Delineating the northern extent of common bottlenose dolphins (*Tursiops truncatus)* sighted in the Roanoke Sound, NC

Jacquelyn Salguero

Introduction

Common bottlenose dolphins (hereafter referred to as bottlenose dolphins), *Tursiops truncatus*, inhabit temperate and tropical waters across the world, including both the Pacific and Atlantic Oceans of the United States (Rice, 1998). Within these regions, two main morphotypes of bottlenose dolphins can be distinguished: pelagic and coastal. In the western North Atlantic, along the Eastern United States, coastal populations are managed as distinct stocks, where a "stock" is defined as a group of animals that occupy the same area and interbreed (Rosel *et al*., 2009). Despite being highly mobile with a continuous range, coastal Atlantic bottlenose dolphins have been classified into two main ecotypes based on their primary habitat: "migratory coastal" found along the coastline and "estuarine" primarily residing in areas such as estuaries, bays, and harbors (Hayes *et al.*, 2017, Toth *et al*., 2012).

For management purposes, a number of estuarine stocks have been defined based on their spatial and temporal ranging patterns despite no clear spatial barrier to dispersal, migration, and gene flow (Rosel *et al*., 2009). This pattern of divergence without physical barriers, or sympatry, within inshore populations of bottlenose dolphins can also be seen in populations of bottlenose dolphins, *Tursiops aduncus,* in Moreton Bay, Australia. Significant genetic divergence was found along the small geographic region of Moreton Bay, showing patterns of fine-scale discrete population structuring depending on the varying water depths in the Southern and Northern regions of the bay (Ansmann *et al*., 2012). Another example of this overlapping spatial distribution within bottlenose dolphin populations can be found in Southern Georgia and Jacksonville, Florida estuarine systems which are approximately 80 km apart (Rosel *et al*., 2009). This could be due to inshore populations of estuarine dolphins along the southeastern United States being primarily found in estuaries year-round, and the degree by which populations overlap depends upon biotic and abiotic factors such as spatial distributions, migration patterns, and ecological conditions (Ansmann *et al*., 2012; Richards *et al*., 2013; Rosel *et al*., 2009). Both studies were conducted using genetic markers to determine divergence within populations, confirming previous spatiotemporal distribution studies based on aerial surveys, satellite-linked radio tag telemetry, and photo-identification based mark-recapture efforts. Photo-identification mark-recapture methods serve as a primary means of population monitoring and tracking of bottlenose dolphins over time (Urian *et al.*, 2014).

The Mid-Atlantic Bottlenose Dolphin Photo-Identification Catalog (MABDC) was developed to better improve our understanding of bottlenose dolphin stock structure along the western North Atlantic Ocean. Researchers at various locations along the eastern coast of the United States contribute to the MABDC, which is a central database comprised of photo-ID data across a widespread geographical range (Urian, Hohn, & Hanson, 1999). Currently there are over 25,000 dolphins submitted by teams from 30+ different field site locations.

In North Carolina, there are two defined estuarine stocks of bottlenose dolphins: the Northern North Carolina Estuarine System (NNCES) and the Southern North Carolina Estuarine System (SNCES) stocks (Hayes *et al.*, 2017). The NNCES stock has a population estimate of approximately 823 individuals that range between southern Virginia to central North Carolina (Gorgone *et al*., 2014; Hayes *et al*., 2017). The movements and distributions of these stocks are delineated from photo-ID, satellite-linked tags, and stable oxygen isotopes (Hayes *et al.*, 2017). During the warm water months (July- August), the upper range of this estuarine population is generally the Pamlico Sound (Core, Roanoke, Albemarle sounds, and the Neuse River) and nearshore coastal waters outside of Beaufort, North Carolina and as north as Virginia Beach, Virginia (<1 km from shore) (Garrison *et al.,* 2017b; Hayes *et al.*, 2017). During the colder months, most individuals move out to coastal waters (< 3km from shore) between New River and Oregon Inlet, North Carolina (Hayes *et al.,* 2017). In addition, individuals from the offshore Northern Migratory stock and Southern Migratory stock may overlap with these resident estuarine stocks (Hayes *et al.*, 2017).

