Northern Range of Seasonally Resident Bottlenose Dolphins (*Tursiops truncatus*) Identified along the Outer Banks of North Carolina

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Introduction

Bottlenose dolphins (*Tursiops truncatus*) are distributed worldwide, and are found in distinct populations with definable ranges along coastlines (Constantine, Brunton, and Dennis 2004). The National Marine Fisheries Service (NMFS) manages bottlenose dolphin populations in the United States as stocks. A stock is defined as a group of marine mammals of the same species that can produce viable offspring and are functioning elements of their ecosystem (Wade and Angliss 1997). Stock definition is based upon ranging and residency patterns, as well as genetics, morphology, life history, and contaminants (Shane, Wells, and Würsig 1986; Wade and Angliss 1997). In the Northeast Atlantic, niche specialization through time has resulted in the identification of two distinct ecotypes of bottlenose dolphins, coastal and pelagic, with genetic divergence associated with social organization and foraging ecology (Louis et al. 2014). Within these two ecotypes, some individuals may be transient, defined as animals that migrate year-round with no definable home range; most individuals can be classified as either resident to a certain area or seasonally resident, spending some months in one area and moving elsewhere seasonally in response to temperature, resource availability, habitat suitability, predation, or other environmental parameters (Mason and Taylor 2016).

In the western north Atlantic, coastal bottlenose dolphins are distributed continuously from the western tip of Florida to Long Island, NY. This ecotype is composed of stocks that occupy both coastal and estuarine systems. Bottlenose dolphins are present in the Roanoke Sound from April through November, and are part of the Northern North Carolina Estuarine System (NNCES) stock (Waring et al. 2015). The NNCES, defined by the National Marine Fisheries Service (NMFS), is composed of an estimated 823 individuals, based on a photo-ID mark-recapture survey in 2013 (Gorgone et al. 2014). While originally thought to occupy only as far north as the NC/VA border, photo-identification data revealed that bottlenose dolphins in the NNCES stock occupy estuarine and coastal waters from the Pamlico Sound through southern VA and the lower Chesapeake Bay (Fig 1). The Roanoke Sound provides an important summer habitat for members of the NNCES stock (McKeowen and Taylor 2015); these individuals are seasonally resident to the sound. However, photo-identification studies examining the northern extent of their range during summer are limited. Additionally, current estimates of NNCES abundance in estuarine waters are limited due to uncertainty about their northernmost range. Greater understanding of the movement patterns of seasonally resident dolphins from the Roanoke Sound can help to identify the northern range of this stock, which may have important

implications for management, since dolphins that move across state boundaries may be more difficult to manage.

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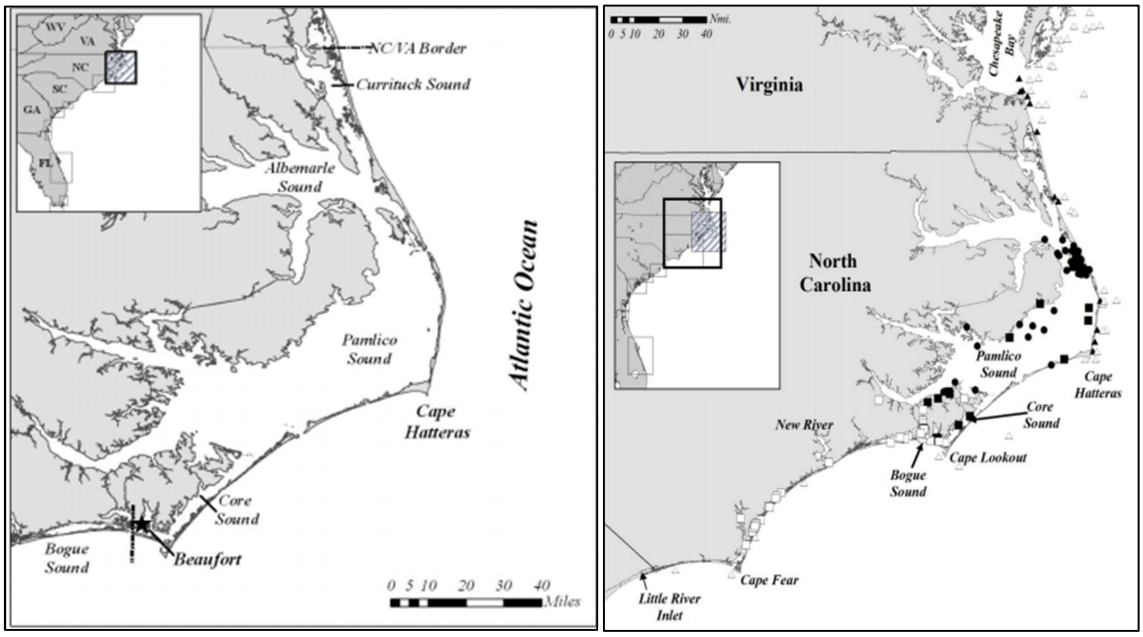

Figure 1. Boundaries of NNCES stock as designated in 2009 (A) and distribution of sightings of individuals in NNCES stock as of May 2016 (B). Individuals identified through photo-identification are symbolized by squares, and filled symbols indicate individuals that are part of the NNCES stock. Data obtained from nmfs.noaa.gov.

Photo-identification is essentially a mark-recapture method that can be used to estimate abundance and explore the ranging patterns of bottlenose dolphins, by photographically capturing naturally 'marked' individuals and monitoring them over time. (Cheney et al. 2013 However, this approach may introduce potential biases in identifying individuals over time (two individuals may look very similar, fins may acquire new notches, etc., so it is important to have criteria for evaluating image quality, level of distinctiveness of markings, and variability in researchers performing the matches. (Urian et al. 2015). The Mid-Atlantic Bottlenose Dolphin Catalog (MABDC) was developed in 1997 to compile eastern US bottlenose dolphin sighting data. It includes 19 individual catalogs of dorsal fin images, and allows for collaboration and matching to be made using the web-based system on OBIS-SEAMAP (Fuentes and Taylor 2016; Urian et al 1999).

This study involves the examination of two of these contributing catalogs- NC-OBXCDR and VA-HDR (Table 1). The Outer Banks Center for Dolphin Research (OBXCDR), established in 2008, is

Table 1. MABDC catalogs used for matching.

