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*Community overlap of bottlenose dolphins (*Tursiops truncatus*) found in coastal waters near Charleston, South Carolina*

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Abstract

Long-term photo-identification (photo-id) research into the identity, distribution and movements of dolphins in the estuarine waters near Charleston, South Carolina has been conducted since 1994. However, relatively little is known about dolphins in adjacent coastal waters. In our study, movements of dolphins between estuarine and coastal waters were investigated both to characterize short-term movements and determine the degree of mixing between putative coastal and estuarine dolphins. Bi-monthly photo-id surveys were conducted along a 33 km transect of the Charleston coastal area from January 2003 to December 2006. Using ArcGIS spatial analysis, dolphins sighted along the coast were separated into two communities: coastal dolphins (68%) and estuarine dolphins (22%); the remaining 10% showed no preference to either area. Over half (57%) of all coastal dolphins were only sighted a single time. The majority of dolphins (69%) were encountered in mixed groups composed of both coastal and estuarine dolphins. Only 17% of groups were composed exclusively of coastal individuals, while 14% of the groups were composed entirely of estuarine individuals. Findings from this study document at least two communities of dolphins and provide insight into the mixing of coastal and estuarine dolphins near Charleston and the movements of coastal dolphins. Newly identified dolphins from the coast were occasionally seen in estuarine waters, but more importantly known dolphins from estuarine waters were not only seen in the coastal waters but the majority of their sightings occurred with dolphins identified as coastal individuals. These results support management and conservation efforts of coastal bottlenose dolphins.
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Introduction

Bottlenose dolphins (*Tursiops truncatus*) occur in estuarine, coastal and offshore waters of the Atlantic coast of the United States (2). The stock structure of these dolphins is complex, comprised of offshore, coastal and estuarine stocks with varying degrees of fidelity to different regions (6, 11). Currently in the western North Atlantic (WNA), five coastal and nine estuarine bottlenose dolphin stocks are recognized based on photo-identification (photo-id), genetics, stable isotope and telemetry data (25). While these data have defined multiple coastal and estuarine stocks delineations, the movements of these WNA stocks are less well known.

The stock structure of WNA inshore bottlenose dolphins has been open to speculation since seasonal migrations by coastal dolphins were first postulated by True in 1890 (21). Later evidence in support of a single coastal migratory stock arose from the spatial and temporal stranding patterns associated with an unusual mortality event (UME) that spanned 1987 to 1988 (8, 15). Recorded UME strandings were largely confined to the coast with little to no observed increase in strandings in estuarine environments (15). This observation supported the idea that there existed a distinct coastal "transient" stock (or stocks) and more localized estuarine stocks (15).

Post-UME research has aimed to resolve questions about bottlenose dolphin stock structure in the WNA. In the late 1990's, four hypothetical stock structures for WNA bottlenose dolphins were proposed: 1) a single stock with a large range, 2) multiple year-round resident stocks with small home ranges, 3) multiple seasonally-resident stocks with large home ranges, and 4) multiple migratory groups with long-range movements (6). As patterns of dolphin movements were explored, a combination of the latter three stock structures appeared to best fit (6). In 2002, the National Marine Fisheries Service (NMFS) provisionally recognized a minimum of seven "management units", including a South Carolina unit, within the coastal migratory stock (26).

Studies continue to suggest a convoluted stock structure amongst 'inshore' WNA dolphins (3, 11, 14). Recently, NMFS has subdivided dolphins found off the South Carolina coast into a South Carolina/Georgia Coastal Stock and a Southern Migratory Coastal Stock, based on genetics and telemetry studies (25). Stock