The Outer Banks Center for Dolphin Research (OBXCDR) has conducted a long-term photo-identification monitoring study of bottlenose dolphins (*Tursiops truncatus*) sighted in the Roanoke Sound, NC; many of these individuals belong to the NNCES stock. The OBXCDR is a contributor to the MABDC and manages the Outer Banks (OBX) Catalog (NC-OBXCDR) (Taylor *et al*., 2014). Seasonal resident estuarine and transient bottlenose dolphins are sighted from April through November (Taylor *et al*., 2014; Taylor *et al*., 2017). Previous photo-ID studies conducted on this population show seasonal exchange as north as southern Virginia during the summer months and Beaufort, NC during winter months (Mason and Taylor, 2016; Shervanick and Taylor, 2016; Yanes and Taylor, 2016; Fuentes and Taylor, 2015; McKeowan and Taylor, 2015). However, recent studies comparing the OBX (NC-OBXCDR) catalog to a site in the Chesapeake Bay regions of Northern Maryland (MD-PCDP catalog) and Southern Virginia (VA-HDR catalog) have shown overlap in individuals from the Roanoke Sound (n=4, n=5 respectively). These sites are beyond the currently defined range of the NNCES stock (Hayes *et al.,* 2017; Young and Taylor, 2017; Jacobs and Taylor, 2018; Grider and Taylor, 2019). These northern sightings highlight a need for further research into the overlap of NNCES bottlenose dolphins with northern stocks.

In this study, we aimed to evaluate the northern range of NNCES individuals sighted during May through August in the Roanoke Sound, NC. We used the MABDC to match individuals from the Roanoke Sound to the Delaware Bay, Delaware (DE-CMWWRC) catalog in order to investigate the northern extent of the NNCES stock. A greater understanding of these complex population structures is necessary in the development and implementation of management policies related to the protection of these marine mammals.

Methods

Study Area

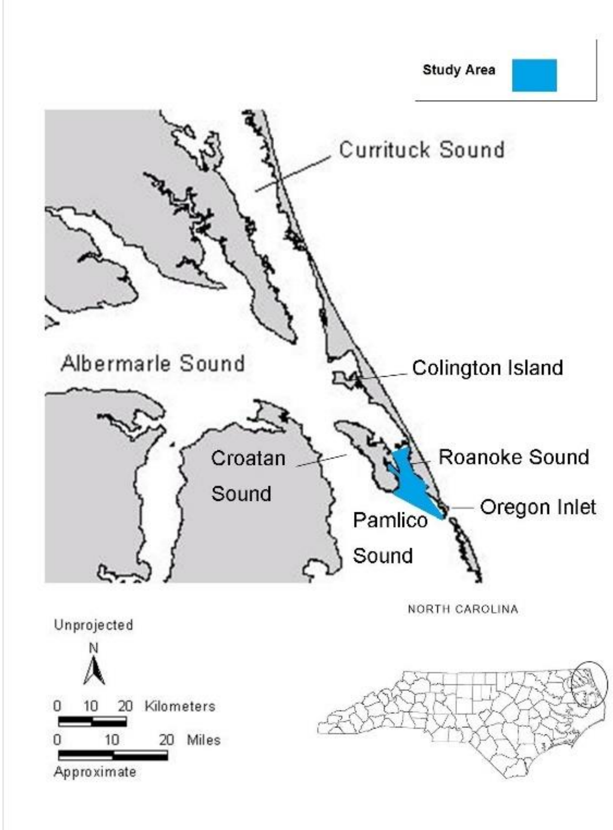

Figure 1) Roanoke Sound Study Area. *Albemarle-Pamlico Estuary System*. The Roanoke Sound is highlighted in blue and extends from the northern tip of Roanoke Island southwards to the Oregon Inlet

The Roanoke Sound is located near the Outer Banks, North Carolina and is part of the Albemarle-Pamlico estuarine system (APES). The Roanoke Sound ranges from the northern tip of Roanoke Island and extends south to the Oregon Inlet. It is bounded on the west by Roanoke Island and on the east by the chain of Outer Banks barrier islands. This sound lies between the Albemarle and Pamlico Sounds, therefore linking the two bodies of water with the Albemarle draining into the Roanoke sound from the north (Figure 1). The total size of the APES is estimated to be 1,243 km^2 (Giese *et al.*, 1985). Since the APES is a downed river valley, tides vary and are primarily influenced by freshwater influxes and wind currents. The APES has several inlets to the ocean including the Oregon, Hatteras, and Ocracoke Inlet, which are located within the southern Roanoke/Pamlico region of the APES system (Giese *et al.*, 1985). The Oregon Inlet is located at the southern tip of the Roanoke Sound and serves as a main passageway to the Atlantic Ocean for resident estuary and migratory bottlenose dolphins.

Furthermore, the ecology of Roanoke Sound is critical to local fisheries as the sound comprises salt marshes and shallow sea grass bed nurseries where many fish, crustaceans, shellfish, and other various marine life spawn and reproduce (Giese *et al*., 1985).