Catalog	*Contact*	*Study Area*	*Study Period*	*Catalog Size*	*Percent matched to MABDC*
NC-OBXCDR	Jessica Taylor, *OBXCDR*	Roanoke Sound, NC	2007-2013	765	7.7%
VA-HDR	Amy Engelhaupt, *HDR Inc.*	Norfolk, VA	2012-2013	442	4.5%

engaged in the long-term monitoring of bottlenose dolphins in the Roanoke Sound, which is performed through opportunistic and dedicated photo-identification surveys. HDR, Inc. conducts photo-identification studies of bottlenose dolphins in waters adjacent to Norfolk, VA. Individual sightings from each catalog are accessible through the MABDC database, and the geographic distribution of sightings between the two catalogs shows clear separation. (Fig 2).

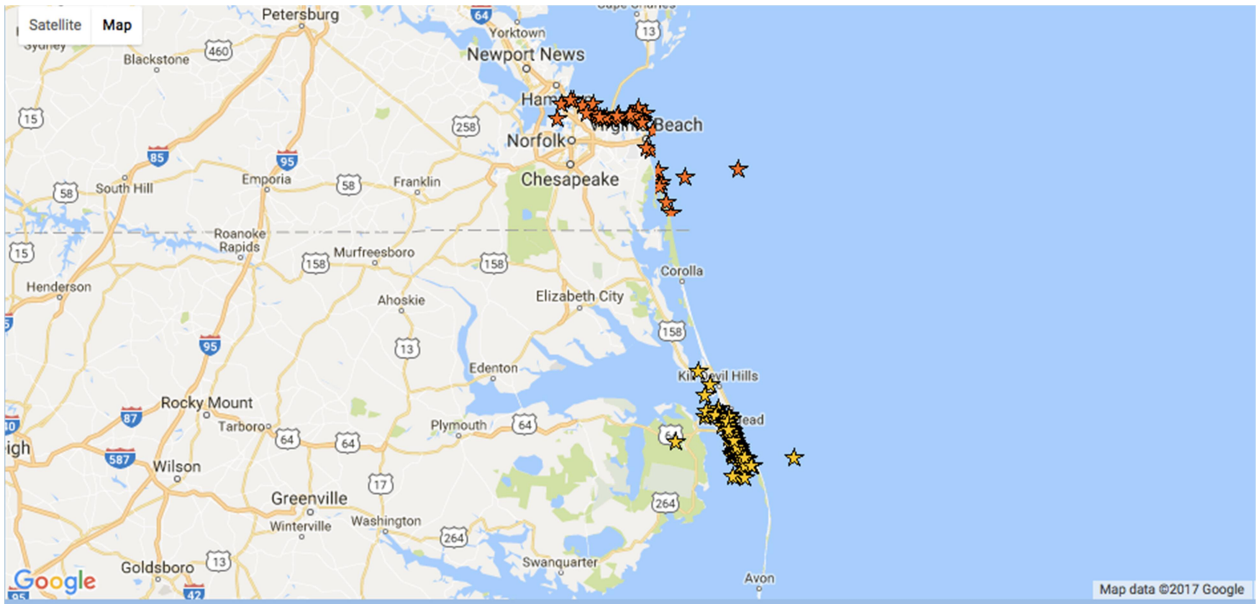

Figure 2. Distribution of individual sightings from VA-HDR (orange) and NC-OBXCDR (yellow). Offshore points likely errors.

This study aims to identify the seasonal movement patterns of bottlenose dolphins, particularly to determine the northern range of the individuals frequently sighted in the Roanoke Sound

and better delineate the northern boundary of the NCCES stock. In conjunction with OBXCDR, I matched dorsal fin data collected in the Roanoke Sound (NC-OBXCDR catalog) with dorsal fin data collected in Norfolk, Virginia (VA-HDR catalog) through the MABDC. This comparison can thereby help show any movement between the individuals sighted in both locations, raising implications for stock determination and northern range delineation.

Methods

Study Area

The study area is located in the Roanoke Sound, a body of water extending 41 km^2 between Roanoke Island and Nags Head in the Outer Banks of North Carolina (Fig 3). The Roanoke Sound is categorized as brackish water, with contributions from the Atlantic Ocean and various rivers that flow into the sound from the west. Most of the sound is shallow and composed of sea grass beds, with an average depth of approximately 1 m; this provides a key habitat for soniferious fish that are known to make up the diet of bottlenose dolphins in North Carolina (Gannon and Waples 2004), and thus serves as a key feeding area. Deeper channels are maintained through dredging to provide passage for large vessels, which enables bottlenose dolphins to travel across the sound. Nursery groups with calves and newborns are frequently sighted throughout their period of seasonal residence (May-October) in Roanoke Sound.

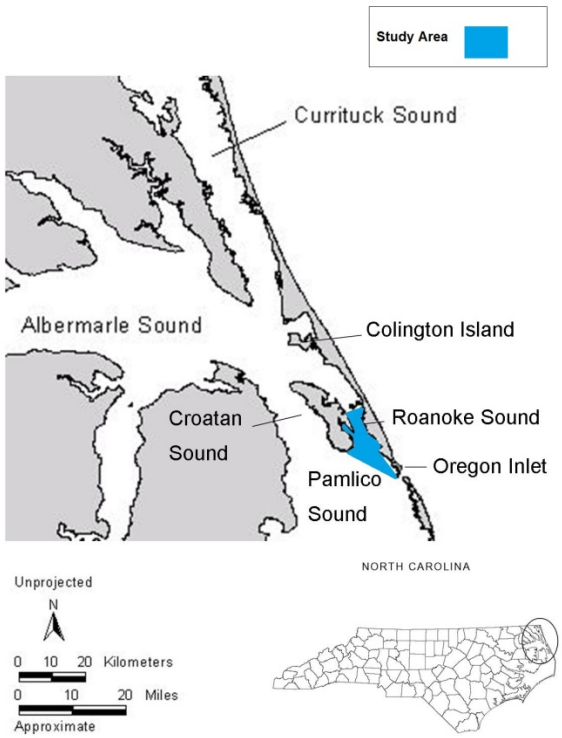

Figure 3. Roanoke Sound study area.

Data Collection

The Outer Banks Center for Dolphin Research conducts opportunistic and dedicated photo-identification surveys to monitor the bottlenose dolphins in the Roanoke Sound. OBXCDR first conducted a dedicated exploratory survey of the southernmost portion of the study site in October 2007, and then conducted dedicated exploratory surveys of the entire Roanoke Sound from June-August 2008, February 2009, May-October 2009, May-October 2010, and May-October 2011. Following these exploratory surveys, a standardized transect route was used to cover the study area. This transect route was developed on MapSource and transferred to a handheld GPS unit for onboard use.