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identity of dolphins within WNA bays, sounds and estuaries is also being refined, including estuarine dolphins near Charleston, SC (the Charleston Estuarine System Stock) (25). In the late 1990's NMFS established the Mid-Atlantic Bottlenose Dolphin Catalog (MABDC) in an effort to clarify dolphin movement patterns. Initially, researchers from ten study sites, from Cape May, New Jersey to Jacksonville, Florida, contributed dolphin identification and sighting data (4). The MABDC database contained 2,377 dolphins in 2001 with approximately 14% (n=323) identified from multiple sites (10). By 2010 the MABDC had grown to 7,730 dolphins (pers. comm., Kim Urian, MABDC curator). Prior to the current study, no dolphins from the Charleston study area had been identified elsewhere using the MABDC database (22). Gubbins *et al.* suggested a seasonal north-south movement of dolphins between Virginia Beach, Virginia and Beaufort, North Carolina (5). Conversely, dolphins sighted near Hilton Head, South Carolina and Jacksonville, Florida were not observed at more northerly sites, suggesting a lack of movement along the entire mid-Atlantic coastline (5).

Photo-id efforts began near Charleston, South Carolina in October 1994 in the Stono River estuary (31) and in early 1997 photo-id surveys of Charleston Harbor, a section of the Intracoastal Waterway northeast of the harbor and the North Edisto River were added. Survey effort was non-systematic and temporally variable following this expansion, with relatively few surveys conducted in 2000 and 2001 (18). As a consequence, long-term sighting data exists for estuarine dolphins near Charleston (18, 31). Conversely, little is known regarding dolphins in adjacent coastal waters and their relationship to estuarine dolphins. The objectives of this study were to individually identify bottlenose dolphins sighted along the coast near Charleston and determine if they represent a distinct community (27), relative to estuarine dolphins, by analyzing degree of mixing.

MATERIALS AND METHODS

Study area

Our study area comprised the nearshore coastal waters between, and was adjacent to, the inlets of two of the surveyed estuarine areas (Charleston Harbor and the Stono River estuary). The survey route ran northeast and southwest of Charleston Harbor, extending to the Isle of Palms Fishing Pier and Sanderling Beach, Kiawah Island, respectively, for a distance of 33 km (Figure 1). The study area consisted of shallow coastal water habitat from the surf zone to approximately 10 m in depth (7). Diurnal tidal fluxes had a mean range of 1.5 m with a spring range of 1.8 m (19).

Data collection and Analysis

From January to December 2003, two photo-id surveys were attempted per month from an outboard powered 5.9 m rigid-hull inflatable boat. From January 2004 to December 2006, one photo-id survey was attempted per month with an additional survey completed once per season. Surveys were conducted approximately 1 km beyond the surf line (Figure 1). This nearshore route represented the "on-effort" portion of the survey. After completion of the nearshore route, an offshore route, 3-4 km from shore, was usually surveyed. This route represented the "off-effort" portion of the survey (Figure 1). The separation of the nearshore and offshore survey routes was necessary because conditions occasionally prevented the offshore route from being surveyed. A survey was considered complete when the entire on-effort transect was covered; opportunistic sightings were collected on the off-effort transect. The off-effort transect allowed for

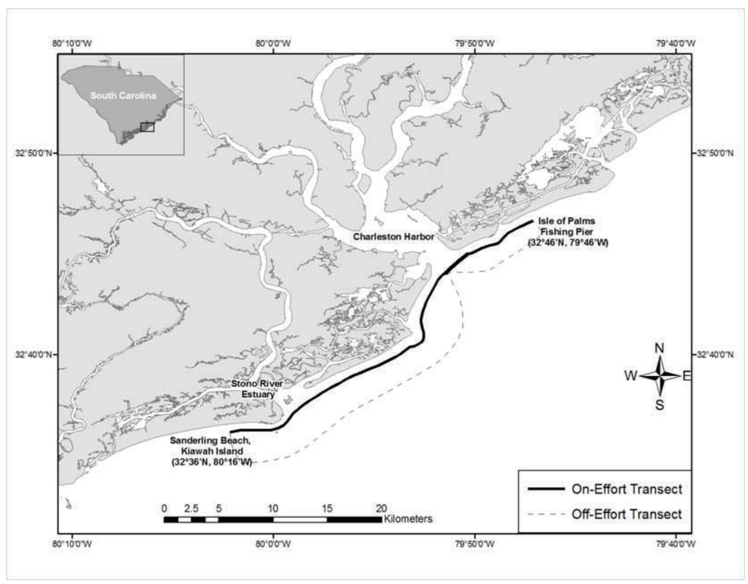

Figure 1 - Charleston coastal study area, including the northeastern (Isle of Palms Fishing Pier) and the southwestern (Sanderling Beach, Kiawah Island) boundaries of the survey route and the on- and off-effort transects.

