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Abundance, Site-Fidelity, and Association Patterns of Coastal Bottlenose Dolphins (Tursiops truncatus) off Southeast Florida

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Thesis of
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Submitted in Partial Fulfillment of the Requirements for the Degree of

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NOVA SOUTHEASTERN UNIVERSITY

HALMOS COLLEGE OF ARTS AND SCIENCES

Abundance, Site Fidelity, and Association Patterns of Coastal Bottlenose Dolphins (*Tursiops truncatus*) off Southeast Florida

By:

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ABSTRACT

The coastal bottlenose dolphin is well studied throughout its natural range, however, most of the study areas comprised wide, well-protected habitats such as bays and estuaries, and not narrow coastal sandbanks. This study identifies a residential group of coastal bottlenose dolphins utilizing the narrow sandbanks within the Northwestern Atlantic waters off the coast of Palm Beach County, Florida, USA. From 2014-2020, 313 boat surveys were conducted, and 585 individual dolphins were identified using photo-ID. Twenty-four animals were determined to be full-time and 66 animals were determined to be part-time residents. Full-time and part-time residents associated in three social tribes, with encounters consisting of members of multiple tribes commonly observed. Association patterns were highly correlated to site-fidelity, indicating the presence of a unique residential group which regularly interacts with transient animals likely passing between Central Florida and Biscayne Bay. Future research within this natural corridor will focus on habitat utilization by residents and transients, and the behavioral nature of encounters between social tribes.

KEYWORDS: Marine mammal, group size, cetacean, behavior, resighting, half-weight

1. INTRODUCTION

1.1 Preface

Site fidelity and social patterns in bottlenose dolphins (*Tursiops truncatus*) are highly variable, dependent on habitat type, food availability, and population size, among other things (Quintana-Rizzo and Wells, 2001; Vermeulen, 2018). The narrow sandbanks of Southeast Florida, nestled between the coastline and the Florida Current, are extremely biologically productive (Arena et al., 2007) and provide a unique ecosystem to study dolphin behavior. The relationships among factors known to influence dolphin social behavior globally are poorly studied (Quintana-Rizzo and Wells, 2001), and analyzing the open-ocean, semi-closed habitat in this region can allow for better understanding of the diversity of dolphin social patterns. While dolphins have been thoroughly studied throughout Central Florida as well as at the southern end of the peninsula (Mazzoil et al., 2011, 2020; Mcfee et al., 2012; Richards et al., 2013; Durden et al., 2017, 2019; Nekolny et al., 2017), no literature describes the residential dolphins living within this unique habitat. As threats in the region, such as increased boat traffic and toxic algae blooms continue to increase (Tominack et al., 2020; McHugh et al., 2021), an understanding of how many dolphins reside in this region and how they associate with each other and/or neighboring groups could pave the way more effective conservation action. This study is the first to document residential bottlenose dolphins in this region and uses photo-identification techniques, combined with association pattern analysis, to describe the relationship between these animals and the larger western North Atlantic population.

1.2 The Common Bottlenose Dolphin

Common bottlenose dolphins (*Tursiops truncatus*) are some of the most widespread and well-studied marine mammals on the planet (Caldwell et al., 1965; Rice, 1998; Goodall et al., 2011; Chen et al., 2017). Their range extends across all tropical and temperate oceans, with genetically unique populations documented from the southern coast of Australia and South America to the northern end of Europe (Goodall et al., 2011; Louis et al., 2018; Van Aswegen et al., 2019). Across this global range, there is a substantial amount of genetic and phenotypic diversity within the species (Guidarelli et al., 2018), with one of the greatest differences observed between coastal and offshore populations (Tezanos-Pintos et al., 2009; Zaeschmar et at., 2020). The coastal ecotype tends to be smaller and lighter, with a pink or white underside

(Figure 1), while offshore individuals are larger and darker in color, with distinct capes below the dorsal fin (Rossbach & Herzing, 1999; Simoes-Lopes et al., 2019). Genetic work indicates these two ecotypes may even represent two distinct subspecies or species in some parts of their range (Wickert et al. 2016; Costa et al., 2021, 2022).

While adult bottlenose dolphins have few natural predators, they face a myriad of threats today, including overfishing, toxic algae blooms, and bioaccumulation of toxins. Due to the anthropogenic nature of most of these threats, coastal populations are at a higher risk. In coastal regions with large fisheries, interactions with fishing boats are common and can result in entanglement, hooking, and boat strikes, all of which can be fatal for dolphins. A substantial increase in the frequency of dolphin entanglement in South Florida has occurred since 1997. This trend is due in part to the increasing size of the fisheries industry in this region (McHugh et al., 2021).

South Florida also experiences annual red tide events, often caused by a eutrophic production of the dinoflagellate *Karenia brevis*, which can impact local dolphin populations. Dolphins living in areas with regular *K. brevis* blooms exhibit a higher body load of brevetoxin, the respiratory toxin released by *K. brevis*, than other unaffected populations, which may lead to either direct mortality or weakened immune systems. The blooms regularly coincide with largescale mortality events in local dolphin populations, and both the dolphins and prey fishes involved in the die-off show high levels of brevetoxins (Fire et al., 2007; Twiner et al., 2011). Though this most often affects the gulf coast, the length and size of these red tide blooms has increased in the last few years, expanding into the waters of Southwest Florida, and putting the dolphins in this area at higher risk (Tominack et al., 2020).

Bottlenose dolphins are apex predators in the western Atlantic (Connor et al., 2000) Due to this high trophic position, bottlenose dolphins are at an increased risk for bioaccumulation of human-introduced toxins in their environment. Bottlenose dolphins sampled in the Florida Keys show high levels of mercury and persistent organic pollutants (POPs). Further, while females showed lower toxin rates than males, infant mortality increases with overall toxin concentration, indicating females may transfer toxins to offspring during pregnancy and nursing (Damseaux et al., 2017). Any factor that elevates infant mortality rates could have widespread impacts on population dynamics through time (Damseaux et al., 2017). These threats may also have yet unknown effects on the social structure of dolphin populations (Brightwell et al., 2020).

Figure 1. The coastal bottlenose dolphin (*Tursiops truncatus*) (Taras Oceanographic Foundation)

1.3 The South Florida Coastal Ecosystem

Along the eastern coast of South Florida, the deep-water Florida Current (a portion of the Gulf Stream) approaches shore closer than at any other point in the country (Avent et al., 1977). Unlike in other regions of Florida, where shallow sandbanks extend for up to 100 km offshore, the coastline in this region has a steep drop-off near shore, with depths of 20m common within 5 km of shore (Figure 2) (Kajiura & Tellman, 2016). The area off Palm Beach County has a small shallow-water bank composed of primarily a narrow sand bank and hard reef systems, however, this sand bank makes up only 30% of the area within six kilometers of shore. The rest of the area is made of a combination of hard corals, bedrock, and granite continental shelf (Finkl et al., 2005). There are also many sunken vessels and artificial reefs in this region, increasing the number of fish in the area. While the shallow-water bank in this part of Florida is narrow, it supports an exceedingly high level of biodiversity, with over 177 fish species found on the reefs in this region (Arena et al., 2007). The combination of narrow bank and high biodiversity makes this area a hotspot for large predators. One of the largest aggregations of blacktip reef sharks in the world moves through this area annually, and other shark species are common year-round (Kajiura & Tellman, 2016). Beyond the continental shelf, in over 200m of water, cetaceans including offshore bottlenose dolphins, Risso's dolphins (*Grampus griseus*), pilot whales (*Globicephala macrorhynchus*), and false killer whales (*Pseudorca crassidens*) have been recorded. Nearshore, however, there have only been opportunistic reports of Atlantic spotted dolphins (*Stenella frontalis*) (Herzing & Elliser, 2016). No coastal bottlenose dolphins have been recorded in the area. Even with this abundance of prey and the presence of other large predators, no research has been done on dolphins in the coastal oceans of Palm Beach County and the surrounding coastline.

1.4 Tursiops Stocks in the Northwest Atlantic

The coastal ecotype of the bottlenose dolphin has been well documented along the Northwestern Atlantic. A National Oceanographic and Atmospheric Association (NOAA) pilot study was completed in 1995, suggesting one large migratory stock of coastal *T. truncatus* extended from South Carolina to Central Florida, with an estimated population of approximately 13,000 individuals (Blaylock, 1995).

