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Golfinho-nariz-de-garrafa-comum (*Tursiops truncatus truncatus*) no estado do Rio de Janeiro: ocorrência, movimentos e residência

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Dissertação apresentada ao Programa de Pós-graduação da Universidade Federal do Estado do Rio de Janeiro como requisito para a obtenção do grau de mestre em Ciências Biológicas (Biodiversidade Neotropical).

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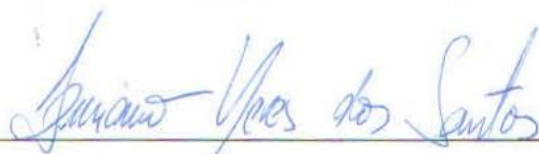
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“Mais que uma bandeira, a preservação da natureza é um dever ético da espécie humana.”

- Ibsen de Gusmão Câmara

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1 Manuscrito

Occurrence, movements and residency of common-bottlenose-dolphin *Tursiops truncatus truncatus* in Rio de Janeiro state, Southeastern Brazil

Guilherme Maricato, Liliane Lodi, Israel S. Maciel, Sheila M. Simão, Rodrigo H. Tardin, Tatiana F. Maria

1.1 Abstract

Although populations of *Tursiops truncatus* are well studied worldwide, recent studies indicate two subspecies occurring in the Brazilian coast, in which the subspecies *Tursiops truncatus truncatus* is little known. To fill this gap, the present study aimed to study the occurrence, movements and residency of *T. t. truncatus* in Rio de Janeiro state. The study area was divided into three subareas: (1) Cabo Frio coast – CF; (2) Rio de Janeiro coast – RJ; and (3) Oceanic subarea – OC. In CF, 475 individuals from 18 groups were photo-identified. In RJ, 110 individuals were photo-identified from six groups. In OC, 45 individuals from 3 different groups were photo-identified. A total of 16 individuals were resighted in both coastal areas, totaling 614 individuals analyzed. In CF, most groups (44.4%) were identified in winter, followed by summer (38.9%) and autumn (16.7%), with no significant differences in group size among seasons ($p = 0.6$). All groups sighted contained calves. In RJ, five groups were sighted during fall (83.3%) and only one in winter (16.7%). Half of the groups with calves and the group size varied independently of the composition ($p = 0.08$). In OC, all groups were sighted in spring. Groups sighted near to coast (mean = 36.42, SD = 28.70) tended to be larger than the groups seen in oceanic areas (mean = 18.83, SD = 4.31). Only 9.6% of individuals seen in CF were recaptured. Of these, most (82.9%) were recaptured only once. Individuals with low degree of residence were the majority (low = 65.8%, medium = 17.1%, high = 17.1%). Considering both coastal areas, the pattern remained. Of the 614 individuals analyzed, only 9.3% were recaptured and individuals with low degree were the most frequent in the analyzes (low = 68.4, medium = 12.3%, high = 19.3%). The maximum distance between recaptures varied from 1.2 to 18.1 km in CF (mean = 9.6, SD = 4.5) and 15.2 and 16.2 km in RJ (mean = 15.7, SD = 0.6). The distance between the coastal subareas varied between 112.7 and 137.6 km (mean = 126.5, SD = 6.8). Three pairs of adults were recorded associated on three

different occasions. Of these pairs, two were recorded in both coastal subareas and a pair recorded only in CF. The results indicated that the individuals of *T. truncatus truncatus* found in the study area are transient, presenting, in general, low residency (CF subarea: 65.8%; Coastal subareas: 68.4%) with individuals travelling between the two coastal subareas studied. Given these characteristics, it is likely that there is a metapopulation of the subspecies and that the individuals studied belong to it.

Keywords: Displacements; Individual identification; Photo-identification; Resightings; Southwestern Atlantic Ocean.