greater coverage of the study area when weather and sea conditions permitted, which also allowed for sightings of coastal individuals further from shore in a habitat without distinct boundaries. Surveys were conducted at a speed of approximately 30 km/h and in Beaufort Sea States of 3 or less. During surveys, two to four observers maintained a visual watch for dolphins in a 180° arc about the bow of the survey vessel, from the shore to approximately 1 km offshore.

Once an individual or group of dolphins was sighted, an attempt was made to photograph the dorsal fin and other distinguishing features of all dolphins within the group using a Canon EOS-1D with a 100-400 mm f4.5 lens (30). Field and photo-identification protocols have been described previously (18). Briefly, sighting data recorded included: location (via a hand-held GPS), group size estimates (minimum, maximum and best), number of calves and/or neonates, behavior, weather conditions, shrimp boat association and a record of digital images collected. Sightings constituted grade one quality in cases when the number of photographically identified individuals was equal to or greater than the best field estimate (28). Following a sighting, the survey recommenced on-transect with observers again visually searching for dolphin groups until completion of the survey.

Digital dorsal fin images were downloaded, sorted using Photoshop 7.0 and photo-analyzed using standard methods (24, 9). Images were rated for quality (based on focus/clarity, contrast, angle, partial obstruction and distance), distinctiveness and prevalence of the parasite *Xenobalanus* on the fin (13). Poorly rated images were eliminated and images were subsequently matched to dolphins found in the National Ocean Service/Center for Coastal Environmental Health and Biomolecular Research (NOS/CCEHBR) bottlenose dolphin dorsal fin catalog using a customized Microsoft Access database (FinBase) or added to the catalog if they represented a new individual (1). Each match or new fin was verified by a second researcher.

Data from on- and off-effort sightings were extracted with queries from FinBase and imported into ArcGIS 9.1 and Microsoft Excel 2003 for data manipulation and statistical analysis. Sighting locations of all individuals identified during the coastal study, in addition to all historical (1994-2002) sighting locations (17), were mapped in ArcGIS. Historical sightings were included to better classify individuals into a community. COLREGS lines of demarcation were used as an objective, albeit arbitrary, boundary between estuarine and coastal waters. COLREG lines are published by the U.S. Department of Commerce for mariners to discern which waters to follow inland navigation rules versus following international regulations for preventing collisions at sea (23).

The degree of mixing between communities was investigated by comparing the community affiliation (coastal or estuarine) of all dolphins identified in a sighting. Three sighting compositions were possible: 1) all coastal individuals, 2) all estuarine individuals or 3) mixed coastal and estuarine individuals. Dolphins with 60% or more of their sightings in coastal waters were defined as “coastal”, this included individuals sighted a single time along the coast. Some estuarine dolphins were sighted along the coast as well as in estuarine waters; however to be defined as estuarine, less than 40% of their sightings could occur in coastal waters. It was recognized there may be limitations of the data due to lack of consistent survey effort prior to this study. Given coastal surveys were not conducted previously, effort adjusting would have been highly skewed and was not performed. Using 60% as the percentage of sightings in an area allowed us to classify individuals as coastal or estuarine demonstrating where the majority of their sightings occurred. This method also allowed individuals with very few sightings to be classified into a group versus being classified as no preference. Once an individual was classified to a community, descriptive data (means, ranges, percentages) were calculated for total number of sightings and number of times individuals were sighted along the coast and in estuarine waters.