Field Data Collection

Photo-identification data was collected during both dedicated and opportunistic surveys within the Roanoke Sound. Dedicated boat-based surveys were conducted May through October 2008-2016 following a standardized transect route. All surveys took place onboard a 16' or 17' center console research vessel. Sighting data included animal activity state, group size estimates, geospatial locations, and environmental measurements. Group size estimate data included total group size and numbers of calves, including young-of-the-year (YOYs). Geospatial data included start/end GPS coordinates and general location name. Environmental conditions such as salinity, water temperature, air temperature and wind speed, weather (cloud coverage, visibility), Beaufort Sea Scale, and water swell were also recorded. Standard photo-identification techniques were used (Würsig and Würsig, 1977). All dedicated boat-based surveys were conducted by the Outer Banks Center for Dolphin Research (OBXCDR) under NMFS General Authorization Permits LOC-13416 and LOC-17988 awarded to J. Taylor. Opportunistic data was collected aboard the Nags Head Dolphin Watch. Sightings were conducted onboard two engine operated pontoon boats (30' and 36' vessels). Data collection was recorded on the same standardized sighting sheets used in dedicated sighting surveys. Each dolphin watch vessel adhered to the NMFS Viewing Guidelines for bottlenose dolphins for the Southeast region.

Data Processing

All sighting data were processed using FinBase (Adams *et al.,* 2006). FinBase is a *Microsoft Access* program designed to operate as an image manager and multipoint analysis tool for photo grading, photo analysis, and photo/sighting data management. All images were assigned a fin distinctiveness and photo quality grade, unique survey and sighting number, and catalog ID number that correspond to an individual bottlenose dolphin sighted by OBX-CDR. Every match or new dolphin entered into the catalog was verified by a second researcher. All sighting data was entered into FinBase as well.

Data Analysis

Once cataloged into the OBXCDR FinBase system, images and sighting data were uploaded to the MABDC. A sample of individuals added to the OBXCDR catalog since the last matching study in fall 2019 was selected for comparison to the DE-CMWWRC catalog. The sample dataset was a compilation of 29 distinct (D1, D2), good quality dorsal (Q1, Q2) dorsal fin images. The DE-CMWWRC catalog was filtered to match individuals based on a quality grade and distinctiveness score (See Table 1). Potential matches were then submitted for further evaluation and confirmation by J. Taylor and M. Laurino of the Cape May Whale Watch & Research Center.

Table 1. MABDC catalogs used in this matching study. The NC-OBXCDR and DE-CMWWRC catalogs were matched using the MABDC. Total catalog size prior to filtering for Distinctiveness and Quality for NC-OBXCRD and DE-CMWWRC respectively are 1067 and 265. Number of compared are how many total fins were evaluated from each catalog as potential matches after filtering based on distinctiveness and quality grades. Percent matched is the percent of matching fins from our test group to the MABDC DE-CMWWRC individuals.

Catalog	Contact	Study Area	Study Period	Total Catalog Size	Number of Fins Compared	Percent Matched to MABDC
NC-OBXCDR	Jess Taylor	Roanoke Sound, NC	2007 – present	1067	29	0%
DE-CMWWRC	Melissa Laurino	Delaware Bay, Delaware	2017 – 2019	265	221	0%

Results

There were no matches to the MABDC when comparing the NC-OBXCDR and DE-CMWWRC catalogs. An explanation of possible limitations of this study are described further in the discussion section.

Discussion

The purpose of this study was to further delineate the northern extent of the Northern North Carolina Estuarine Stock (NNCES). We did not find any matches; however, this is not to conclude that the northern spatial distribution and range of bottlenose dolphins sighted in the Roanoke Sound, NC does not extend to the Delaware Bay, DE. Here we examine possible limitations of our study that may explain our lack of matches between these two study sites.

First, we examined a limited sample size (n=29) of fins sighted in the Roanoke Sound. From May through October there is estimated to a minimum of 823 dolphins that migrate into the Roanoke Sound study area. It is likely that a more robust sample size could reveal additional results since previous studies found a small number of individuals matching to more northern study sites. For example, Young and Taylor (2017) found 4 matches out of 59 individuals when comparing the NC-OBXCDR catalog to a site in the Chesapeake Bay regions of Northern Maryland (MD-PCDP catalog).

Second, the DE-CMWWR catalog has only been active since 2017 and therefore has a limited pool of potential matches. It is possible bottlenose dolphins sighted in the Roanoke Sound have movements north to the Delaware Bay study site but have yet to be sighted. Previous studies assessing the sighting patterns of dolphins in the Roanoke Sound showed a continuous increase of new individuals sighted over a five-year period (Taylor, J., Fearnbach, H., & Adams, J., 2017). Additionally, to ensure the accuracy of matches, we only matched good quality and distinctive fins. This filter limited the pool of potential matches to the DE-CMWWR catalog (n=221). Therefore, as the number of sighted fins increases, the total number of potential matches increases from newly added individuals as well as updated images of existing individuals that currently did not meet the filtering criteria.

