0.0	19.0	6.1	5	1	0
11/5/2014	6	0.0	19.0	6.7	23	2	0
11/5/2014	7	0.0	19.0	4.7	32	2	0
11/5/2014	8	0.0	19.0	5.4	7	0	0
11/5/2014	9	0.0	19.0	6.0	5	1	0
11/5/2014	10	0.0	19.0	6.1	12	0	0
11/5/2014	11	0.0	19.0	6.4	15	1	0
1/21/2015	1	0.5	12.0	3.0	3	1	0
3/8/2015	1	0.5	9.3	7.2	4	0	0
3/8/2015	2	0.5	9.3	7.5	8	1	0
3/8/2015	3	0.5	9.3		4		
3/8/2015	4	1.0	9.7	2.7	2	1	0
3/10/2015	1	0.5	10.0	7.8	6	0	0
3/10/2015	2	0.5	10.8	7.8	4	0	0
3/10/2015	3	0.5	10.8	7.8	4	0	0
3/10/2015	4	0.5	10.8	6.6	18	3	0
3/10/2015	5	0.5	11.0	5.1	5	2	0
4/22/2015	1	1.5	18.4	6.8	4	0	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
4/22/2015	2	1.0	19.0	10.4	5	2	0
4/22/2015	3	1.0	19.1	9.4	42	3	0
4/22/2015	4	0.5	19.4	6.6	7	0	0
4/22/2015	5	0.0	19.6	8.3	6	1	0
4/22/2015	6	0.0	19.6	8.3	4	0	0
4/22/2015	7	1.0	19.6	5.8	30	0	0
4/22/2015	8	0.5	19.2	7.8	30	1	0
4/22/2015	9	1.0	19.1	7.8	25	3	1
4/22/2015	10	1.0	18.8	8.0	7	2	0
4/22/2015	11	1.0	19.0	7.9	5	0	0
4/22/2015	12	2.0	19.2	6.7	2	0	0
5/3/2015	1	0.5	19.7	7.8	35	4	0
5/3/2015	2	0.0	19.7	8.6	4	1	0
5/3/2015	3	0.0	19.5	8.2	3	0	0
5/3/2015	4	0.0	20.4	7.9	75	6	0
5/3/2015	5	0.0	20.1	8.2	10	0	0
5/3/2015	6	0.5	20.8	6.5	2	1	0
5/3/2015	7	3.0	20.8	3.8	4	0	0
5/20/2015	1	1.5	23.5	5.5	3	0	0
5/20/2015	2	1.0	23.5	8.2	3	0	0
5/20/2015	3	0.5	23.7	8.1	3	1	0
5/20/2015	4	0.5	24.1	3.3	2	0	0
5/20/2015	5	1.0	24.2	7.0	6	0	0
5/20/2015	6	0.5	24.4	7.3	12	0	0
5/20/2015	7	0.5	24.4	8.2	12	2	0
5/20/2015	8	0.0	24.5	9.4	30	1	0
5/20/2015	9	0.5	24.5	8.9	1	0	0
7/30/2015	1	2.0	29.5	4.6	60	6	1
7/30/2015	2	2.0			25	3	1
8/21/2015	1	1.0	29.4	4.9	10	1	2
8/21/2015	2	1.5	30.2	5.5	22	5	2
8/21/2015	3	1.5	30.0	5.6	5	1	0
8/23/2015	1	3.0	29.1	7.4	15	5	0

Appendix A, Table 2. Summary of group sightings of bottlenose dolphins during Little River surveys between August 2014 and August 2015.