RESULTS

Dolphins were sighted during all 120 surveys conducted during 2003-2006 totaling 723 on- and off-effort sightings (unless otherwise noted both on- and off-effort were used). During photo analysis, 1,221 individually distinct dolphins were identified (Figure 2). Using sighting location data, dolphins were assigned to one of two groups: 1) coastal dolphins - those that were observed along the coast 60% of the time and

2) estuarine dolphins - those that were observed along the coast occasionally but were observed in estuaries 60% of the time. Some individuals were sighted along the coast but did not show a preference to either area (less than 60% of time in either area).

Most of the 1,221 dolphins identified during this study were classified as coastal (68%, n=833); 22% (n=268) were classified as estuarine; 10% (n=120) showed no preference to either area. Coastal dolphins were sighted 1-28 times (mean=1, median=2.2), with more than half being sighted once (57%, n=435). Only one coastal dolphin was sighted 28 times (0.1%) and 17 (2%) were sighted 10 or more times. For coastal individuals sighted more than once, the interval between sightings ranged from 1 to 90 months with a mean inter-sighting interval of 27.0 ± 15.9 months (median time of 26.0 months). Estuarine dolphins were sighted along the coast 1-15 times (mean=3.4, median=2). Most (74%, n=131) were sighted along the coast 1-4 times.

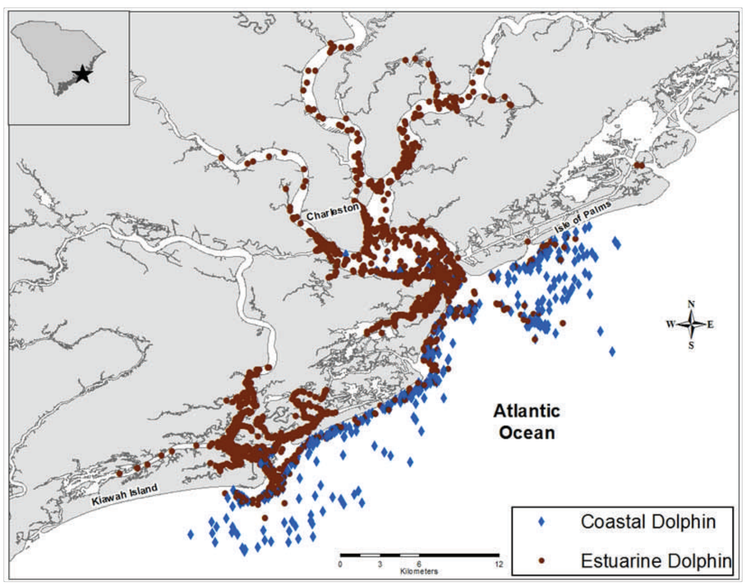

Figure 2 - Sighting locations of individual coastal and estuarine dolphins during 2002 – 2006.

Groups of two or more dolphins were analyzed for association between coastal and estuarine dolphins. A total of 545 sightings with two or more catalog (identifiable) individuals were used for the community mixing analysis (Figure 3). Sightings of groups of all coastal or all estuarine dolphins accounted for 17% (n=94) and 14% (n=76) of the total, respectively; 69% (n=375) of sightings contained a mix of coastal and estuarine individuals. The majority of sightings, regardless of composition, occurred near the two largest inlets, east of Charleston Harbor and within the Stono River Inlet. During this study, dolphins were associated with shrimp boats in 17% of the sightings (Figure 4).

Figure 3 - Some sightings along the coast were comprised of a large number of dolphins, with both adult and juvenile dolphins present.

Figure 4 - Dolphins were sighted behind shrimp boats on multiple occasions along the coast; at times they were also seen following behind shrimp boats returning from the coast into the harbor.

DISCUSSION

Our results support the presence of multiple dolphin communities in the inshore waters near Charleston, South Carolina. Findings indicate the likelihood of at least two communities in the Charleston area - coastal and estuarine dolphins. However, some individuals did not demonstrate a preference for either area as they were seen along the coast and in the estuaries. The majority of dolphins (69%) sighted along the coast were in mixed groups, of both coastal and estuarine dolphins. COLREGS lines of demarcation appeared to provide a useful and precise method in separating coastal and estuarine dolphins. By allowing 40% of sightings to be inside estuarine waters, the chance that individuals would be misclassified as a result of following a shrimp boat inshore of the COLREGS line was minimized.