Finally, bottlenose dolphins are highly mobile animals with varying, overlapping seasonal migration patterns. Photo-identification based mark recapture experiments on such mobile populations can have inaccuracies due to differences in the probability of sightings of individuals. For example, previous studies conducted on the Roanoke Sound dolphin population found three separate population clusters when assessing the probability and frequency of sighted individuals from 2008 to 2013. The “transient” population only had a 0.15 probability of being sighted and was generally only photo captured on a single day versus “resident” population clusters which had a 0.60 and 0.91 probability and were sighted 6 to 19 days a season (Taylor et al., 2017). Therefore, it is possible our data is inherently skewed towards capturing individuals less likely to be migrating further (resident populations) than transient individuals.

In conclusion, as more sighting data is added to the DE-CMWWRC catalog, a more thorough analysis can be conducted. A greater understanding of these complex population structures is necessary in the development and implementation of management policies related to the protection of these marine mammals.

Works Cited:

Adams, J. D., Speakman, T., Zolman, E., & Schwacke, L. H. (2006). Automating image matching, cataloging, and analysis for photo-identification research. Aquatic Mammals, 32, 374–384.

Ansmann, I. C., Parra, G. J., Lanyon, J. M., & Seddon, J. M. (2012). Fine-scale genetic population structure in a mobile marine mammal: inshore bottlenose dolphins in Moreton Bay, Australia. Molecular Ecology, 21(18), 4472-4485.

Garrison, L.P., A.A. Hohn and L.J. Hansen. 2017b. Seasonal movements of Atlantic common bottlenose dolphin stocks based on tag telemetry data. Southeast Fisheries Science Center, Protected Resources and Biodiversity Division, 75 Virginia Beach Dr., Miami, FL 33140. PRBD Contribution # PRBD-2017-02, XX pp

Gorgone, A. M., T. Eguchi, B. L. Byrd, K. M. Altman, and A. A. Hohn. 2014. Estimating the abundance of the northern North Carolina estuarine system stock of common bottlenose dolphins (*Tursiops truncatus*). NOAA Technical Memorandum NMFS-SEFSC-664. 22p.

Grider, M. and J. Taylor. 2019. Examining the northern spatial extent of estuarine bottlenose dolphins sighted in Roanoke Sound, NC. Report submitted to the MABDC in November 2019. 7 pp.

Hayes SA, Josephson E, Maze-Foley K, Rosel, PE, editors. 2017. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2016. NOAA Tech Memo NMFS NE Vol 241: 274.

Richards, V. P., Greig, T. W., Fair, P. A., McCulloch, S. D., Politz, C., Natoli, A., ... & Lopez, J. V. (2013). Patterns of population structure for inshore bottlenose dolphins along the eastern United States. Journal of Heredity, 104(6), 765-778.

Rosel, P. E., Hansen, L., & Hohn, A. A. (2009). Restricted dispersal in a continuously distributed marine species: common bottlenose dolphins *Tursiops truncatus* in coastal waters of the western North Atlantic. Molecular Ecology, 18(24), 5030-5045.

Taylor, J., Fearnbach, H., & Adams, J. (2017). Use of Clustered Mark-Recapture Methods to Monitor Bottlenose Dolphins (Tursiops truncatus) in the Outer Banks, North Carolina. In *Poster presented at the 22nd Biennial Conference on the Biology of Marine Mammals, Society for Marine Mammalogy, Halifax, Canada*.

Taylor, J., Hart, L., Krumsick, H., and J. Adams. 2014. Preliminary Examination of Skin Lesions on Bottlenose Dolphins (*Tursiops truncatus*) in the Outer Banks, North Carolina. Poster presentation at the Southeast and Mid-Atlantic Marine Mammal Symposium, 28-30 March 2014, University of North Carolina Wilmington, Wilmington, NC.

Urian, K.W., A.A. Hohn, and L J. Hansen. 1999. Status of the Photo-identification Catalog of Coastal Bottlenose Dolphins of the Western North Atlantic: Report of a Workshop of Catalog Contributors. NOAA Technical Memorandum NMFS-SEFSC-425, 22 p

Waring, G. T., E. Josephson, K. Maze-Foley, and P. E. Rosel. 2015. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments. NOAA Technical Memorandum NMFS-NE-238. National Oceanic and Atmospheric Administration, Woods Hole, MA. 161 pp; 106-136 pp.

Young, A. and J. Taylor. 2017. Northern range of seasonally resident bottlenose dolphins (*Tursiops truncatus*) identified along the Outer Banks, North Carolina. Report submitted to the MABDC in August 2017. 15 pp.