Dedicated transect surveys were conducted from a 16' or 17' outboard vessel, once in November 2011 and then at least once per month from April-November 2012 and 2013, except for May and July 2013 due to weather and boat issues. For each dolphin sighting along the dedicated survey, the transect location was marked on the GPS, and the group of dolphins was then slowly approached for photographs so as to limit any impacts on their natural behaviors. Photo-identification was conducted following standard procedures (Wursig and Wursig 1977). Additional data including location, date, time, number of dolphins sighted, observed behaviors, and environmental variables such as salinity, water temperature, visibility, sightability, cloud cover, and Beaufort Sea State (BSS) were recorded. Sightings ended upon meeting one of the following parameters: (1) dolphins were exhibiting avoidance behavior, (2) dolphins were lost, (3) sighting lasted the limit of one hour in accordance with the General Authorization permit under which the surveys were conducted, or (4) 100% of dorsal fins were photographed. Following the conclusion of each sighting, the vessel returned to the transect location where the sighting began and continued along the transect route until either another group of dolphins were sighted or the transect route was completed.

Opportunistic data was collected multiple times daily between the months of May and October from 2008-2013 aboard the Nags Head Dolphin Watch. Data collection and survey methodology did not differ much from the dedicated surveys, but rather than following a set transect, the vessel moved freely around the Roanoke Sound. Additionally, the approach towards the group of dolphins was from further away, and the sightings were limited to a half hour as outlined by the National Marine Fisheries Service (NMFS) Recommended Viewing Guidelines for bottlenose dolphins in the southeast region.

Analysis

All images taken from dedicated and opportunistic surveys were sorted and graded for photo quality using FinBase (Adams et al 2006), and then either entered as a new fin or matched to an individual in the OBXCDR photo-identification catalog. Sighting data was also entered into FinBase and linked to the corresponding fin images. All matched fins were verified by a second individual in order to ensure matches were valid. Verified fins were then sent to Kim Urian from the Duke University Marine Lab to be entered into the MABDC. Poor quality images or fins with low/no distinctiveness were excluded from analysis.

In a prior study, Taylor et al. 2016 used a Bayesian mark-recapture approach (Fearnbach et al 2012; Durban et al 2010) to identify clusters of individuals with different patterns of capture probability over time. Clusters 2 and 3 were identified as having high site fidelity (Taylor et al. 2016), and individuals in those clusters were then matched to the VA-HDR catalog through the MABDC (n=59). All matches were then verified by Jessica Taylor (NC-OBXCDR), Amy Engelhaupt (VA-HDR) and Kim Urian.

Results

Table 2 shows the matched dolphins from clusters 2 and 3 of the OBXCDR catalog to the VA-HDR catalog. The other NC catalogs encompassed a study area further south than the Roanoke Sound, into the Pamlico Sound and near Beaufort, NC. Out of the individuals matched, 80% were also matched to other NC catalogs, and 40% were matched to another VA catalog. Two individuals were matched both to other NC and VA catalogs, indicating their movement is not unidirectional (i.e. solely northward or southward). One individual had no other catalog matches. All matched individuals were likely females, since they were all spotted with calves.

Table 2. Summary of individuals matched to the VA-HDR catalog.

OBXCDR ID	Alias	VA-HDR ID	Sex	Cluster	Other NC Matches	Other Non-NC Matches
15	Knobby Top	316	F	2	NC-NCMM 2015; NC-DUML-UNCW; NC-RMD; NC-NCMM	-
33	FB717	274	F	2	NC-NCMM 2015; NC-DUML-UNCW; NC-RMD; NC-NCMM; NC-DUML	VA-SB
242	Jess Squared	276	F	2	NC-RMD; NC-NCMM	VA-SB
246	Rocky	317	F	3	NC-RMD	-
818	-	318	F?	2	-	-

Five out of 59 individuals were matched to the VA-HDR catalog (Fig 4). This might not be indicative of their true movements, since the VA-HDR catalog is limited to only two years of data collection.

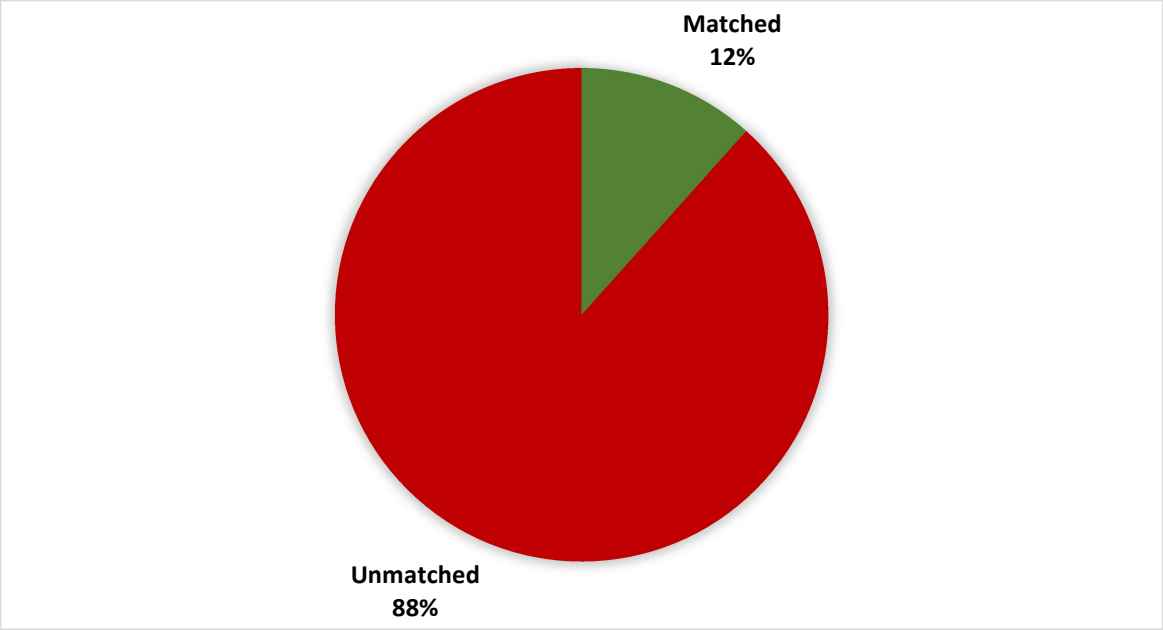

Figure 4. Percentage of OBXCDR individuals matched to the VA-HDR catalog.

Table 3 shows the number of sightings for matched individuals in each catalog. The mean number of sightings was 15.4 in OBXCDR and 1.8 in VA-HDR. More sightings in the OBXCDR catalog is likely as a result of longer effort each season and more years included in the catalog.