1.2 Resumo

Embora populações de *Tursiops truncatus* sejam bem estudadas em todo o mundo, estudos recentes indicam duas subespécies ocorrentes na costa brasileira, o que torna a subespécie *Tursiops truncatus truncatus* pouco conhecida. A fim de preencher esta lacuna o presente estudo objetivou estudar a ocorrência, os movimentos e a residência de *T. t. truncatus* no estado do Rio de Janeiro. A área de estudo foi dividida em três subáreas: (1) Costa da cidade de Cabo Frio – CF; (2) Costa da cidade do Rio de Janeiro – RJ; e (3) Subárea oceânica – OC. Em CF, 475 indivíduos, provenientes de 18 grupos, foram foto-identificados. No RJ, 110 indivíduos foram foto-identificados, derivados de seis grupos. Já em OC, foram foto-identificados 45 indivíduos de 3 grupos distintos. Um total 16 indivíduos foi reavistado nas duas áreas costeiras, totalizando 614 indivíduos analisados. Em CF, a maior parte dos grupos (44,4%) foi identificada no inverno, seguido do verão (38,9%) e do outono (16,7%), não havendo diferença significativa no tamanho dos grupos entre as estações do ano ($p = 0,6$). Todos os grupos avistados continham filhotes. Já no RJ, cinco grupos foram avistados no outono (83,3%) e somente um no inverno (16,7). Metade dos grupos continha filhotes e o tamanho dos grupos variou independentemente da composição ($p = 0,08$). Em OC, todos os grupos foram avistados na primavera. Grupos avistados próximos na costa (média = 36,42; DP = 28,70) apresentaram uma tendência a serem maiores do que os grupos avistados em áreas oceânicas (média = 18,83; DP = 4,31). Somente 9,6% dos indivíduos avistados em CF foram recapturados. Destes, a maior parte (82,9%) foi recaptura somente uma vez. Indivíduos com baixo grau de residência foram maioria (baixo = 65,8%; médio = 17,1%; alto = 17,1%). Considerando ambas as áreas

costeiras, o padrão se manteve. Dos 614 indivíduos analisados, somente 9,3% foi recapturado e indivíduos com baixo grau foram os mais frequentes nas análises (baixo = 68,4; médio = 12,3%; alto = 19,3%). A distância máxima entre recapturas variou de 1,2 a 18,1 km em CF (média = 9,6; DP = 4,5) e entre 15,2 e 16,2 km no RJ (média = 15,7; DP = 0,6). A distância entre as subáreas costeiras variou entre 112,7 e 137,6 km (média = 126,5; DP = 6,8). Três pares de adultos foram registrados juntos em três diferentes ocasiões. Destes pares, dois foram registrados em ambas as áreas costeiras e um par registrado apenas em CF. Os resultados indicam que indivíduos de *T. t. truncatus* encontrados na área de estudo são transientes, apresentando, em geral, baixa residência e com indivíduos transitando entre as duas subáreas costeiras estudadas. Dadas estas características, é provável que haja uma metapopulação da subespécie e que os indivíduos estudados façam parte dela.

Palavras-chave: Deslocamentos; Identificação individual, Fotoidentificação; Reavistagens; Oceano Atlântico Sul Ocidental.

1.3 Introduction

Population density and distribution assessments are critical to assess the effects of anthropogenic activities and ecosystem variability (Morris & Doak 2002; Rodrigues et al. 2006). As well as the distribution, analyzing the movements and residence patterns of a species is crucial for understanding its ecology, dynamics, social structure and population evolutionary trajectory (Silva et al. 2008).

The tendency of individuals to remain in the same area are driven by changes in individual needs and in the distribution of their co-specific, predators and resources (White & Garrot 1990; Switzer 1993, 1997; Nathan et al. 2008). It means that the knowledge of the residency patterns can provide important information, such as the spatio-temporal distribution of the food resources of the species (Damuth 1981; Fowler 1990; Jetz et al. 2004; Podgórski et al. 2013) and the gene flow between populations occurring in different areas (Wiens 1976; Slatkin 1987; Berendonk & Spitze 2006; Drees et al. 2011).

Individuals can be resident in areas with high food resources availability and few threats, such as predators and anthropogenic impacts (Knip et al. 2012; Habel et al. 2015). Understanding the residency of a species may contribute to the conservation, since

individuals may be subject to potential local threats (Warkentin & Hernández 1996; Atkins et al. 2016).

Studies of marine species with high locomotion abilities have posed a major challenge for researchers over years (Redfern et al. 2006). Marine mammals, such as dolphins, live in open and fluid environments, usually feeding on preys with high mobility (Lodi & Borobia 2013). Therefore, their distribution changes temporally since there is a change in biological and ecological requirements of the species (Forcada 2008). As a result, these animals are highly mobile and tend to have a larger home range than similarly sized terrestrial mammals (Tucker et al. 2014).

Cetaceans are mammals best adapted to the marine environment and the knowledge of their species has great implication in marine conservation. As top predators, they are subject to much of the impacts in an environment, such as accumulating contaminants at high concentrations, becoming environmental sentinels (Smith & Gangolli 2002).

They are flagship species, known for being charismatic and with great potential to promote public awareness and to raise funds for conservation (Veríssimo et al. 2011). They are also umbrella species. Because they are widely distributed, their conservation may contribute to the conservation of many co-occurring species (Simberloff 1998).