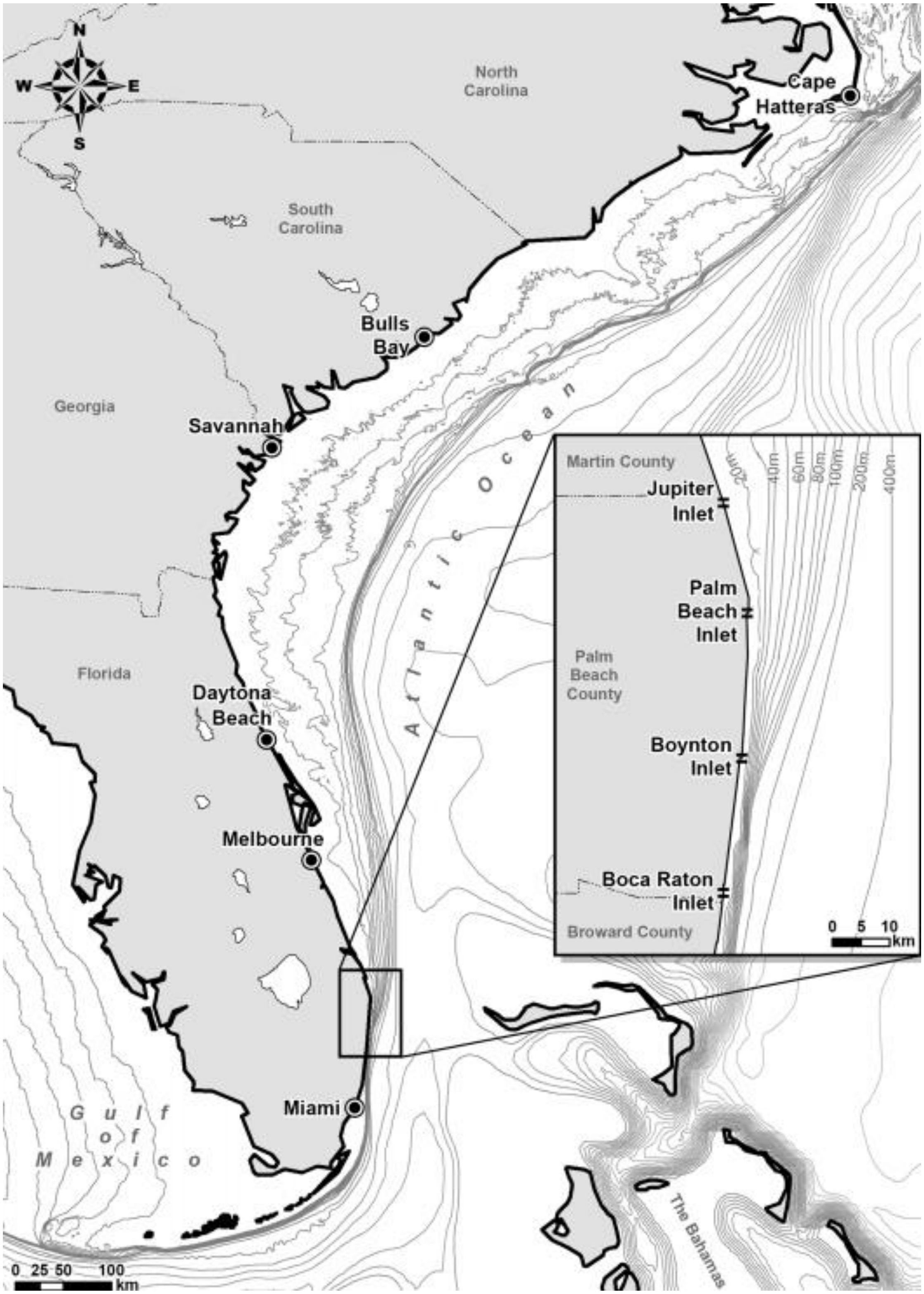

Figure 2. Bathymetric map of the southeastern United States. The shelf narrows dramatically in Palm Beach County, Florida, resulting in a small shallow sand bank. Adapted from Kajiura & Tellman (2016).

More recent studies have determined that this stock consists of smaller unique stocks. There is little to no genetic crossover between coastal dolphins sampled in Georgia and in Northern Florida (Rosel et al., 2009) and dolphins in Georgia, Florida, and South Carolina all showed significantly different susceptibilities to skin lesions (Hart et al., 2012). This larger region of coastline is now thought to have four genetically distinct residential coastal stocks, including the South Carolina/Georgia stock, Northern Florida Coastal Stock, Central Florida Coastal Stock, and Florida Keys stock (Torres et al., 2005; Bills & Keith, 2012; Taylor et al., 2016; NOAA, 2017) (Figure 3). It should be noted, the Florida Keys stock shows large behavioral differences from other Atlantic coastal stocks and may be more closely related to the stocks of Western Florida and the Caribbean (Lewis & Schroeder, 2003; Caballero et al., 2012; Costa et al., 2022).

While the Central Florida Coastal Stock (CFCS) has been given substantial attention, almost all studies have focused on the dolphins residing permanently in the Indian River Lagoon, with little focus on the oceanic population (Mazzoil et al., 2011, 2020; Mcfee et al., 2012; Richards et al., 2013; Durden et al., 2017, 2019; Nekolny et al., 2017). Between Fort Pierce and Vaca Key, Florida (the Northern limit of the Florida Keys stock) the proximity of the Florida Current to shore and the lack of a wide, shallow shelf may act as a biological boundary inhibiting coastal *T. truncatus* from residing in this area (NOAA, 2017). Coastal bottlenose dolphins tend to reside in areas with a wide sand bank, in depths between 1-15 meters, as the sand banks are full of potential prey and serve as protection from ambush predators who may attack young dolphins (Rossbach & Herzing 1999;). There are reports of offshore bottlenose dolphins off the coastal shelf of this region (Herzing & Elliser, 2016), but there is currently no literature assessing the presence of the coastal ecotype in this area. While this region is technically considered part of the range of the CFCS, it is not surveyed during NOAA stock analysis, due to the assumption that no residential or frequent dolphins inhabit this area (NOAA, 2017). If a residential group of coastal *T. truncatus* were to exist in this undocumented region, it would be an important group to study, due to its geographic position between supposedly unconnected stocks. With dolphins in surrounding regions facing increased threats (Fire et al., 2007; Damseaux et al., 2017; Brightwell et al., 2020; McHugh et al., 2021), the existence of a potential genetic or cultural bridge between