Table 3. Number of sightings for matched individuals.

OBXCDR ID	VA-HDR ID	Number of Sightings (NC)	Number of Sightings (VA)
15	316	15	1
33	274	19	3
242	276	12	1
246	317	23	1
818	318	8	1

Most matched individuals were seen 10-20 times in the OBXCDR catalog, with only one with less than 10 and one with greater than 20 sightings (Fig 5). There were far fewer sightings for matched individuals in the VA-HDR catalog, with a maximum of three sightings (Fig 6).

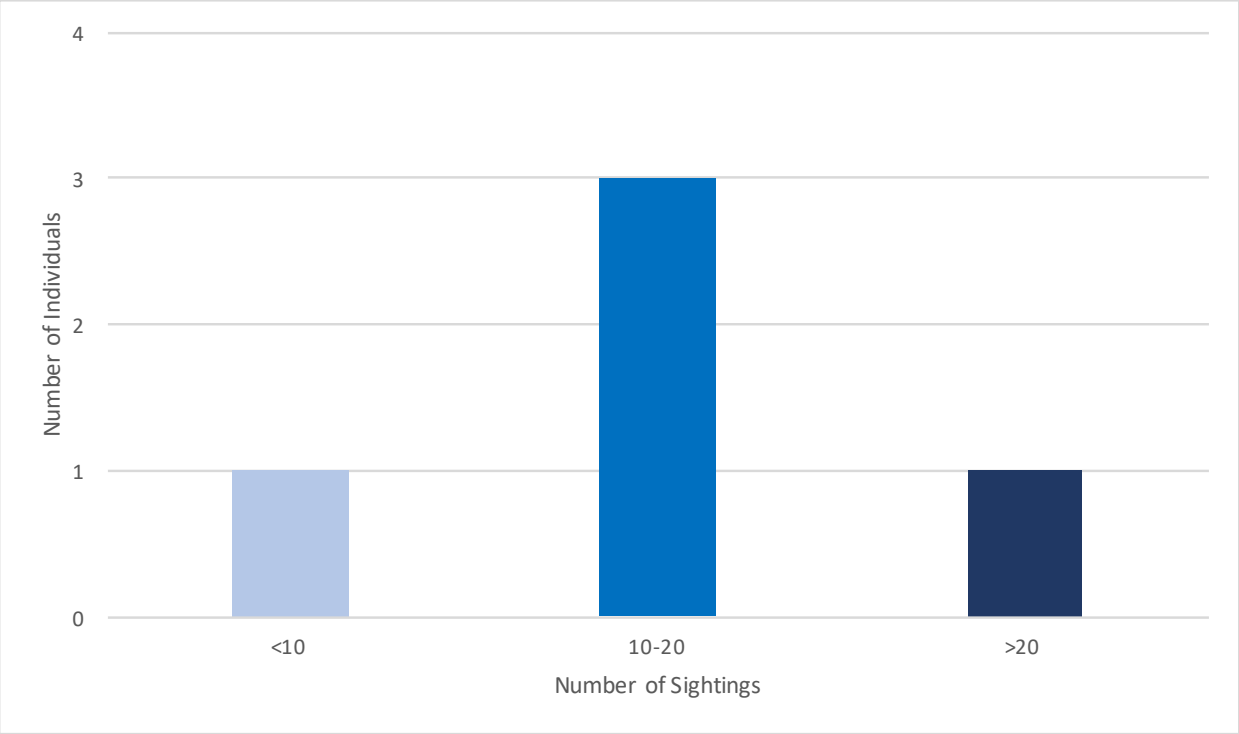

Figure 5. Number of sightings for matched individuals (N=5) in the OBXCDR catalog.

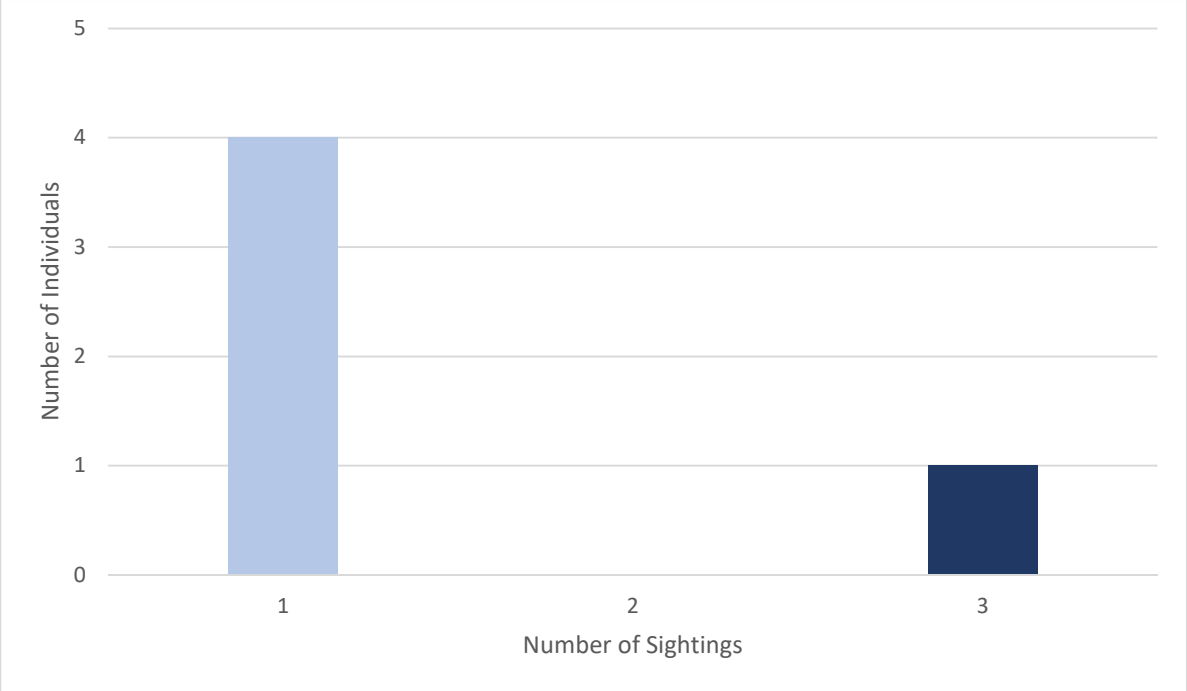

Figure 6. Number of sightings for matched individuals (N=5) in the VA-HDR catalog.