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
8/21/2014	1	0.5		8.2	8	0	0
8/21/2014	2	1.0		9.0	9	1	0
8/28/2014	1	3.0	26.0		8	0	0
8/29/2014	1	2.0	26.5	8.2	10	0	0
9/2/2014	2	1.0	28.0	9.0	45	0	0
9/2/2014	3	3.0		7.5	14	1	0
9/10/2014	1	1.0	27.0	7.6	2	0	0
9/10/2014	2	0.5	28.0	8.1	45	0	0
9/10/2014	3	1.0		5.7	45	0	0
10/25/2014	1	1.0	20.0	9.5	8	0	0
10/25/2014	2	1.0	20.0	10.0	40	2	2
10/25/2014	3	0.5	20.0	9.8	42	0	2
10/25/2014	4	0.5	20.0	8.0	30	0	0
10/25/2014	5	1.0	20.0	6.4	1	0	0
10/25/2014	6	0.5	21.0	7.1	20	0	0
10/25/2014	7	3.0	21.0	5.2	10	0	0
10/25/2014	8	3.0	21.0		8	0	0
10/25/2014	9	2.0	21.0		6	0	0
10/25/2014	10	2.0	21.0	4.8	7	0	0
10/27/2014	1	1.0	23.0	9.6	4	1	0
10/27/2014	2	1.0	23.0	9.4	6	0	0
10/27/2014	3	1.0	23.0	9.2	1	0	0
10/27/2014	4	1.0	23.0	9.3	20	2	2
10/27/2014	5	1.0	23.0		6	0	2
10/27/2014	6	1.0	23.0	9.1	15	1	0
10/27/2014	7	0.5	23.0	8.7	22	1	1
10/27/2014	8	0.5	23.0	8.1	35	1	4
10/27/2014	9	0.5	23.0	8.6	17	0	0
10/27/2014	10	0.5	22.0	8.6	23	6	2
10/27/2014	11	0.5	22.0	7.0	5	0	0
10/27/2014	12	0.5	22.0	5.9	1	0	0
11/3/2014	1	0.5	19.0	8.5	7	0	0
11/3/2014	2	0.5	19.0	9.0	1	0	0
11/3/2014	3	0.5	19.0	9.8	3	0	0
11/3/2014	4	0.5	19.0	9.8	20	6	0
11/3/2014	5	0.5	19.0	9.8	15	3	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
11/3/2014	6	0.5	19.0	9.5	11	0	0
11/3/2014	7	1.0	19.0	9.0	1	0	0
11/3/2014	8	2.0	19.0	9.1	2	0	0
11/3/2014	9	2.0	19.0	10.2	11	3	0
11/3/2014	10	2.0	19.0	9.3	34	5	3
11/4/2014	1	3.0	19.0	9.0			
11/4/2014	2	2.0	19.0	9.3	10	0	0
11/4/2014	3	2.0	19.0	8.6	5	1	0
11/4/2014	4	2.0	19.0	8.8	46	1	0
1/22/2015	1	0.0	10.5	2.6	1	0	0
1/22/2015	2	1.0	11.2	2.5	1	0	0
1/22/2015	3	0.5	11.3	2.0	1	0	0
1/22/2015	4	0.5	11.4	7.5	3	1	0
1/22/2015	5	1.0	10.9	7.7	3	1	0
1/22/2015	6				1		
1/22/2015	7	0.0		2.0	5	0	0
3/9/2015	1	0.5	9.3	9.4	32	5	0
3/9/2015	2	0.5	9.3	7.7	1	0	0
3/9/2015	3	0.0	9.6	8.2	9	0	0
3/9/2015	4	0.0	10.1	6.1	4	1	0
3/9/2015	5	0.0	11.0	7.3	2	1	0
3/9/2015	6	0.0	11.4	8.0	4	1	0
3/9/2015	7	0.0	11.4	2.9	1	0	0
3/9/2015	8	0.0	11.6	2.5	5	2	0
3/16/2015	1	0.0	11.9	8.5	1	0	0
3/16/2015	2	0.0	12.8	8.0	1	0	0
3/16/2015	3	0.0	12.9	8.3	15	2	0
3/16/2015	4	0.0	16.1	3.6	3	0	0
5/2/2015	1	0.0	18.5	2.4	2	1	0
5/2/2015	2	0.5	18.1	4.3	2	1	0
5/2/2015	3	0.5	18.6	7.0	2	0	0
5/2/2015	4	0.0	19.0	8.0	1	0	0
5/2/2015	5	3.0	19.5	7.4	5	2	0
5/4/2015	1	1.0	20.2	9.0	12	0	0
5/4/2015	2	0.5	20.9	5.5	2	1	0
5/4/2015	3	0.5	21.1	7.3	3	0	0
5/4/2015	4	0.5	21.1	5.3	7	0	0
5/4/2015	5	0.5	21.1	4.7	4	0	0
5/4/2015	6	0.5	21.2	5.0	5	0	0

Date	Sighting Number	Sea State	Water temp (°C)	Depth (m)	Dolphin Best	Calf Best	Neonate Best
5/4/2015	7	0.5	21.3	8.0	15	1	0
5/4/2015	8	0.5	21.3	7.0	1	0	0
8/13/2015	2	1.0	29.1	6.3	19	2	0
8/16/2015	1	1.0	28.8	8.9	12	2	0
8/16/2015	2	0.5	29.1	5.0	15	2	0
8/16/2015	3	1.0	29.1	7.0	20	2	0
8/16/2015	4	1.0	29.1	6.6	2	1	0

Appendix B: Dorsal fin matches between catalogs.