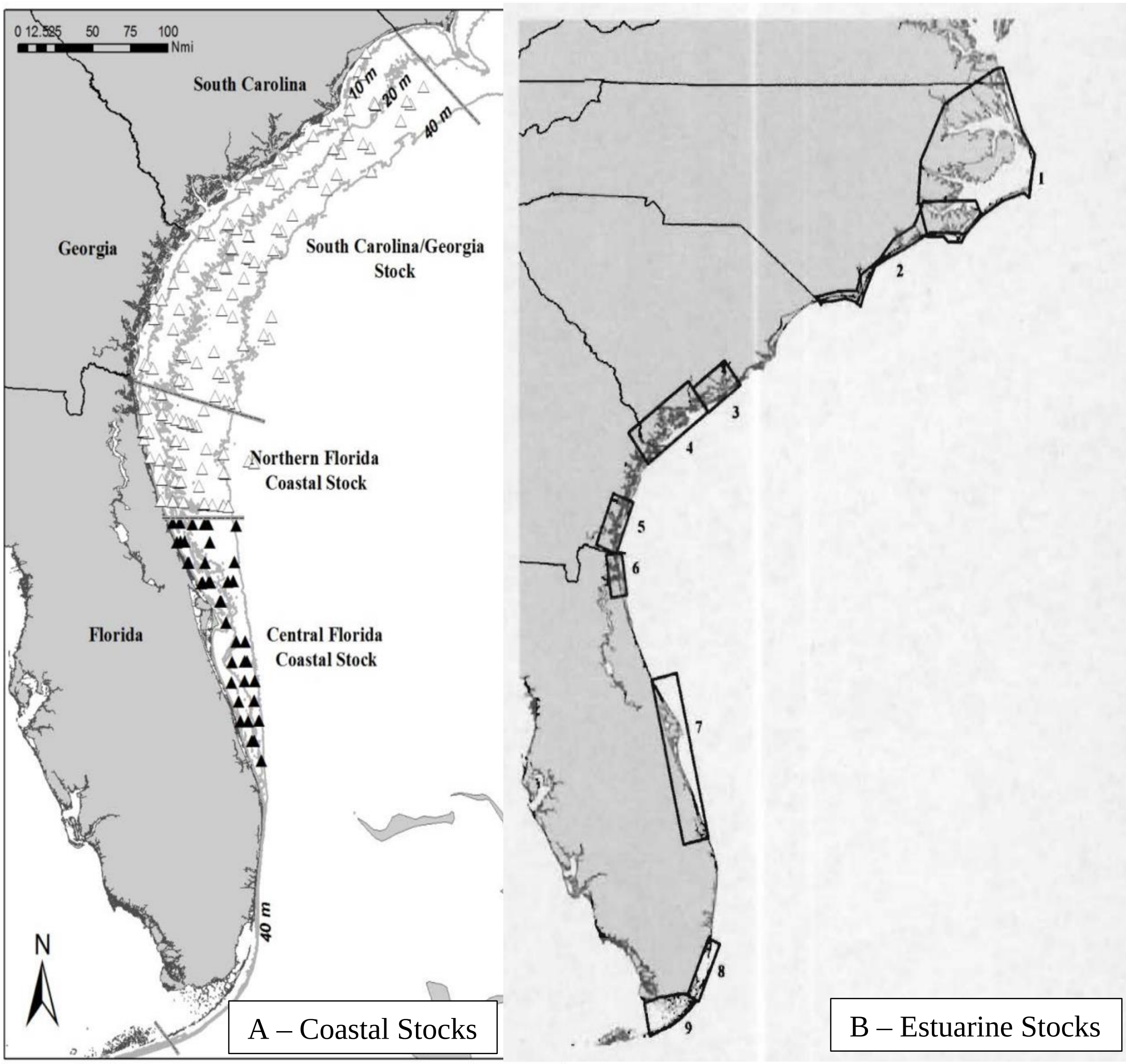

Figure 3. Recognized residential stocks of coastal (A) and estuarine (B) bottlenose dolphins in the western North Atlantic. White triangles denote sightings in the SCGS and NFCS, while black triangles denote sightings in the CFCS. Black squares denote known habitat of residential estuarine populations. Though the boundary of the Central Florida Coastal Stock extends beyond the study area, no sightings have been documented south of Cocoa, FL. Note the gap in sightings between Cocoa, FL and Biscayne Bay, FL (8). Adapted from (A) NOAA, (2017) and (B) Rosel et al., (2011).

the northern CFCS, the Indian River population, and the Biscayne Bay and Florida Keys Stocks would greatly aid in efforts to conserve and protect the dolphins along the entire eastern coast of Florida.

1.5 Photo Identification of Small Cetaceans

Photo-identification of individual animals has long been used as a method of calculating population size and behavioral patterns in long-term small cetacean studies (Urian & Wells, 1996; Middleton et al., 2011; Diaz Lopez, 2012; Benmessaoud et al., 2013; Pace et al., 2021). This technique, first described by Würsig & Würsig (1977), is most used for bottlenose dolphins, and utilizes the unique scaring pattern on the trailing edge of the dorsal fin to identify individuals. The method has since been standardized, with labs across the globe following the same protocol (Urian & Wells, 1996) This allows researchers to compare individuals within a single study site or across neighboring populations (Middleton et al., 2011). Images used in photo-identification studies must be of high quality, with the full dorsal fin in clear focus. The fin should be perpendicular to the observer, and identifiable fin features should not be covered by waves, *Xenobalanus* (a small barnacle common on dolphin fins), or other objects. If a photo meets these requirements, it is considered suitable for photo-identification studies and can be used to identify an individual within or across study populations (Urian & Wells, 1996). This identification method cannot account for the small number of adult animals with no scaring on their fins or calves who have yet to obtain any identifiable markings, and as such can result in slightly low estimates for capture-recapture studies (Urian & Wells, 1996; Middleton et al., 2011). In these cases, other identification techniques such as facial recognition can be used (Genov et al., 2018).

1.6 Association Patterns in Bottlenose Dolphins

Bottlenose dolphins form large and complex social networks with bonds between individuals ranging from short-term associations to decade-long alliances (Genov et al., 2018; Genoves et al., 2018). While their social structure is often described as fission-fusion, this is highly dependent on a multitude of factors (Vermeulen, 2018) and it seems that habitat type may be one of the best predictors for social structure (Quintana-Rizzo and Wells, 2001).

In closed habitats (i.e., those with barriers preventing the immigration and emigration of large numbers of individuals), high site-fidelity and strong associations are common (Quintana-Rizzo and Wells, 2001). Sites like the Indian River Lagoon in eastern central Florida show high levels of male-male bonding, with small sex-specific tribes existing within the larger population (Durden et al., 2019). This social structure is also found in Shark Bay, Australia, where males form hierarchical alliances separate from females (Genov et al., 2018).

In contrast, semi-closed habitats may allow large groups of transient animals to pass through a region. In southern Australia, bottlenose dolphins appear to form associations not based on sex, but on site-fidelity. Year-round residents of a region tend to associate with other residents, while transient animals associate with each other. Sex is not a predictor of association patterns in these habitats, as social groups often consist of both sexes (Passadore et al., 2017). In the semi-closed habitats of both the Tunesian coast and the Istanbul Strait, this is also the case, with residential, transient, and sporadically visiting dolphins forming distinct social groups (Benmassaoud et al., 2013; Bas et al., 2019). Off the coast of Slovenia in the Adriatic Sea, three distinct tribes of bottlenose dolphins exist. These animals associate in mixed-sex groups that share the same habitat year-round, but the three tribes rarely interact with one another (Genov et al., 2018).

In more open-water habitats, like those off the coast of northeastern New Zealand, dolphins show a tendency towards larger social groups with weaker bonds. In these groups, tribes may exist, but associations expand beyond tribal lines. These larger social groups are less likely to be sex-specific, with all dolphins interacting more randomly throughout the population (Zaeschmar et al., 2020).

While the coast of Southeast Florida is a generally open habitat, coastal bottlenose dolphins' preference for shallow waters combined with the nearness of the deep-water Florida Current may make this habitat more comparable to that of the semi-closed Istanbul Strait than the true open habitat of New Zealand. In this case, association patterns in Southeast Florida could be expected to exhibit characteristics of both open and semi-closed habitats, dictated in-part by site-fidelity, but with higher numbers of weak bonds instead of strong tribal alliances.

1.7 Importance of Study

This study is the first comprehensive population study of small cetaceans in this region. While much attention has been given to the bottlenose dolphins of the Indian River Lagoon, coastal populations in central Florida to the north, and Biscayne Bay to the south, the area between these regions is understudied and unrepresented in the literature. While all other bottlenose dolphin population studies in the US occur in relatively shallow, naturally protected areas like estuaries and bays, this study occurs on a relatively narrow sand bank directly adjacent to the deep-water Florida Current. Understanding the site-fidelity and association patterns of a population living in a unique and understudied habitat-type could give insight into the behavioral flexibility and social evolution of the species.

2. OBJECTIVES

1) Establish a comprehensive database of individual coastal bottlenose dolphins between Bathtub Reef (27º11' N, 80º09' W) and Boynton Beach Inlet (26°54’ N, 80°04’W)
2) Determine if a residential population of coastal bottlenose dolphins exists in the region and differentiate these individuals from part-time or sporadically visiting individuals
3) Determine if social sub-groups exist and map the social relationships within this region
4) Determine if encounter group size is associated with social sub-group or site fidelity

3. MATERIALS AND METHODS

3.1 Data Collection

All research was conducted under the federal permits: LOA #13386, LOA# 18152 and LOA# 22291 of the Taras Oceanographic Foundation. Under this Level B harasment permit, researchers may approach dolphins with the research vessel, but may not enter the water, touch the dolphins, or introduce any foreign substance into the water during an encounter. Harassment in this study was defined as any action that compromises or alters the natural behavior of the dolphins.

Weekly and bi-weekly boat surveys were conducted roughly one km offshore, along the coast of southeast Florida, from Bathtub Reef (27º11' N, 80º09' W) to Boynton Beach Inlet

(26°54’ N, 80°04’W) (Figure 4), during all seasons between 2014 and 2020. In total, 313 surveys were conducted on the pre-determined transect in favorable weather conditions (Beaufort Wind Scale ≤ 3, swell < 2m, no rain, no fog) to reduce detection favorability bias (Table 1). Between two and five researchers completed all surveys, alternating between binocular observation and visual observation using polarized glasses, as they traveled along the transect at 5-8 knots. If dolphins were spotted, the research vessel would leave the transect and approach the group. Global Positioning System (GPS) coordinates and oceanographic conditions including water temperature, tide cycle, and swell/sea state were recorded at the start of every survey and at any point in which dolphins were encountered.

An encounter was defined as an observation of one or more dolphins during a survey. Any dolphins seen by researchers before returning to the transect and resuming survey speed were considered part of the same encounter. Group size (the total number of dolphins within an encounter) was estimated in the field, but due to the inaccuracy of field counts (Gerrodette et al., 2019), all group sizes were confirmed via photo-identification analysis. An attempt was made to photograph all dolphins within an encounter using a Nikon D300 camera regardless of the presence of visible markings. Encounters were limited to one hour or until researchers were confident all individual dolphins had been photographed, as to not unnecessarily harass the animals. After an encounter, the research vessel returned to the transect and continued the survey.