The majority of matches were cluster 2 individuals (Fig 7). Out of all individuals in the sample (n=59), over 15% of cluster 2 individuals (N=28) were matched to the VA-HDR catalog, while only 3% of cluster 3 individuals (N=31) were matched (Fig 8).

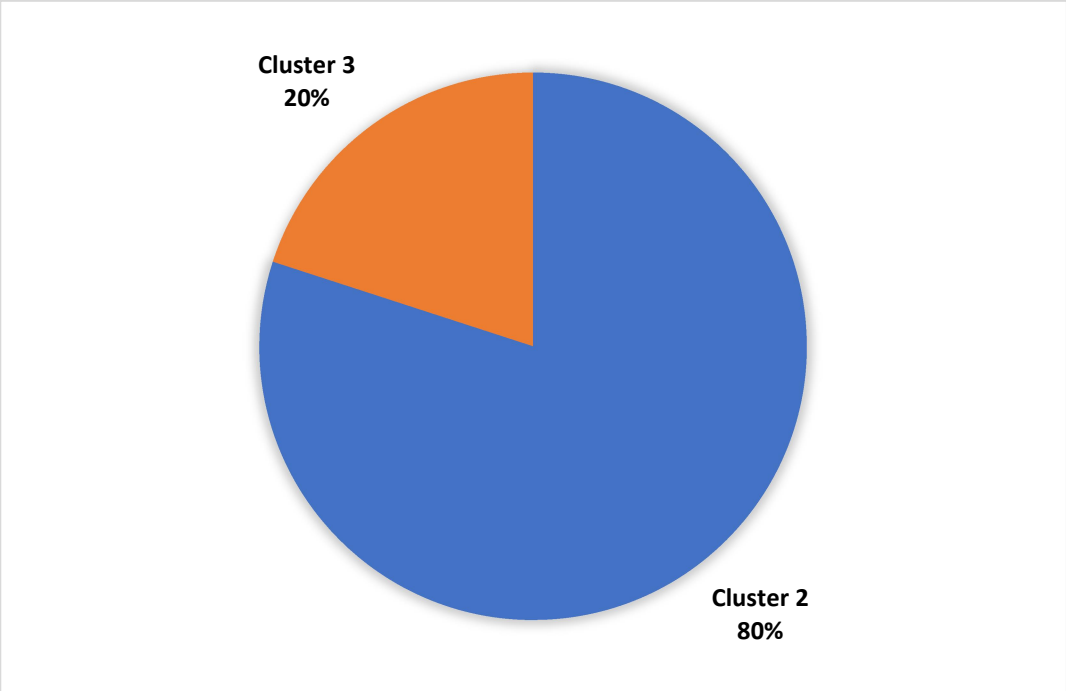

Figure 7. OBXCDR matched individuals by cluster.

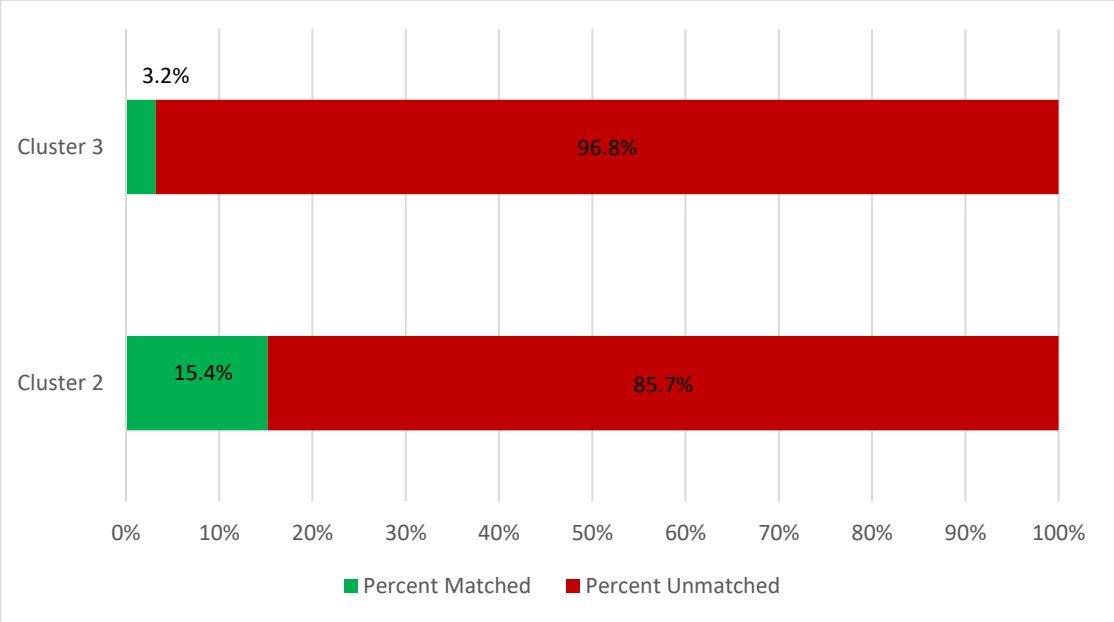

Figure 8. Percent of individuals from each cluster matched.

Sightings in the OBXCDR catalog are confined to dates from April-October, while the VA-HDR catalog ranges from January-November, with no sightings in March, May, or June. Sightings in the Roanoke Sound begin to rise in May, peak in June and July, and then start to decrease in August. Sightings in Virginia peak in July and August, then begin to decline through October and rise again in November and January (Fig 9).