A total of 96 D1 dorsal fins and 66 D2 dorsal fins were compared between dorsal fin catalogs from adjacent areas such as southern North Carolina and Charleston. Herein, a list detailing catalog identification (ID) numbers between the present study and the DUML/UNCWW catalog as well as the NOS Charleston catalog is provided (Table 1). In addition, the spatio-temporal variability of these matches is shown on table 2.

Appendix B, Table 1. List of ID numbers matched between dorsal fin catalogs in the Carolinas via the Mid-Atlantic Bottlenose Dolphin Catalog.

	Present study Catalog ID	DUML/UNCW Catalog ID	NOS-Charleston Catalog ID
1	1023	21200	
2	1049		1044
3	2055		2330
4	3003	10240	
5	3006	10330	
6	3019		3050
7	3026	10030	
8	3027	21190	
9	3030	82920	
10	3051		3102
11	3064		3106
12	6049		3130
13	7426		7189
14	8106	91100	
15	8137		7503
16	8169		3088
17	9018		3134
18	9023		7496
19	9046	60070	

Appendix B, Table 2. Dorsal fin matches (n = 162) between the current study and historical catalogs from the Carolinas.

ID	Stock	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1023						2015	2006	2006	2015	2014			
1030						2015			2014			2005	
3003								1998, 2013	2002	1998		1999	
3006							2013	2003, 2013	1998		1999		
3026	SNCESS		2002, 2014	1999				1995, 2006	1996	1997	1996	2003	2002,2006
3027	SNCESS		2014	2015			2011	2006					2014
3030	SNCESS						2011					2013	2014
8106	SNCESS			2015				2006, 2013					
9046	SNCESS		1998			2000	2002,1996	2003		1998	2001	1998	2014
1049					2007	2015							
8169					2005				2015	2014		2014	
3019							2003				2013		
7426						2003, 2009		2015					
9018						2008		2013					
2055			2008				2013	2013			2013	2007	2007
3051						2015			2014		2014	2005	
9023						2015			2013				2007
6049									2013		2013		2007
8137						2015			2013				2007
3064												2014	2005

Table Key	**Murrell's Inlet**	**Little River**	**Historical CCU**	**Southern North Carolina**	**Charleston, SC**

Appendix C: Proposed changes to stock descriptions.