However, short-range movements are difficult to detect and should be interpreted considering the life cycle of the species (Forcada 2008). Besides, the high longevity, the slow reproductive cycle, the extensive home range and the fact that they spend most of their daily activities underwater are difficulties for studying cetaceans (Connor et al. 2000; Acevedo-Gutierrez 2008).

The common-bottlenose-dolphin, *Tursiops truncatus*, is included within the Delphinidae, which is the most diverse family of cetaceans, and is a cosmopolitan species, found in both coastal and oceanic environments. This species may exhibit a wide variety of movement patterns, including seasonal migration, stable residency, and temporary residency with seasonal or annual fidelity (e.g. Shane et al. 1986; Simões-Lopes & Fabian 1999; Lodi et al. 2008; Wedekin et al. 2008; Tardin et al. 2013; Lodi & Tardin 2018). However, the information about some populations is scarce, especially on Brazilian waters.

On the Brazilian coast, *T. truncatus* can be found from Amapá to Rio Grande do Sul (Lodi et al. 2016), including Fernando de Noronha Archipelago (Silva Jr. 2010), Trindade Island (Carvalho & Rossi-Santos 2011) São Pedro e São Paulo Archipelago (Meirelles et al. 2016), Rocas Atoll (Meirelles et al. 2016) and Cagarras Archipelago (Lodi & Monteiro-

Neto 2012). They are widely distributed in both coastal and oceanic waters, including populations residents in the South and seasonal residents in the Southeast (Simões-Lopes & Fabian 1999; Lodi et al. 2008; Lodi & Monteiro-Neto 2012). Due to the extensive home range, this species is exposed to several anthropic impacts, such as bycatch, habitat degradation, reduction of food resources due to overexploitation, vessel traffic and disordered tourism (Di Benedetto & Ramos 2001; Britto et al. 2004, Lusseau 2005; IUCN 2018).

In Brazil, studies such as size and group composition (e.g. Wedekin et al. 2008; Lodi & Monteiro-Neto 2012), movements and distribution (e.g. Lodi et al. 2008; Wedekin et al. 2008; Tardin et al. 2013) behavior and habitat use (e.g. Barbosa et al. 2008), size and group organization (e.g. Barbosa et al. 2008) and residency (e.g. Simões-Lopes & Fabian 1999; Hoffmann et al. 2008, Giacomo & Ott 2016) have already been conducted. Although the species being monitored systematically and continuously in Southern Brazil (e.g. Simões-Lopes & Fabian 1999; Hoffmann et al. 2008, Giacomo & Ott 2016), in Southeastern a large part of their records is based on opportunistic observations, except for the Cagarras Archipelago (e.g. Lodi et al. 2018; Lodi & Monteiro-Neto 2012). Despite efforts, the species is not yet fully understood.

The common-bottlenose-dolphin (*T. truncatus*) is classified as a "Least Concern" species on a global scale, at the International Union for Conservation of Nature (IUCN, 2018 version 2) Red List, but in Brazil population size, geographical distribution patterns and their state of conservation are unknown, therefore, categorized as "Data Deficient" (Rocha-Campos et al. 2011).

Recent studies have suggested different morphological groups of the common-bottlenose-dolphin (*T. truncatus*) on the Brazilian coast. Costa et al. (2016) suggest that the morphological groups are distinct subspecies (*T. truncatus truncatus* and *T. truncatus gephyreus*) with parapatric distribution. Wickert et al. (2016) suggest that the differences between the morphological groups are sufficiently different to separate them into two distinct species (*T. truncatus* and *T. gephyreus*). Genetic studies conducted by Fruet et al. (2017) suggested that these groups should be treated as evolutionarily significant units, considered oceanic and coastal.

Based on the distribution and color patterns described in the literature (Ott et al. 2016), we recognize individuals of the present study as being *Tursiops truncatus truncatus*, commonly known as "oceanic" subspecies (Figure 1).



Figure 1 – *Tursiops truncatus truncatus* in Cabo Frio coast.

Little is known about the oceanic populations of *T. truncatus* around the world (Wells & Scott 2018) and for Brazil it is not different. Most of the studies carried out refer to the subspecies *T. truncatus gephyreus* (known as coastal), but studies with the subspecies *T. truncatus truncatus* are scarce (e.g. Milmann et al. 2016 – São Pedro e São Paulo Archipelago; Tardin et al. 2013 – Cabo Frio; Lodi & Tardin 2018 – Cagarras Archipelago).