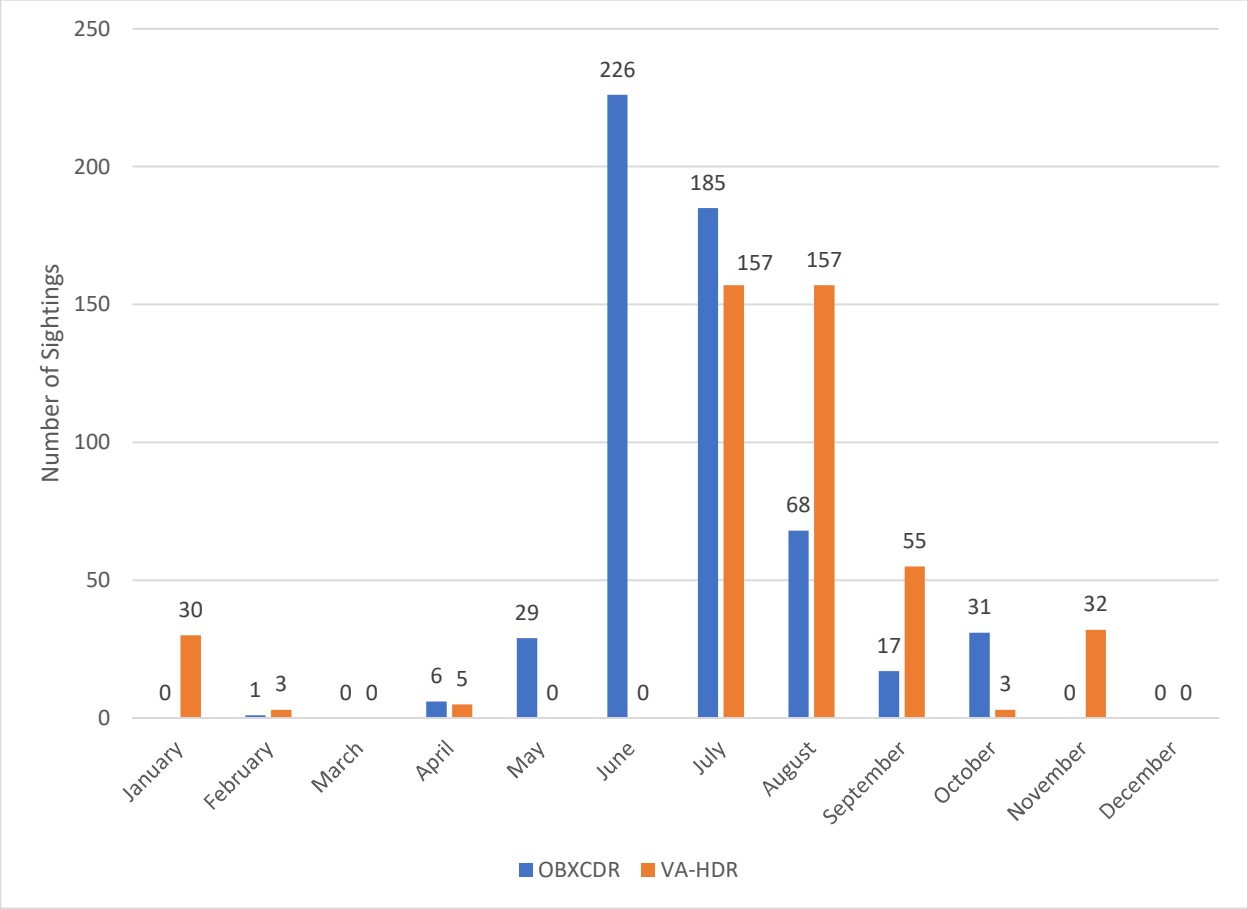

Figure 9. Seasonality of all individual sightings for all OBXCDR and VA-HDR catalogued individuals.

Sightings for matched individuals in the Roanoke sound peaked in June, but ranged from May-October. In Virginia, matched individuals were only sighted in July and August (Fig 10). This suggests seasonality to the movement of individuals into Virginia, but since the sightings did not occur on the same year, exact movement cannot be determined. Matched individuals exhibit monthly differences in peak sightings, with ID#15, 242, and 246 sighted most often in June, 818 in July, and 33 in August (Fig 11). 30% of matched individuals were not seen in the sound until after May. Sightings for all matched individuals in the sound begin to drop after August, and 60% are no longer present after September.

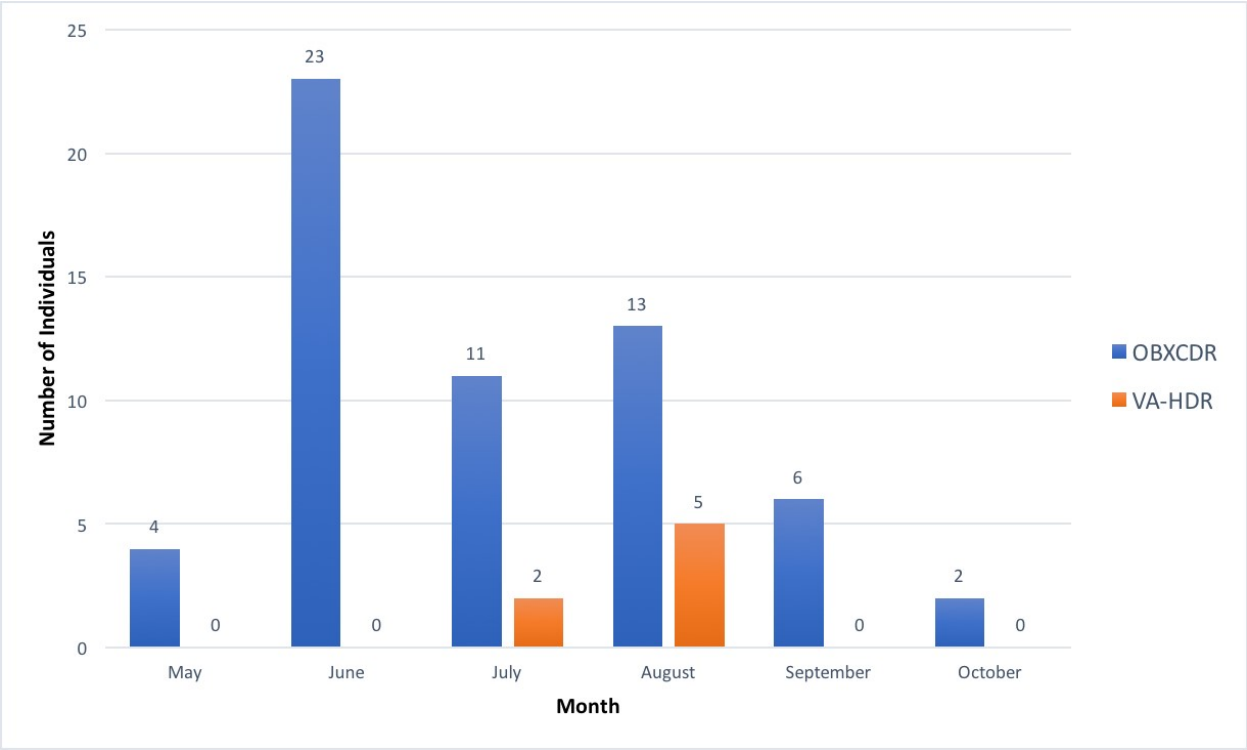

Figure 10. Seasonality of sightings for all matched individuals.