To gain insight as to why there were so many mixed composition groups, sighting data was examined regarding the length of the sighting and the subarea(s) in which the mixed group(s) were observed. Of sightings 45 minutes or longer, 50% were composed of coastal, estuarine and dolphins showing no preference. With longer sighting durations there is a higher likelihood of subgroups moving within close proximity of each other and being considered part of the same group (and in analysis being determined to a mixed group) although they may not actually be interacting. The majority of sightings occurred near the two largest inlets (Charleston Harbor and the Stono River Inlet). These areas represent high tidal exchange and may support higher fish population diversity and/or densities and further study would be necessary to verify this.

Data on movement of dolphins between estuarine and coastal waters near Charleston broadened our understanding of dolphin movements on a wider, more regional, scale. Wells described multiple dolphin communities within a population as “assemblages of dolphins that inhabit similar ranges and that interact socially more often with each other than with other adjacent assemblages” (27). This description provides a framework for the situation found near Charleston. The overlapping ranges of coastal and estuarine dolphins near Charleston, South Carolina may suggest a potential for interbreeding which consequently could have relevance on stock classification. This has not been observed in long-term resident dolphins in Sarasota, Florida which interact with dolphins of neighboring stocks but significant genetic differentiation exists indicating that interaction may not include interbreeding (16).

Such overlapping communities have been reported elsewhere including the southeastern United States. Winn *et al*. initially discussed the existence of ‘ocean’ and ‘river’ dolphins. They suggested that most ‘river’ dolphins do not travel very far offshore, but that there is some movement between the ocean and protected waters (29). Dolphins off North Carolina utilized both coastal and estuarine environments and also made long range coastal movements (13). In the Gulf of Mexico near Sarasota, Florida, dolphins were assigned to different communities or assemblages based on the number of individual sightings, the proportion of sightings in the Gulf or inshore waters and the geographic locations of sightings (4). Genetic studies later confirmed the existence of these communities (16). Another study compared dolphins from four mid-Atlantic sites (Virginia Beach, Virginia; Beaufort, North Carolina; Hilton Head, South Carolina; Jacksonville, Florida) and reported overlap between coastal and estuarine dolphins (5). Over half of coastal sightings near Charleston were found to be of mixed composition, in contrast to other studies. Fazioli *et al.* noted little mixing (14%) between ‘Gulf’ and ‘Inshore’ dolphins near Sarasota, Florida (4). The difference in degree of mixing between Sarasota and Charleston may be related to variables between the two sites such as population size, the size of the inlets or distance surveyed from shore. In Charleston, only opportunistic sightings occurred at 3 km offshore with the majority of the sightings within 1 km. In Sarasota, survey effort extended 9.3 km offshore (4). Read *et al.* focused on individual dolphins sighted along the Outer Banks of North Carolina that were also sighted elsewhere along the mid-Atlantic (13). However, they did not report whether dolphins that were sighted both in the estuaries and along the coast were associated with one another (13). If mixing occurs between estuarine and coastal dolphins in other areas, as observed in our study, perhaps there is greater overlap between the different WNA stocks than initially thought (25). Similar to findings shown in Read *et al.* individual sighting patterns can be used to help identify monitoring strategies of dolphin stocks (13).

In our study, coastal dolphins were primarily sighted once, with only a small number sighted five or more times. Time between resights varied from less than a week to almost nine months, with the majority occurring approximately two months apart. This two month time frame was often within the same season, suggesting some coastal individuals are primarily transients or short term/seasonal residents. In 1994 Zolman (31) identified seasonal residents that were only sighted during fall and winter over a 15-month photo-id study in the Stono River Estuary. Since then these seasonal residents are thought to range outside of this area into other surrounding estuaries such as Charleston Harbor. In a similar region, Caldwell found few resights during a three-year study along the coast near Jacksonville, Florida and only nine of the 684 identified dolphins were sighted five or more times (3). Additional studies may address whether a seasonal pattern exists in Charleston coastal dolphin resightings especially individuals only sighted once in this study. Such inter-seasonal resights could then be used to determine whether or not there is a seasonal component to when coastal and local estuarine dolphins interact. With continued effort, some single-sighted coastal individuals may be resighted and help provide insight into this.