In order to protect a species, it is necessary to understand the relationship between populations and their habitats (Cañadas et al., 2005). It is supported by “The National Plan of Action for the Conservation of Aquatic Mammals: Small Cetaceans” (*Plano de Ação Nacional para a Conservação de Mamíferos Aquáticos: Pequenos Cetáceos – PAN*) which indicates that a goal for the conservation of the common-bottlenose-dolphin (*T. truncatus*) is to better investigate the distribution patterns of this species in Brazilian waters.

Based on the lack and necessity of information about the ecology of the subspecies, this study aimed to analyze how individuals of *T. truncatus truncatus* use the coastal and oceanic waters of the Rio de Janeiro state. It was done through the evaluation of the occurrence pattern, characterization of the movement of the photo-identified individuals

within the coastal and oceanic subareas and between these subareas, and investigation of residency.

1.4 Materials and methods

1.4.1 Study area

The studied area comprises the Rio de Janeiro state (21.30°S; 40.95°W – 23.36°S; - 44.72°W), Southeastern Brazil. This coast has a peculiar characteristic compared to the Brazilian coast. Its orientation changes from north-south to east-west, receiving strong influence of north-northeast winds mainly in summer (Valentin 1984, Duarte & Viana 2007). For analysis purposes, the study area was divided in three subareas: (1) Cabo Frio coast (Northern RJ state, including Arraial do Cabo and Búzios municipalities), (2) Rio de Janeiro coast (Rio de Janeiro and Niteroi municipalities), and (3) Oceanic subarea, which comprised from South boundary of the Rio de Janeiro state to Cabo Frio municipality approximately 200 km from the coast. These three subareas are described in Figure 2.