If any other cetacean species were seen during surveys, animals were photographed, group size was estimated, and GPS coordinates were documented, but no database was made for non-bottlenose cetaceans in this study.

3.2 Photo Identification and Abundance

Surface photographs of unique markings on the dorsal fin of *T. truncatus* were used to identify individual animals, as is standard in dolphin photo-ID studies (Urian & Wells, 1996; Middleton et al., 2011; Diaz Lopez, 2012; Benmessaoud et al., 2013; Pace et al., 2021). Only photographs in which the full dorsal fin is visible and in-focus at roughly a 90-degree angle to the camera lens were used for identification. A digital database of all identifiable individuals was produced and used for determining population abundance and site fidelity.

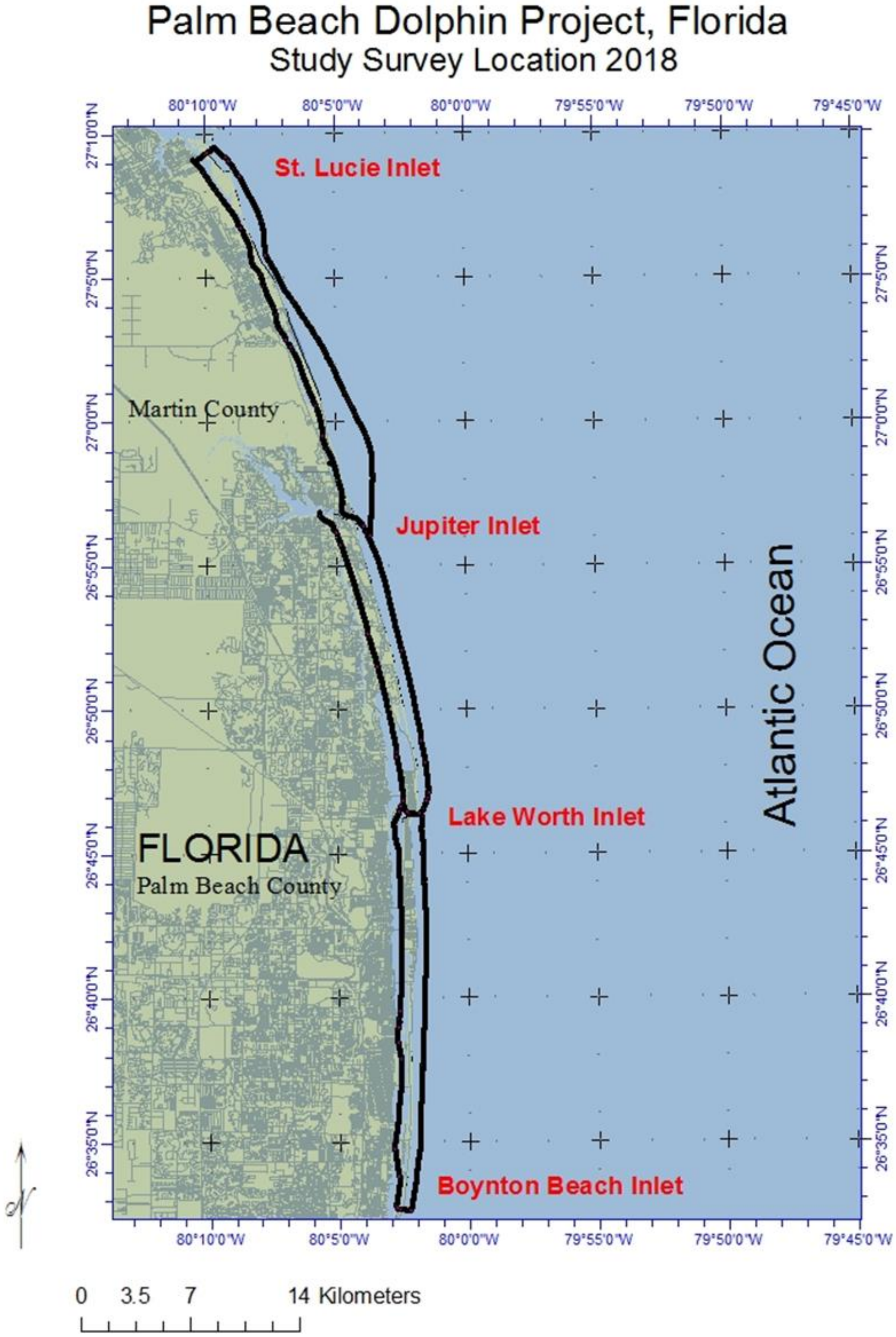

Figure 4. The Taras Oceanographic study area, from Bathtub Reef (27º11' N, 80º09' W) to Boynton Beach Inlet (26°54' N, 80°04'W)

Table 1. Yearly records of surveys and encounters with duration in hours from 2014-2020

Year	2014	2015	2016	2017	2018	2019	2020	Total
Surveys	24	20	28	40	95	86	20	313
Survey Duration (hrs)	27.68	43.65	67.35	73.18	138.38	67.4	36.21	453.85
Encounters	28	16	29	31	81	64	19	268
Encounter Duration (hrs)	20.46	21.12	25.32	19.42	35.68	38.12	8.48	168.6

3.3 Site Fidelity

Site fidelity was analyzed using resighting ratios (Diaz-Lopez, 2012; Benmessaoud et al., 2013; Bas et al., 2019). Annual and quarterly resighting ratios were determined for each individual. Years were broken into 4 quarters (Jan-Mar, Apr-Jun, Jul-Sep, and Oct-Dec) to account for animals that are only present in certain portions of the year. Resighting ratios were calculated as the number of quarters (or years) where an individual was observed (n_s) divided by the number of quarters (or years) where they could have been present (current quarter [S] minus the quarter first seen [S_f] plus one).

$$Resite\ Ratio = \frac{n_s}{S - S_f + 1}$$

Animals were then divided into three arbitrary, but useful categories based on the methods put forward by Benmessaoud et al. (2013) and Diaz Lopez (2012).

1. Full-time residential dolphins have both an annual and quarterly resighting ratio greater than or equal to 0.5.
2. Part-time residential dolphins have a quarterly resighting ratio less than 0.5 but greater than or equal to 0.25.
3. Sporadic visitor dolphins have resighting ratios below 0.25.

3.4 Association Patterns

Association patterns for all full-time and part-time residential dolphins were examined. Coefficients of Association (CoA) were determined using the half-weight index (HWI), as this index is most accurate for long-term, open-water surveys (Quintana-Rizzo & Wells, 2001; Benmessaoud et al., 2013; Vermeulen 2018).

$$HWI = \frac{x}{x + \frac{1}{2}(Y_a + Y_b)}$$

Half weight index was calculated using the given equation, where *x* is the number of encounters that include both animals *a* and *b*, Y_a is the number of encounters that include animal *a* but not animal *b*, and Y_b is the number of encounters that include animal *b* but not animal *a*. When calculated, a pair of animals are given a value between 0.00 and 1.00, with HWI= 0.00 indicating no association and HWI=1.00 indicating a perfect association (the two are always seen together).

Using a similarities matrix and a hierarchal cluster analysis, these associations were compared across full-time and part-time residents to identify if natural social sub-groups exist (Benmessaoud et al., 2013). A dendrogram was produced in R Studio (R Core Team 2020) to visually represent this analysis (Genov et al., 2018; Bas et al., 2019). The site-fidelity categories of animals within each sub-group were compared using a two-tailed chi square test to determine if site fidelity was correlated with association patterns. A Fruchterman Reingold network was produced using all association levels more than twice the mean HWI to visualize the social structure more accurately and to determine if intertribal interactions were common (Genov et al., 2018). A histogram was constructed from all CoA values between full-time and part-time residents.

3.5 Group Size

Mean encounter group size was recorded as a baseline for the hypothesized population. Mean encounter group size was also compared among encounters made up of full-time individuals, part-time individuals, or mixed groups using a one-way analysis of variance (ANOVA) test to determine if site fidelity had any association with encounter group size. Mean group size was calculated for other cetacean species observed and compared to *T. truncatus,* using an unpaired two-tailed t test.