It should also be noted that during the current study, dolphins were sighted behind shrimp boats based out of South Carolina, North Carolina, Georgia and Florida. Caldwell found that of three dolphins sighted near Jacksonville, Florida, two were subsequently sighted near Hilton Head, South Carolina, while one was later sighted near Myrtle Beach, South Carolina (3). In all three locations, the dolphins were sighted behind shrimp boats (3). Given Charleston's location between Hilton Head and Myrtle Beach, it is likely that some coastal dolphins travel through the study area behind shrimp boats. Both all coastal and mixed groups were observed associated with shrimp boats. It should be noted that no dolphin groups classified as all estuarine were sighted behind shrimp boats.

Feeding behind shrimp boats may be considered a specialized foraging strategy. Foraging behaviors can be an ecological determinant of overall dolphin habitat use and can create, or reinforce, spatial structure within a population. Specialized foraging strategies have been strongly associated with contrasting environmental characteristics, primarily depth, in dolphins in Florida Bay (20). Differences in stomach contents between coastal and estuarine South Carolina dolphins and observations of 'strand feeding' by estuarine dolphins provides some evidence for different foraging specializations between dolphins from these two Communities (12,31). Thus, similar to observations found in the Florida Bay study, the bathymetric and heterogeneous surroundings of coastal and estuarine environments in the Charleston region may contribute to existence of multiple dolphin foraging strategies which constrains the habitat use, distribution and social patterns of these dolphins.

Findings from our study investigating movements of dolphins between estuarine and coastal waters suggest at least two dolphin communities near Charleston: coastal dolphins (68%) and estuarine dolphins (22%), with 10% not classified. The large amount of interaction observed between the Charleston estuarine and coastal dolphins seems to contradict the lack of mortality in the putative estuarine dolphins along the U.S. Atlantic coast during the 1987/1988 UME which claimed more than 740 presumably 'coastal' dolphins (24). Previous studies from the mid-Atlantic have investigated areas where coastal dolphins may be migrating to, however, data is lacking on possible interactions between local estuarine dolphins and these migratory dolphins (5, 22). Our previous research demonstrated the distribution of dolphins within the estuaries of Charleston and now findings from this study provides evidence that these dolphins also utilize the near coastal area outside of the estuary as well.

Continued coastal photo-id survey effort near Charleston may document resights of dolphins that were only sighted once in the current study and serve to further document potential seasonal patterns of individual dolphin presence along the coast and the degree of interactions between coastal and estuarine dolphins. Movements between locales can be explored through the wider perspective afforded by the MABDC. Further exploration of dolphin-shrimp boat associations may also help delineate possible patterns in regards to mixing of communities and movement of animals. Further genetic studies of the local coastal dolphin community, as well as estuarine dolphins, would be important in addressing mechanisms that drive population structure and whether the two communities are reproductively isolated. The Charleston Estuarine Stock is considered a strategic stock by NMFS and thus potential impacts can have significant effects (25). Photo-id studies indicate seasonal abundance estimates vary with higher number of animals in summer than winter and a mean population estimate of ~500 dolphins (17).

Data on the degree of division among estuarine and adjacent coastal dolphins provide important information related to the degree of connectivity at many different levels and can assist in the management of overlapping stocks. Information on community structure may help to describe stocks that are located in close proximity to each other. For these stocks, it is important to know the degree of interaction between coastal and estuarine dolphins and whether these individuals are part of the Charleston Estuarine management unit or another coastal management unit(s). Biological threats such as diseases and human/fishery interactions have the potential to impact dolphin stocks and further understanding of each community/stock is essential for management and conservation efforts.

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