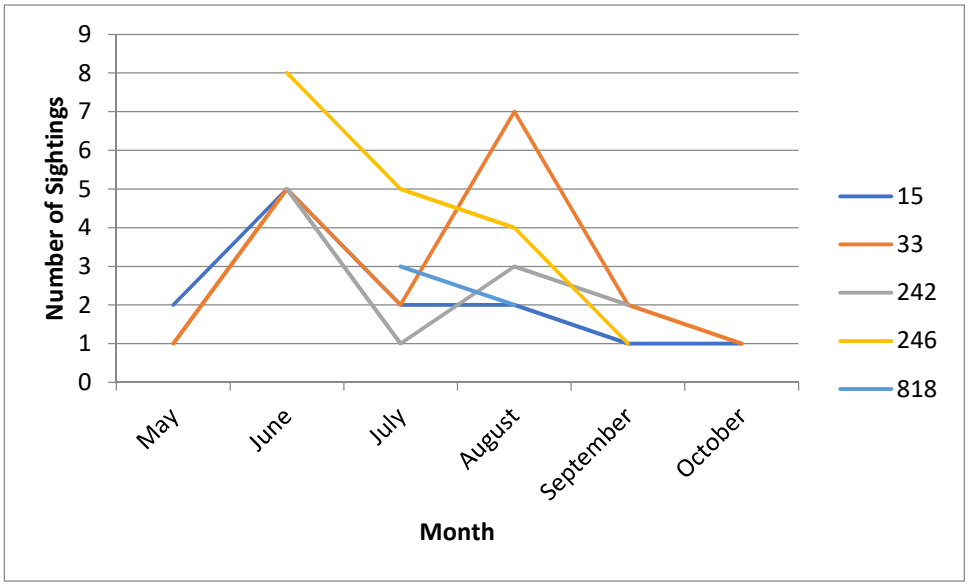

Figure 11. Sightings for matched individuals in the Roanoke Sound by month.

Matched individuals were sighted throughout the northern and southern portions of the Roanoke Sound, meaning they move throughout the sound and do not just remain in one location (Fig 12). Matched individuals were sighted up into the Chesapeake Bay rather than along the southern coastline of VA, and in comparison with all sightings (Fig 2), the matched individuals cluster in the upper portion of the range.

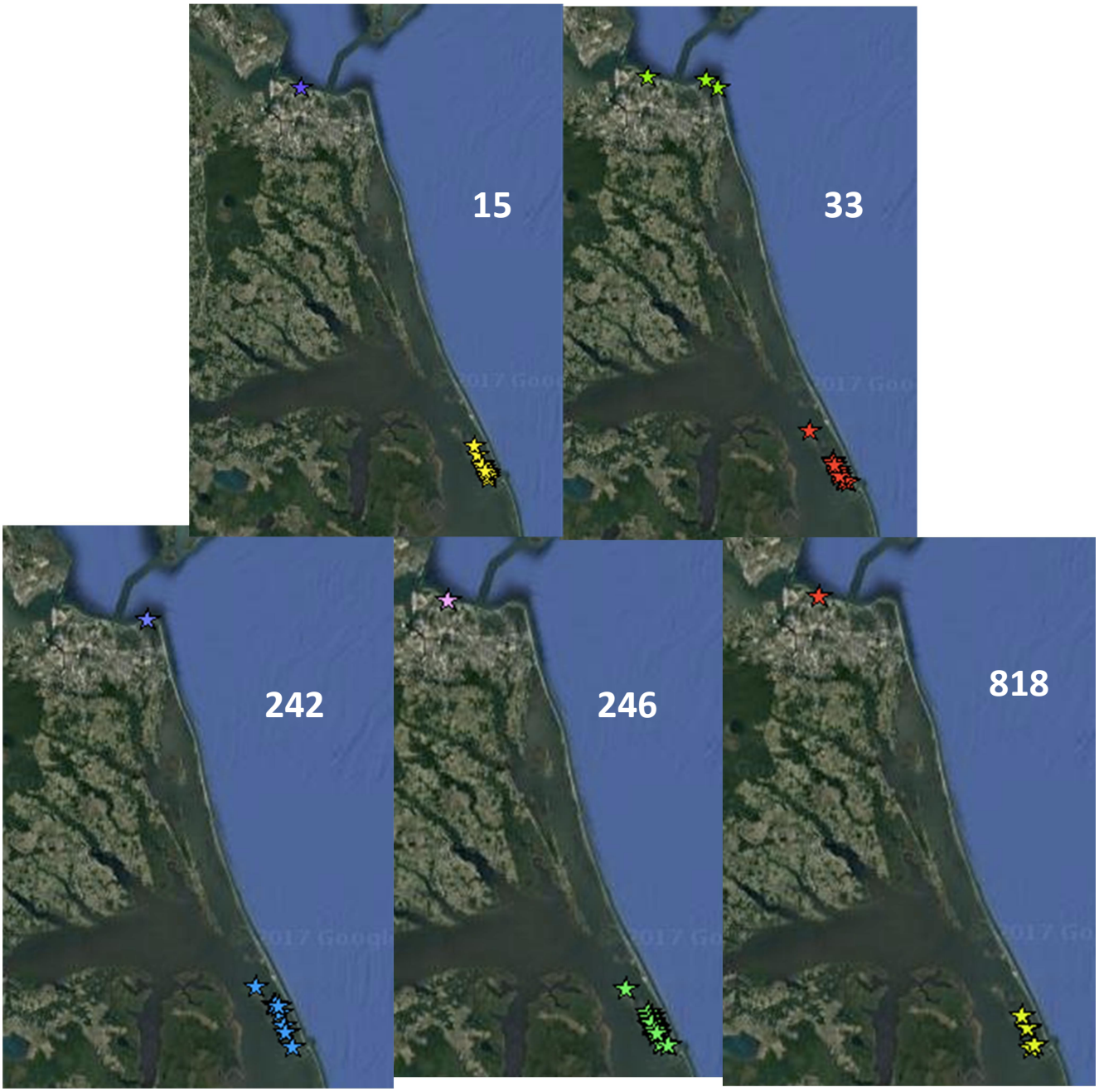

Fig 12. Locations of sightings for matched individuals

Discussion

The primary objective of this study was to examine the northern extent of the bottlenose dolphins known to be seasonally resident to the Roanoke Sound, and part of the NNCES stock.

Out of all cluster 2 and 3 individuals, 12% were matched to the VA-HDR catalog out of Norfolk, VA. This provides insight into the movement of the most commonly sighted dolphins in the Roanoke Sound, and confirms their northward movement along the coastline. The results of this study support the current boundary for the NCCES stock.