4. RESULTS AND DISCUSSION

4.1 Photo Identification, Abundance, and Site Fidelity

We encountered 268 bottlenose dolphin groups over 313 surveys. Within the study area, 585 individual dolphins were identified, with discovery of new individuals approaching a plateau after approximately 18 quarters (Figure 5). When determining site fidelity, dolphins who had

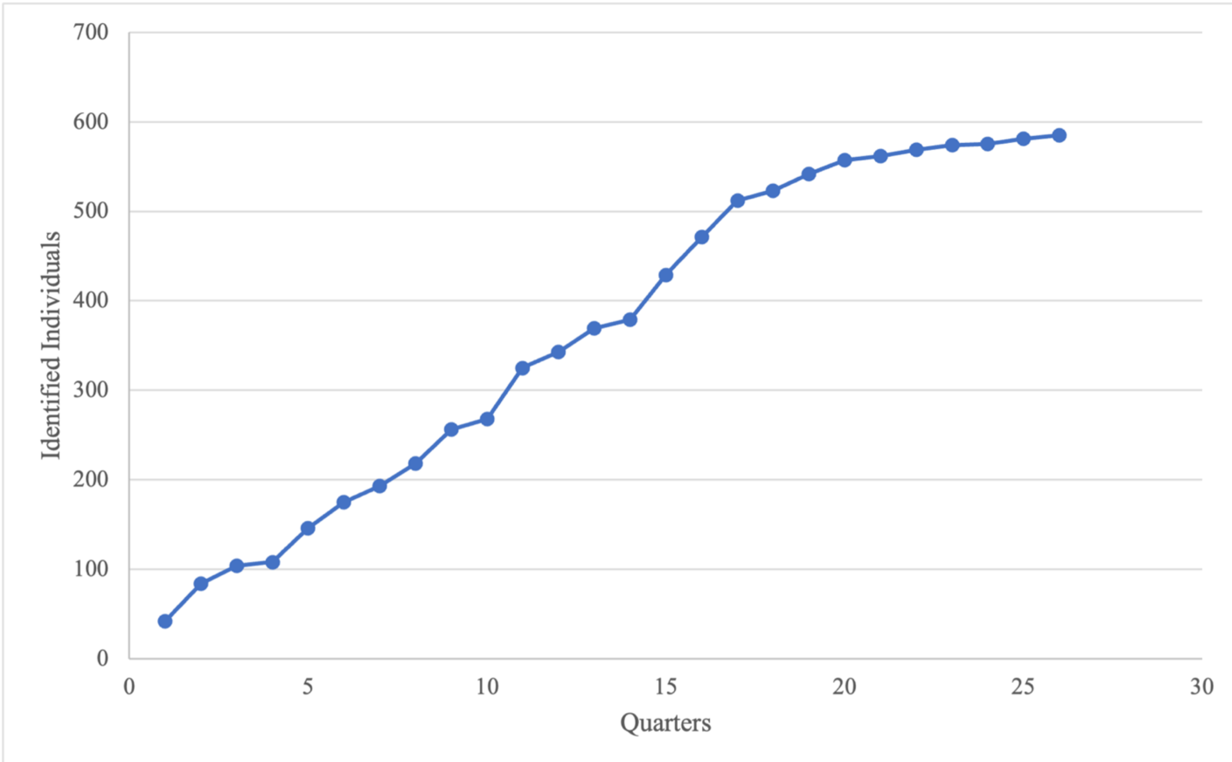

Figure 5. Discovery curve of identified individuals over 26 quarters. New animal sightings began to plateau at quarter 18 with around 550 animals.

been in the area for less than 1 year were removed, as these individuals could not statistically be anything but residential. Following the removal of these individuals, 568 dolphins remained in the data set, as they had been seen at least one year prior to the end of the study. Four hundred seventy-eight individuals identified were sporadic visitors, 66 individuals were part-time residents (PTRs), and 24 individuals were full-time residents (FTRs) (Figure 6). Of 268 encounters, 144 encounters included full-time residential animals (53.7%) and 206 included either full-time or part-time residential animals (76.9%) (Figure 7).

We also encountered 14 groups of *Stenella frontalis* over the course of the study period. No other cetacean species were observed.

4.2 Association Patterns

Coefficients of Association for all full-time and part time residents were calculated and relationships are displayed as a dendrogram in Figure 8. Mean Half-Weight of associations across the group was 0.067 (SD=0.14). Hierarchical cluster analysis revealed three loosely associated tribes. Tribe A consisted of 37 animals, Tribe B consisted of 34 animals, and Tribe C consisted of 19 animals. Site fidelity was strongly correlated to social patterns (χ^2=29.4487, $p<0.05$), with 21 of the 24 full-time residents belonging to Tribe A (Figure 9).

While HWI's were higher than the average within tribes, dolphins regularly associated with individuals outside of their tribe, creating a more complex network. Figure 10 represents this network, displaying all relationships higher than twice the mean HWI as edges (2χ=0.135). In this open habitat, dolphins appear to create high numbers of weak bonds (Figure 11), in contrast to the smaller, more strongly bonded tribes seen in geographically isolated habitats such as the Indian River Lagoon or the Adriatic Sea (Durden et al., 2019; Genov et al., 2018). This social structure is more similar to that observed in other open habitats like those off the coast of New Zealand (Zaeschmar et al., 2020). Unlike in New Zealand, however, site-fidelity does have a strong correlation to association patterns. In this group, all but three full-time residents associate in a single tribe, with part-time residents making up the other two tribes. This is reflective of other semi-closed habitats, for example, the Istanbul Strait in Turkey (Bas et al., 2019).

Given the presence of both the coastline and the Florida Current as potential physical barriers for coastal bottlenose, this region may be better classified as a semi-closed habitat.

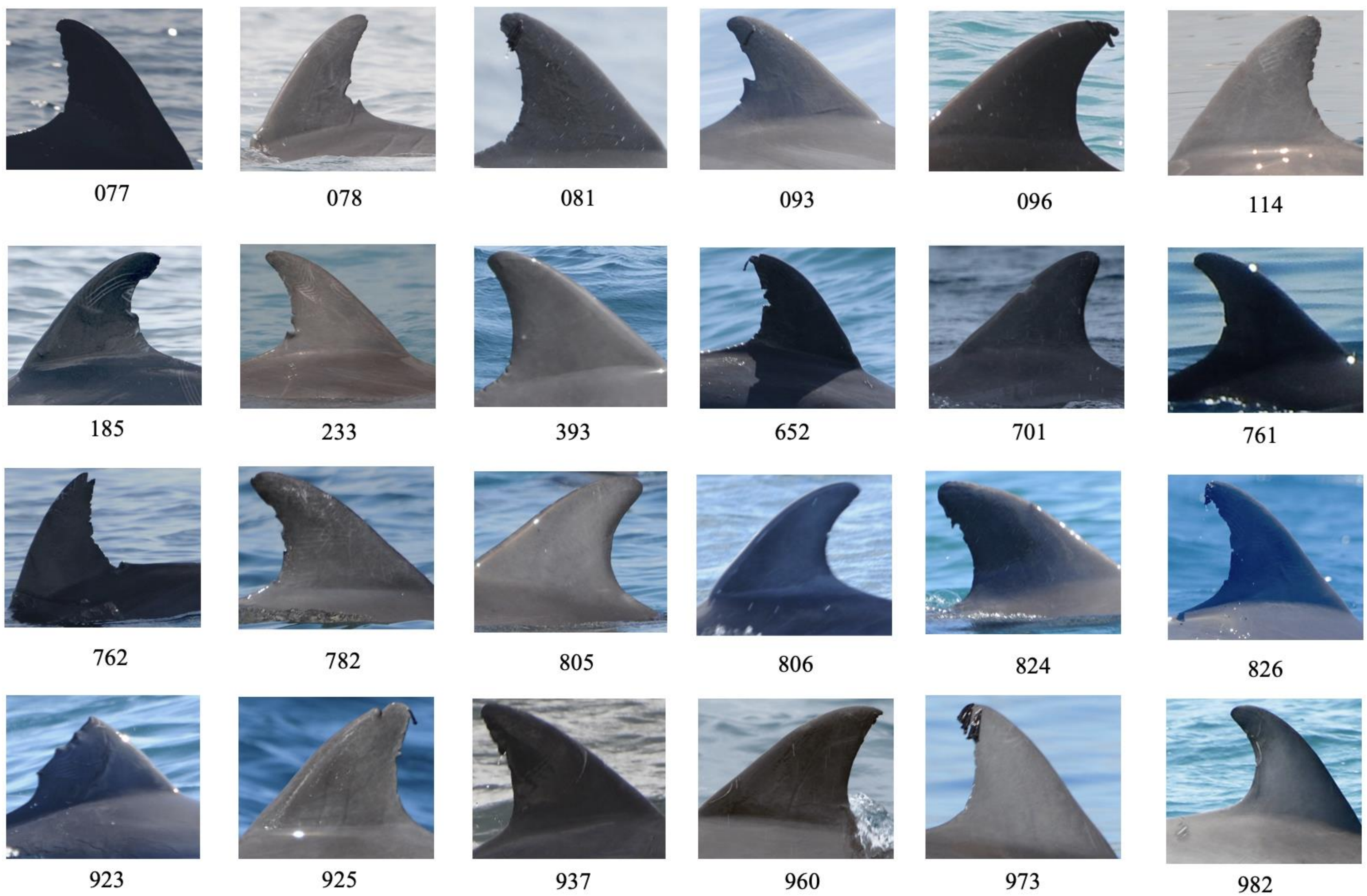

Figure 6. All full-time residential coastal bottlenose dolphins (*Tursiops truncatus*). Individual dolphins were identified using unique markings on their dorsal fin and assigned a unique three-digit identification number for use upon resighting.