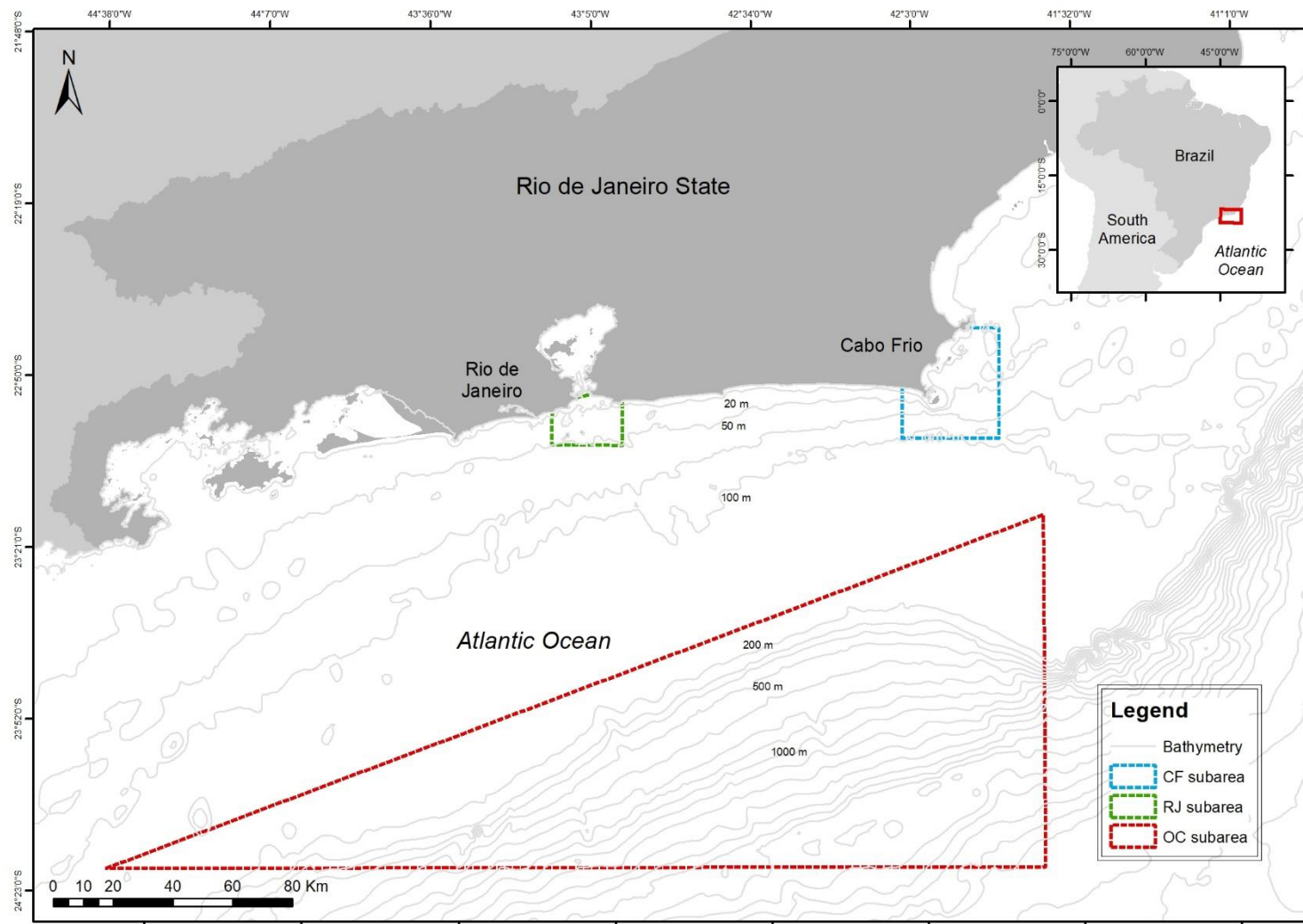


Figure 2 – Study area map showing the three subareas. CF = Cabo Frio; RJ = Rio de Janeiro; OC = Oceanic.

(1) Cabo Frio coast (CF: 23.03°S; 42.04°W – 22.87°S; -41.83°W) features a narrow and irregular continental shelf, presenting large hollows and steep slopes, with the 100 meters isobath located on maximum 10 km away from the coast (Reis *et al.* 2013, Duarte & Viana 2007) and is marked by a mix of two water bodies (Brazil Current and South Atlantic Central Water). These factors result in an upwelling, which prevails during spring and summer (Carbonel 1998), resulting in high primary productivity and high fish productivity (Mazzoil *et al.* 2008). These characteristics provide better conditions for the occurrence of different species of cetaceans (Keiper *et al.* 2005), especially because cetaceans need high energy requirements (Costa 2008). Although upwelling areas account for less than 1% of the ocean surface, approximately 50% of fishing activities are concentrated in these areas (Rodríguez 1973). Due the high productivity, surrounding landing facilities and exportation industries, the region has great fishing activity (Pimenta *et al.* 2014), which can lead to negative interactions with cetaceans, such as scaring, trampling and bycatch.

Given the high transparency of the waters and beauty beaches, diving and recreational fishing activities are common in the region, causing intense nautical tourism (TurisRio 2019). In addition, commercial fishing is also a strong activity in the region (Petrobras 2013).

Two marine protected areas are included in CF region. In the northern portion, the *Área de Proteção Ambiental do Pau Brasil* (IUCN category VI – State decree numb. 31,346, June 06th 2002, INEA) and, in the southern portion, the *Reserva Extrativista Marinha do Arraial do Cabo* (IUCN category V – Unnumb. law, January 03rd 1997, ICMBio).

(2) Rio de Janeiro coast (RJ: 23.06°S; 43.20°W – 22.58°S; 43.05°W) belongs to the most populated city in the state, with more than six million inhabitants, and one of the most populous cities in Latin America (IBGE 2018). The 100 m isobath is located 80 km from the coast (Reis *et al.* 2013), making the continental shelf more extensive and with smooth slope when compared to CF. Cagarras Archipelago is situated in this region, which is an island system located 3.5 km from the coast and it is considered a nesting area of seabirds like magnificent frigatebird and brown booby (Lodi 2005). The guano that covers its rocky shores has high content of nitrogen and phosphate, serving as fertilizer for phytoplankton (Lodi 2005). The RJ coast suffers from several anthropogenic activities, such as overfishing (Tubino *et al.* 2007; Amorim & Monteiro-Neto 2016), the Ipanema submarine

outfall (Carreira & Wagener 1998) and the influence of the eutrophic waters of Guanabara Bay (SisBaHiA 2018).

The RJ coast presents two marine protected areas. In the western portion, the *Monumento Natural do Arquipélago das Ilhas Cagarras* (IUCN category III – Federal law numb. 12,229, April 13th 2010, ICMBio) and, in the eastern portion, the *Reserva Extrativista Marinha de Itaipu* (IUCN category V – State decree numb. 44,346, September 30th 2012, INEA)

(3) Oceanic subarea (RJ: 23.41°S; 44.60°W – 23.70°S; 41.51°W) corresponds to the region after the shelf break, characterized by depths above 120 m and oligotrophic waters, occasionally being influenced by waters rich in nutrients from the upwelling (Mahiques et al. 2004).

1.4.2 Data collection

Data collected in each subarea was conducted by five different projects: CF subarea: *Cetáceos da Costa Azul* (“Cetaceans of the Blue Coast”); RJ subarea: *Baleias e Golfinhos do Rio de Janeiro* (“Whales and Dolphins of Rio de Janeiro”) and *Ilhas do Rio* (Phases I, II and III; “Rio Islands Project”); CF and RJ subareas: *Monitoramento de Cetáceos* (“Monitoring of Cetaceans”); Oceanic subarea: *Talude* (“Shelf Break”).