Four out of five (80%) individuals matched were in cluster 2, with only one match from cluster 3(Fig 7), and a higher proportion of cluster 2 individuals were matched than cluster 3 (Fig 8). These results indicate that individuals with higher site fidelity and greater sighting probability in Roanoke Sound don't range beyond the Roanoke Sound. A next step would be to match cluster 1 individuals, which have the lowest sighting probability and therefore least site fidelity to determine if these individuals show larger ranges than cluster 2 or 3 individuals.

The seasonality of the movements of matched individuals between NC and VA remains uncertain. Most matched individuals were present in the Roanoke Sound between the months of May-October, but they were only sighted in VA in July and August. Additionally, most individuals (n=3) have not been matched to another VA catalog, and a majority have been sighted near Beaufort, NC (n=4), as detailed in Table 3. This indicates that individuals that move northward into VA also move southward along the Atlantic Coast into the southernmost range of the NNCES stock. This suggests that the population as a whole does not move solely south or north of the Roanoke Sound, but additional data would be needed to support this conclusion. It is also interesting to note that all matched individuals were likely females; usually, males are expected to range further than females, but no cluster 2 or 3 males were sighted in VA-HDR. Again, more data can better support this conclusion, because it may be the case that they were just not photographed in VA-HDR.

There were a few limitations to this study: first the VA-HDR catalog only included dolphins from a short time period. Sightings only took place over the span of two years, while the OBXCDR catalog encompasses seven years of sighting data. For this reason, there were more overall sightings in the Roanoke Sound (Fig 5) than VA (Fig 6), and matched individuals also were sighted more often in NC than in VA (Fig 10). Therefore, all results and conclusions must be taken in light of this limited data. With future updates to the VA-HDR catalog, a better picture of the movement of these individuals can be obtained.

In order to further delineate this stock's northernmost range, the next step will be to look at catalogs north of VA. Elbon and Taylor (2017) matched dolphins commonly sighted in Roanoke Sound to the NJ-CMWWRC catalog, but no matches were made. The next step will be to compare the same sample of dolphins to the MD-PCP catalog, which encompasses a study area through the Chesapeake Bay up into the Potomac River. Both studies will better define the

northernmost range of the NNCES and allow for better understanding of bottlenose dolphin movement and site fidelity.

Works Cited

Adams, J.D., Speakman, T., Zolman, E., and L.H. Schwacke. 2006. Automating Image Matching, Cataloging, and Analysis for Photo-Identification Research. Aquatic Mammals 32(3): 374-384.

Cheney, B., P.M. Thompson, S.N. Ingram, P. S. Hammond, P.T. Stevick, J.W. Durban, R.M. Culloch, et al. "Integrating Multiple Data Sources to Assess the Distribution and Abundance of Bottlenose Dolphins Tursiops Truncatus in Scottish Waters." *Mammal Review* 43, no. 1 (January 1, 2013): 71–88. doi:10.1111/j.1365-2907.2011.00208.x.

Constantine, R., D. H. Brunton, and T. Dennis. "Dolphin-Watching Tour Boats Change Bottlenose Dolphin (Tursiops Truncatus) Behaviour." *Biological Conservation* 117, no. 3 (May 2004): 299–307. doi:10.1016/j.biocon.2003.12.009.

Durban, J., D. Ellifrit, M. Dahlheim, J. Waite, C. Matkin, L. Barrett-Lennard, G. Ellis, R. Pitman, R. DeLuc, and P. Wade. 2010. Photographic mark-recapture analysis of clustered mammal-eating killer whales around the Aleutian Islands and Gulf of Alaska. Marine Biology 157: 1591-1604.

Elbon, S. and J. Taylor. " Seasonal Exchange of Bottlenose Dolphins in North Carolina." (August 2017). Report to be submitted to the MABDC contributors, 7 pp.

Fearnbach, H., J. Durban, K. Parsons, and D. Claridge. "Photographic Mark-Recapture Analysis of Local Dynamics within an Open Population of Dolphins." *Ecological Applications: A Publication of the Ecological Society of America* 22, no. 5 (July 2012): 1689–1700.

Fuentes, M. and J. Taylor. "Seasonal Exchange of Bottlenose Dolphins Occurring in Beaufort and the Outer Banks of North Carolina." (February 2016). Report submitted to MABDC Contributors, 10 pp.

Gannon, D.P. and D.M. Waples. 2004. Diets of coastal bottlenose dolphins (Tursiops truncatus) from the U.S. Mid-Atlantic coast differ by habitat. Marine Mammal Science 20(3): 527-545.

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.

Louis, M., A. Viricel, T. Lucas, H. Peltier, E. Alfonsi, S. Berrow, A. Brownlow, et al. "Habitat-Driven Population Structure of Bottlenose Dolphins, Tursiops Truncatus, in the North-East Atlantic." *Molecular Ecology* 23, no. 4 (February 1, 2014): 857–74. doi:10.1111/mec.12653.

Mason, E. and J. Taylor. "Seasonal Exchange of Bottlenose Dolphin Resident to the Outer Banks of North Carolina." (2016). Report submitted to MABDC Contributors, 13 pp.

McKeowen, J. and J. Taylor. "Sighting Patterns of Bottlenose Dolphins Observed in the Outer Banks, NC." (February 2015). Report submitted to MABDC Contributors, 11 pp.

Shane, S. H., R. S. Wells, and B. Würsig. “Ecology, Behavior and Social Organization of the Bottlenose Dolphin: A Review.” *Marine Mammal Science* 2, no. 1 (January 1, 1986): 34–63. doi:10.1111/j.1748-7692.1986.tb00026.x.

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

Urian, K., A. Gorgone, A. Read, B. Balmer, R. S. Wells, P. Berggren, J. Durban, T. Eguchi, W. Rayment, and P.S. Hammond. “Recommendations for Photo-Identification Methods Used in Capture-Recapture Models with Cetaceans.” *Marine Mammal Science* 31, no. 1 (January 1, 2015): 298–321. doi:10.1111/mms.12141.

Wade, P. R., and R. P. Angliss. 1997. Guidelines for Assessing Marine Mammal Stocks: Report of the GAMMS Workshop April 3-5, 1996, Seattle, Washington. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-OPR-1593 p.

Waring, G.T., E. Josephson, K. Maze-Foley, and P.E. Rosel, eds. 2015. Common Bottlenose Dolphin (Tursiops truncatus truncatus) Northern North Carolina Estuarine System Stock in U.S. Atlantic and Gulf of Mexico Stock Assessments-2015, pages 161-172.

Würsig, B. and M. Würsig. 1977. The photographic determination of group size, composition and stability of coastal porpoises, *Tursiops truncatus*. Science 198:755-756.