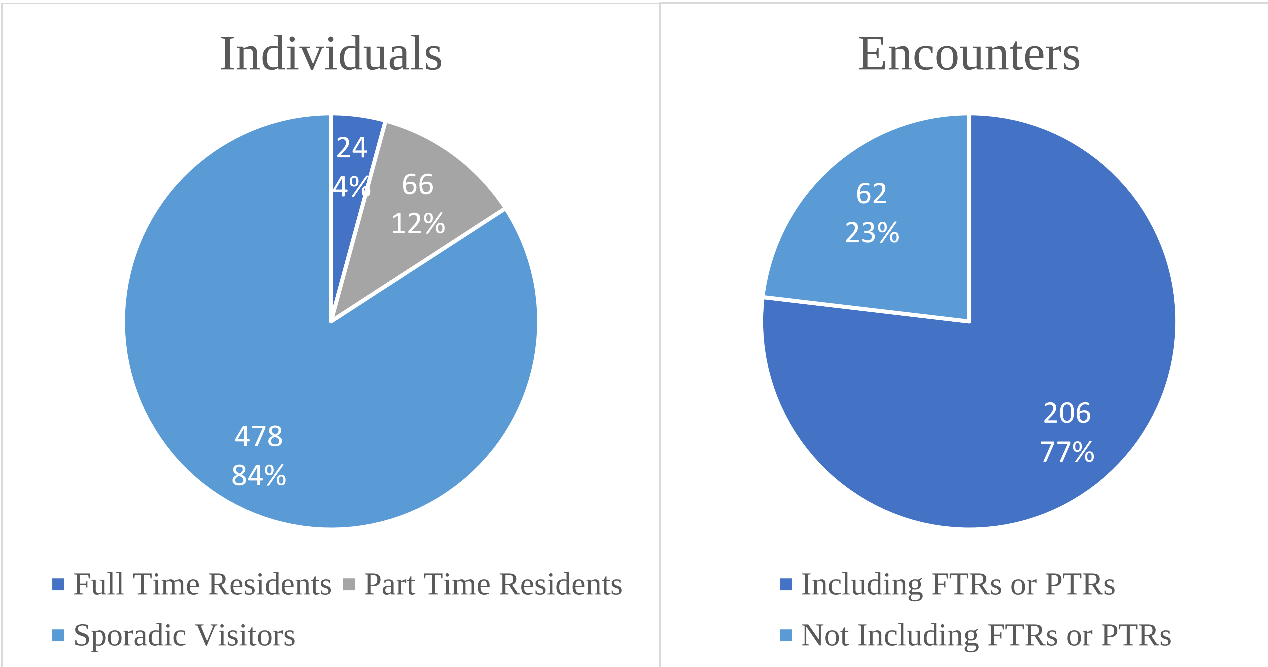

Figure 7. Breakdown of individuals and encounters based on site-fidelity. Residential dolphins only made up 16% of identified individuals but were seen in 77% of encounters.

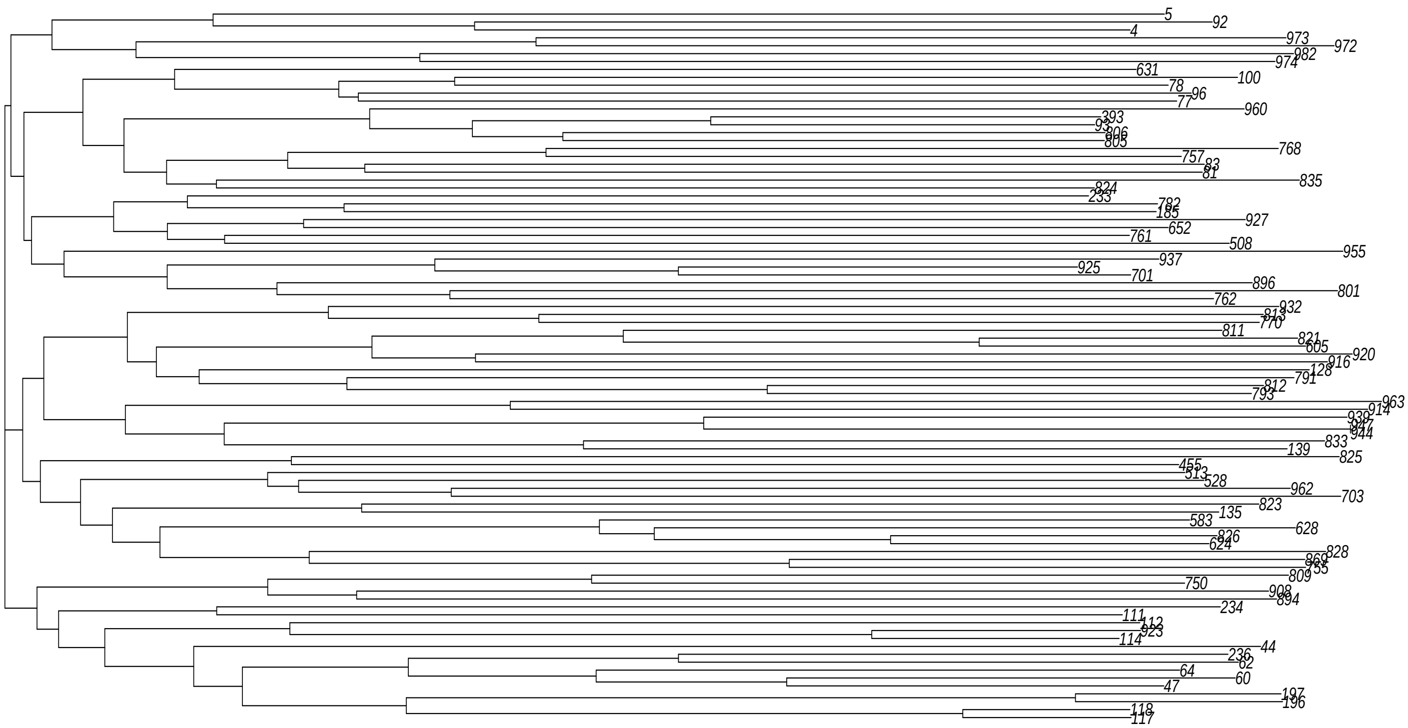

Figure 8. Dendrogram of associations between all identifiable individuals with site fidelity above 0.25.