Data collection followed two distinct sampling protocols: systematic zig-zag transects to equalize sampling effort (*Talude* and *Monitoramento de Cetáceos* projects) and focal-follows to maximize encounters and photo-identification effort (*Cetáceos da Costa Azul*, *Baleias e Golfinhos do Rio de Janeiro* and *Ilhas do Rio*).

In the *Cetáceos da Costa Azul* project, systematic surveys were conducted following haphazard routes onboard a 6.5 m inflatable boat equipped with a 150-hp engine in CF. Data were conducted from November 2010 to December 2012 and during January to June 2014.

Through *Baleias e Golfinhos do Rio de Janeiro* and *Ilhas do Rio* projects, data were collected onboard a 10 m scuba dive vessel equipped with center engine following haphazard routes to maximize encounters. The surveys occurred from August to December 2011, from August to December 2012 and between January 2018 and December 2018.

The *Monitoramento de Cetáceos* project collected data throughout the Rio de Janeiro state, both in coastal and ocean areas. Surveys were conducted onboard a 23.7 m supply vessel following zig zag transects between November 2015 and December 2017.

Strictly oceanic cruises were carried out by the *Talude* project onboard a 36 m research vessel only during fall and spring over the years 2010 to 2014. Group size and composition data were not shared, and it was not possible to perform analyzes of this information in the oceanic subarea.

All data were collected under sea conditions below 4 on the Beaufort scale. When animals were sighted, a distance of at least 15 m was kept avoiding disturbance in their behavior.

1.4.2.1 Occurrence and movements

Groups' coordinates were obtained through Global Positioning System (GPS), and data such as season, group size and presence of calves were reported.

The observation followed focal and continuous sampling (Mann 1999), in which a unique group is sampled over a period with predetermined intervals.

Individuals were considered a group when individuals remained together within a radius of 10 m and displayed generally coordinated surfacing behavior (Smolker *et al.*, 1992). Dolphins less than half the total adult length (2.5 - 3 m) and near an adult were considered calves (Bearzi *et al.* 1997).

1.4.2.2 Residency

Residency was investigated by applying the photo-identification technique. Used since 1970's, this technique is based on capture dorsal fin images, which usually loses tissue over years typically through social interactions. These natural marks allow a reliable individual identification (Hammond *et al.* 1990), allowing abundance, distribution, movements and migration patterns investigations (e.g. Simões-Lopes & Fabian 1999; Lodi *et al.* 2008; Lodi & Monteiro-Neto 2012; Giacomo & Ott 2016).

A catalog of *T. truncatus truncatus* was elaborated for *Cetáceos da Costa Azul* and *Talude* projects using photo-identification. The catalogs of *Baleias e Golfinhos do Rio de Janeiro*, *Ilhas do Rio* and *Monitoramento de Cetáceos* projects were already done and were only matched.

1.4.3 Data analysis

Occurrence, group size and composition

Group size and composition were analyzed locally (each coastal subarea) and regionally (combining all coastal subareas). *T. truncatus truncatus* occurrence and group size were compared according to seasons. Seasons were defined as: Summer (December to February), Fall (March to May), Winter (June to August) and Spring (September to November).

Group size normality was tested through the Shapiro-Wilk test and it was analyzed whether the samples had equal variance through the Bartlett's test. Depending on the result, a parametric or nonparametric test was applied.

The Mann-Whitney U test and Student's t-test were applied to test whether the group size and composition varied in the different subareas, as well as throughout the seasons. It was also tested whether group size was influenced by group composition.

In cases where the variables had more than two components, the Kruskal-Wallis test was applied.

The Fisher's exact test was used to test whether the group composition varied significantly between coastal subareas.

1.4.3.1 Movements

The distance between the recaptures' coordinate was measured through the Near Table tool from ArcMap (ArcGIS Desktop v10.6 – desktop.arcgis.com) to analyze the movements of *T. truncatus truncatus*.

1.4.3.2 Residency

To create three catalogs, one for each subarea, the photographs were sorted so that only good quality photos (i.e., dorsal fin with focus and at an angle of 90° to the photographer) were used. Individuals identified for the first time were considered as capture, and those previously identified as recapture. Each photograph was previously analyzed to identify if the individual was already in the catalog (recapture) or if it would be a new identification (capture). After the creation of the catalogs, the investigation for recaptured individuals between catalogs were performed. All the above procedures were performed through the

Digital Analysis and Recognition of Whale Images on a Network (DARWIN) software v.2.22 (darwin.eckerd.edu).