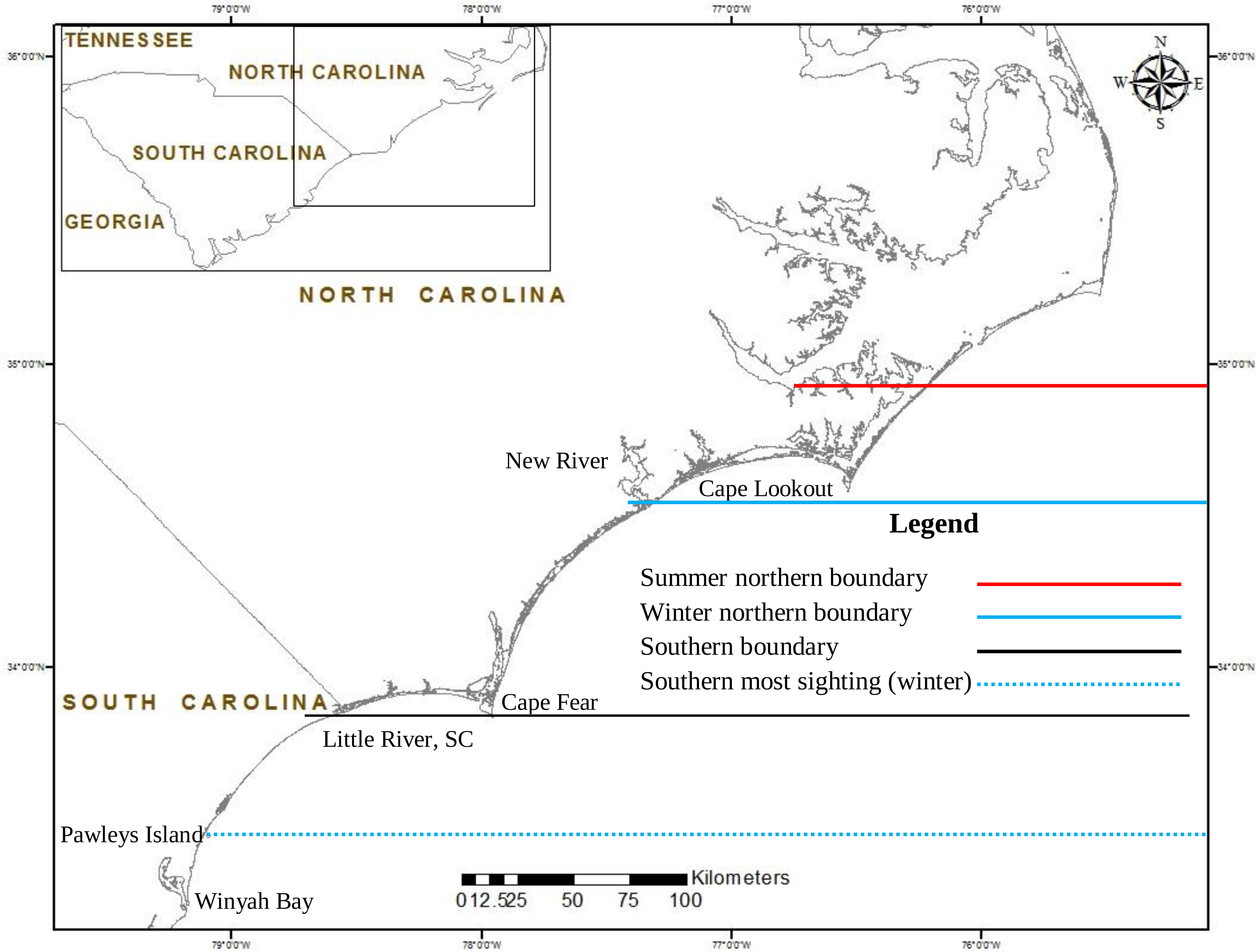
Proposed boundaries for the SC/GA coastal stock, the NSCESS and the southern boundary for the SNCESS have not been investigated through photo-identification surveys. The present study intended to verify some of those boundaries using a combination of photo-identification surveys and comparisons among well-established dorsal fin catalogs. The definition for the northern boundary of the NSCESS was supported. Members of the NSCESS were designated based on long term sighting history within the North Inlet/Winyah Bay Estuarine Reserve (CCU's historical catalog). One NSCESS individual was sighted in coastal waters off Murrell's Inlet, but never photographed in coastal waters north of Murrell's Inlet. An additional two NSCESS individuals were sighted in coastal water off the mouth of North Inlet.

Surveys carried out off Little River were intended to clarify the southern boundary for the SNCESS. Members of the SNCESS were designated based on: 1) long-term sighting history within estuaries and the ICW in southern North Carolina (MABDC) and 2) based on stock descriptions that defined dolphins sighted in inshore waters of southern NC as members of the SNCESS. Several SNCESS dolphins were sighted within the Little River estuary, the ICW, as well as in nearshore coastal waters off Little River and as far south as Pawleys Island, SC during the winter months (December-March). There are no connection between the ICW and the Pawleys Island Inlet; hence dolphins are thought to have moved south following the coastal contour. These data support a revision for the SNCESS southern boundary, perhaps as far south as Pawleys Island (Figure 1).

This study also intended to clarify which stocks are present in the northern South Carolina coast. Data from this study support that multiple stocks overlap in northern South Carolina and that an undefined coastal stock occurs from southern North Carolina to northern South Carolina, possibly as far south as Charleston in the summer (Figure 2). Previous coastal stock descriptions included a Southern North Carolina Coastal Stock ranging from Cape Lookout, NC to Murrell's Inlet, SC and distinct South Carolina and Georgia coastal stocks (Waring *et al.* 2008). Data from the present study support this previous description over the current descriptions of stocks occupying the northern South Carolina coast.

The SM stock is believed to occur off northern South Carolina during late fall (mid-October-mid-November) given that an influx of dolphins was observed during that time and that individuals from this influx were not observed during the winter. Moreover, individuals from this influx were photographed during the previous fall survey and during spring surveys in the subsequent year. Members of the SC/GA stock may be present in the study area; however catalog comparisons were not definitive in designating individuals to this particular stock. Additional survey and matching effort is needed to better define the boundaries and distribution of coastal stocks.

Appendix C, Figure 1. Proposed new southern boundary for the SNCESS.



Appendix C, Figure 2. Proposed ‘new’ southern NC/northern SC coastal stock. Purple lines depict the minimum range.