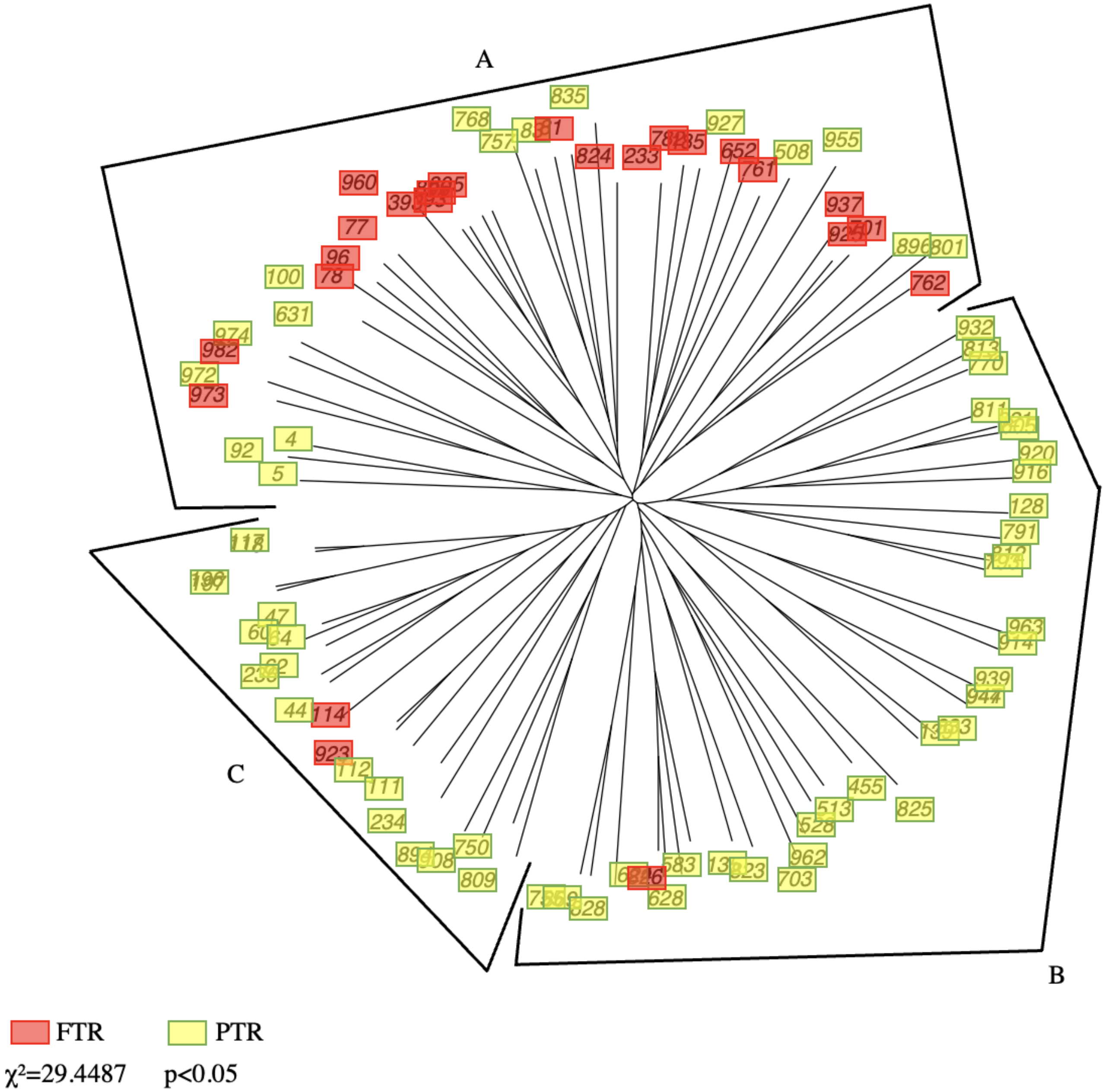

Figure 9. Circular dendrogram of associations between full-time and part-time residents. Tribe A consists of 37 animals – 21 FTRs and 16 PTRs. Tribe B consists of 34 animals – 1 FTR and 33 PTRs. Tribe C consists of 19 animals – 2 FTRs and 17 PTRs.

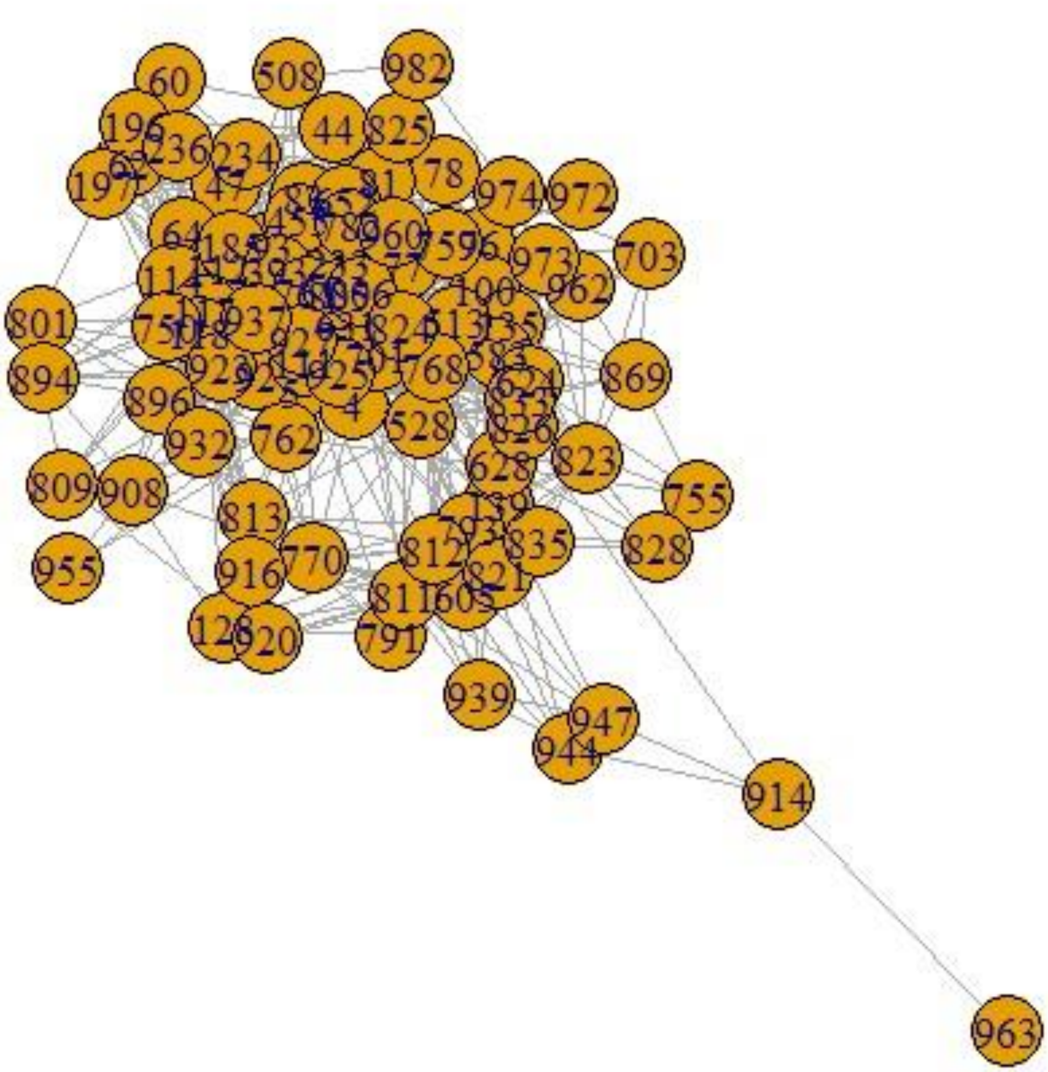

Figure 10. Fruchterman Reingold Network of all associations within the study group at least twice as high as the mean association level (2χ=0.135).

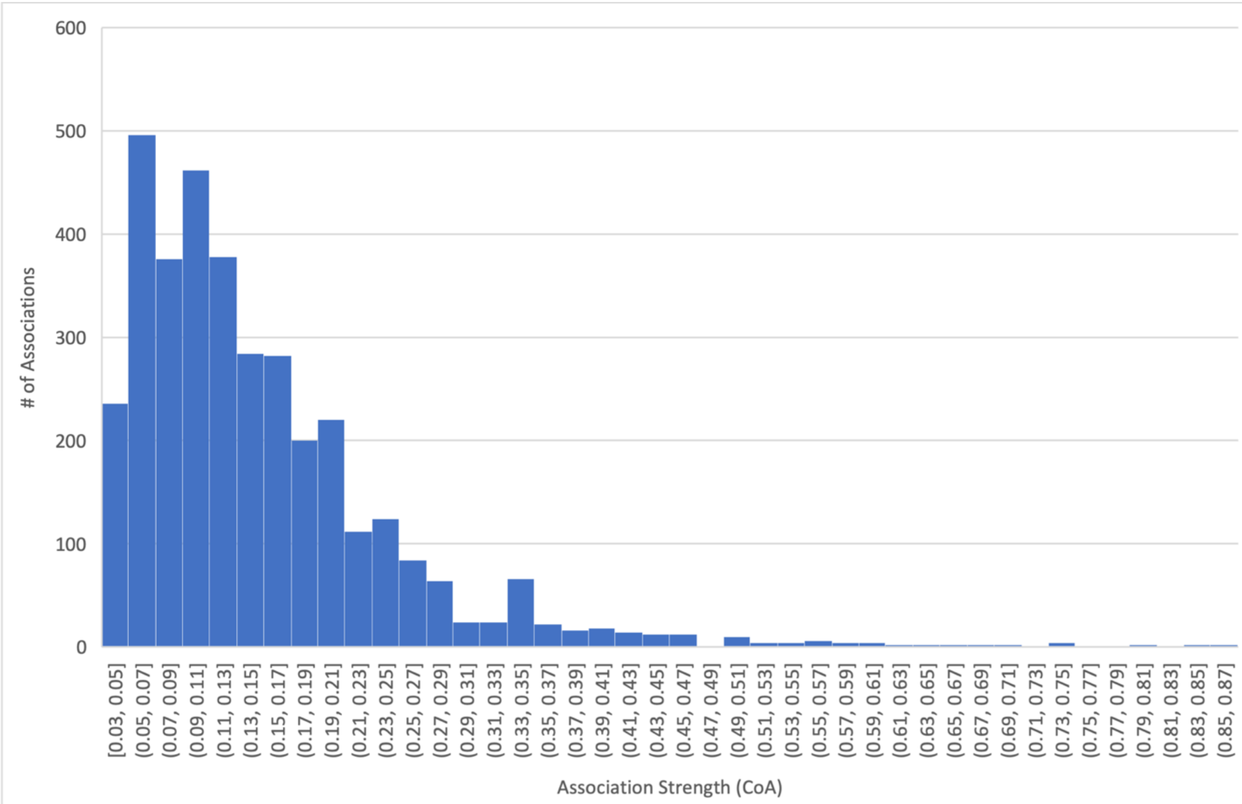

Figure 11. Histogram of Association Strength across the population. The majority of associations are weak level associations (<0.20), with very few strong bonds (mean=0.067, SD=0.14).