The residency was categorized in three degrees (low, medium and high). To define the degree of each recaptured individual three parameters were analyzed (adapted from Passadore *et al.* 2017): (1) the rate of the number of sightings and the number of survey routes from its first sighting to its last, (2) the rate of the number of sightings and the total number of survey routes, and (3) the rate of the number of seasons a dolphin was sighted and the total number of seasons.

These parameters were standardized and, through Agglomerative Hierarchical Clustering (AHC) analysis (Zanardo *et al.* 2016; Hunt *et al.* 2017; Passadore *et al.* 2017) using the Ward distance method and squared-euclidean distance measure, the individuals were grouped according to the dissimilarity. To verify if the data distortion was significant, the cophenetic correlation coefficient (CCC) was calculated. A value above 0.7 indicates a suitable clustering of the data (Rohlf 1970).

1.5 Results

1.5.1 Occurrence, group size and composition

Cabo Frio subarea

Eight groups (44.4%) were found during winter, seven (38.9%) during summer, while three (16.7%) were recorded during fall.

Group size varied between 2 and 120 during summer (mean = 28.29, SD = 41.57), between 30 and 90 during fall (mean = 56.67, SD = 30.55) and from 10 to 50 during winter (mean = 39.38, SD = 15.68) (Figure 3). There was no significant difference of group size among seasons ($H = 6.869$; $df = 9$; $p = 0.6$).

All groups ($n = 18$, 100.0%) sighted in Cabo Frio subarea contained calves and ranged from 2 to 120 individuals (mean = 37.94, SD = 30.37). Statistical tests could not be performed due to the absence of groups without calves.

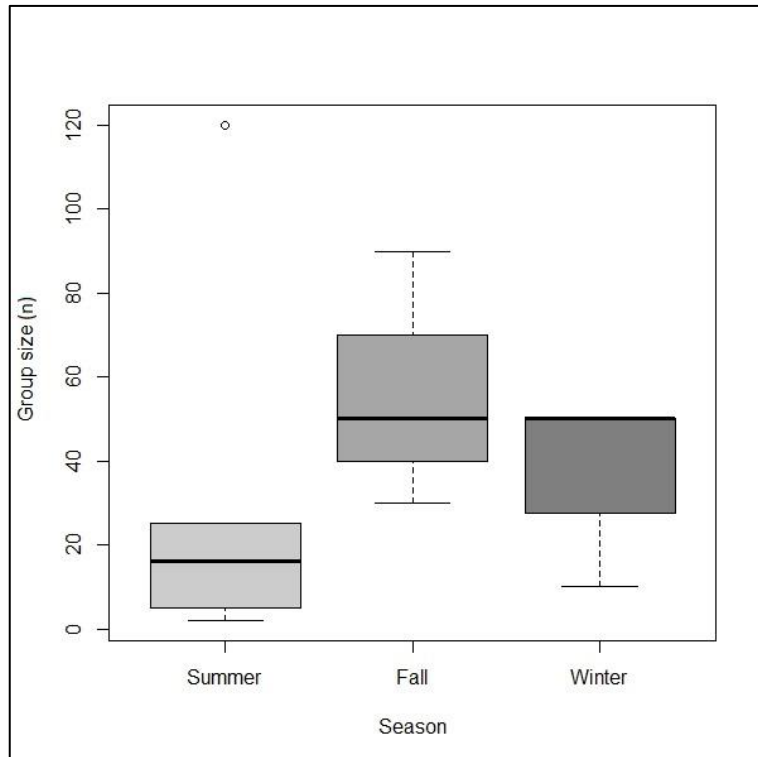


Figure 3 – *T. truncatus truncatus* group size in the different seasons of Cabo Frio subarea. Bottom dashed line = first quartile; below thick line = second quartile; thick line = median; above thick line = third quartile; top dashed line = fourth quartile; white point = outlier.

Rio de Janeiro subarea

Five groups were recorded during fall (83.3%) and only one (16.7%) during winter. No groups were found during spring and summer in this subarea.

During fall the group size ranged from 30 to 80 individuals (mean = 47.00, SD = 22.25), whereas in winter only a solitary individual was sighted (Figure 4). A statistical test could not be performed due to data limitation.