Combined with the existing coastal stocks of bottlenose dolphins to the north and south of this area, it is plausible the narrow, shallow sandbanks of southeast Florida serve as a corridor between the habitats of the Central Florida Coastal and Biscayne Bay stocks, with a small residential group remaining in the corridor consistently. Residential animals associate primarily with one another, as is expected in a semi-closed habitat, but tribes also regularly interact with each other in a larger, more interconnected social network, typical of open habitats.

Interspecific interactions between *T. truncatus* and *S. frontalis* were observed on only two occasions. In one case, the majority of animals were *S. frontalis*, with a single *T. truncatus*, FTR individual #508, passively interacting with the group. The other instance was of a single *S. frontalis* individual and a large group of aggressively behaving *T. truncatus.* Though rare, these interspecific interactions may be important in understanding the ecology and niche partitioning of both species in this region. As such, more data should be collected on these events whenever possible.

4.3 Group Size

The average group size of encounters was 5.27 individuals (SD=4.42). A one-way ANOVA test revealed group size significantly increased in mixed encounters of FTRs and PTRs when compared with encounters of just FTRs or PTRs ($f=59.44$, $df=2$, $p<0.05$) (Figure 12). Encounters consisting of only FTRs had a mean group size of 2.20 individuals (n=34, SD=1.9) and encounters consisting of only PTRs had a mean group size of 2.52 (n=62, SD=2.14). Meanwhile, encounters including both FTRs and PTRs had a mean group size of 7.77 (n=110, SD=4.41). These group sizes are comparable to other populations globally, with coastal bottlenose dolphins typically associating in groups composed of between 2-10 individuals (Benmessaoud et al., 2013; Genoves et al., 2018).

Considering the strong correlation between site fidelity and association patterns combined with the significant increase in average group size when full-time and part-time residents are seen together (over double that of either category alone), it is possible encounters consisting of both FTRs and PTRs do not represent strong FTR-PTR associations but instead represent two independent social groups interacting with one another (Figure 12).

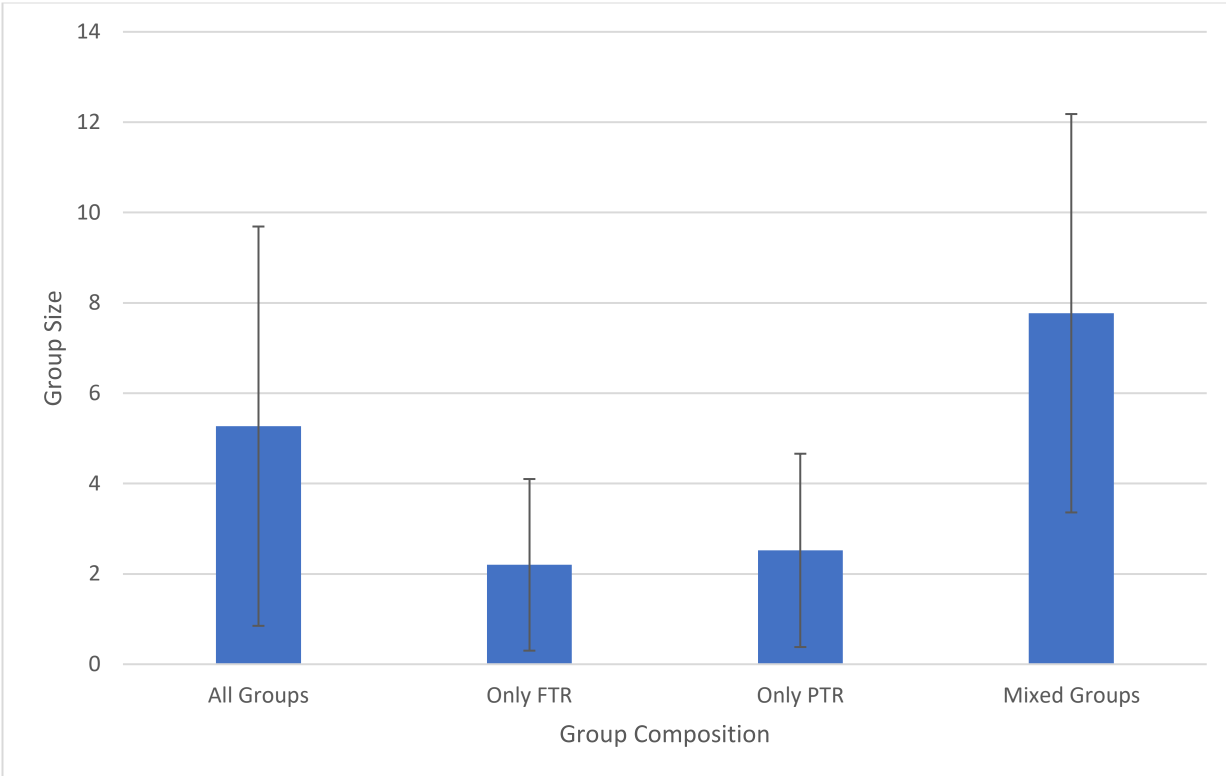

Figure 12. One-way ANOVA - Group size (mean ± standard deviation) based on site fidelity. Encounters with mixed groups were significantly larger than encounters with only FTRs or PTRs.

Aggressive intertribal interactions have been well documented in *S. frontalis* populations in the Bahamas (Myers et. al., 2017), and bottlenose dolphins are known to associate in similar social structures (Louis et al. 2018), so it is possible at least some encounters observed in this study were intertribal aggression events. Further investigation into the behavioral patterns within these mixed encounters are needed to identify whether these mixed group interactions are associative or aggressive.

Though not the focus of this study, groups size in *S. frontalis* encounters was also recorded. Mean group size in *S. frontalis* encounters was 18.7 (SD=10.07, n=14). This was significantly greater than the average group size of *Tursiops* in the region ($t=9.84$, $df=218$, $p<0.05$).

5. CONCLUSIONS

5.1 Conclusions

The high site fidelity of many animals in this area indicates the region most likely serves as a permanent habitat for at least some animals. Coastal bottlenose dolphins in other habitats globally show a tendency towards defined home ranges (Benmessaoud et al., 2013; Baş et al., 2019), so it is likely this study area represents at least a portion of the home range for those animals deemed full-time residents. Animals deemed part-time residents may remain in the region year-round as well, with the study area on the outer limit of their home range, causing them to be seen less often. There is also evidence of a large migratory stock of coastal bottlenose on the southeastern coast of the United States (Gubbins et al., 2003; NOAA 2010), so these part-time residents could be members of that stock as well. Further investigation into the precise timing and location of these PTR sightings is necessary to determine the nature of their behavior outside the study area.

This study supports the hypothesis that bottlenose dolphins in the coastal waters of Palm Beach County, Florida have high site-fidelity and use the region as a permanent or regular home range. These dolphins associate with each other in three tribes, with tribes highly correlated to site-fidelity. It is possible animals seen more infrequently are part of the same, larger residential stock or part of a separate migratory stock which shares habitat with residential animals. The presence of residential bottlenose dolphins warrants further study into their behavior, population health, and genetics, as well as adapted conservation efforts to protect this otherwise undocumented group. With dolphins in surrounding regions facing increased threats (Fire et al., 2007; Damseaux et al., 2017; Brightwell et al., 2020; McHugh et al., 2021), the knowledge of a potential genetic or cultural bridge between the northern CFCS, the Indian River population, and the Biscayne Bay Stock can greatly aid in efforts to conserve and protect the dolphins along the entire eastern coast of Florida.

5.2 Future Considerations

An expansion of the current study area southward towards Biscayne Bay would allow for better understanding of the size of residential animals' home ranges. As photo-ID surveys continue, an increasing number of residential animals will be reliably sexed, which could reveal whether association patterns within this group are sex-based. The addition of facial recognition and bridal mark identification techniques could clarify relationships between cows and calves in and increase identification of unmarked transient individuals. This, paired with habitat-utilization studies, could provide insight into the differences between behavior of residential and transient dolphins in the region. It could also help identify movement patterns of transient animals. Altogether the description of this corridor group warrants more study, not only for its own benefit, but for the benefit of what may be highly interconnected stocks of coastal and estuarine bottlenose dolphins throughout the western North Atlantic.

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