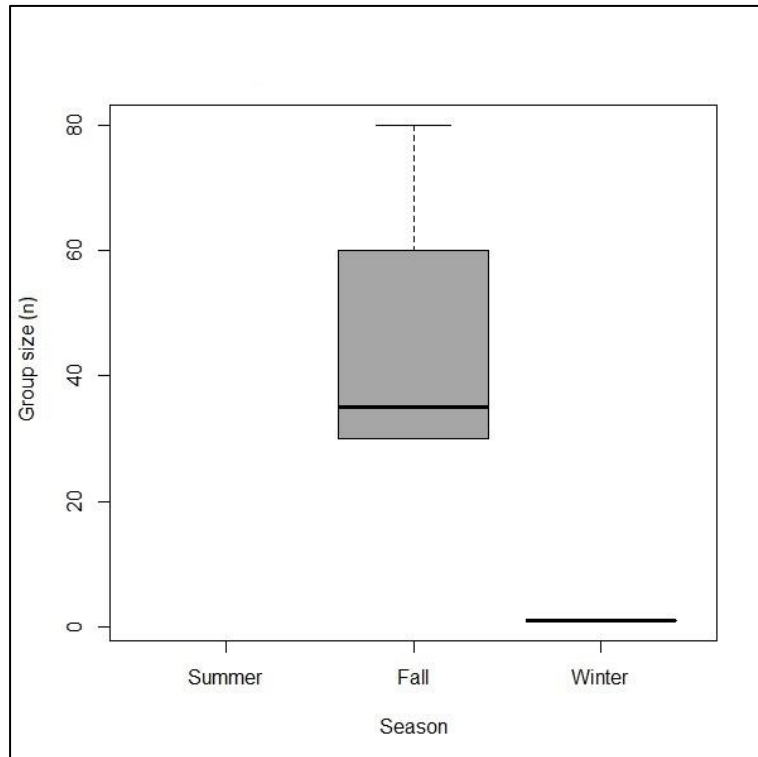


Figure 4 – *T. truncatus truncatus* group size in the different seasons in Rio de Janeiro subarea. Bottom dashed line = first quartile; below thick line = second quartile; thick line = median; above thick line = third quartile; top dashed line = fourth quartile.

Groups with calves (n = 3, 50.0%) varied between 35 and 80 individuals (mean = 58.33, SD = 22.55), while groups without calves (n = 3, 50.0%) were composed of 1 to 30 individuals (mean = 20.33, SD = 16.74) (Figure 5).

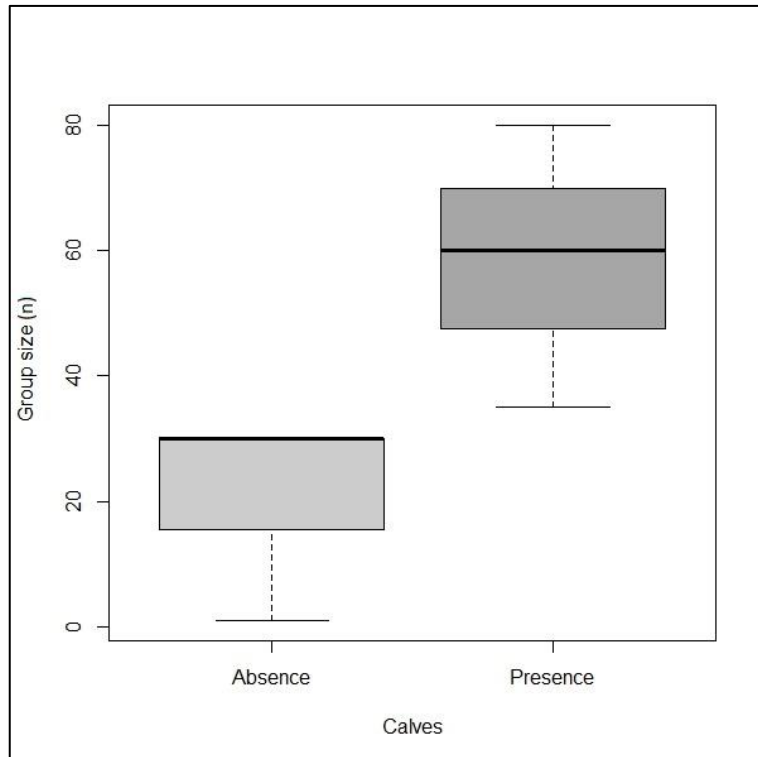


Figure 5 – *T. truncatus truncatus* group size without and with calves in Rio de Janeiro subarea. Bottom dashed line = first quartile; below thick line = second quartile; thick line = median; above thick line = third quartile; top dashed line = fourth quartile.

Group size normality shows evidence that it follows normal distribution ($W = 0.95$; $p = 0.7$) and was confirmed equal variance in group size between groups with and without calves (Bartlett's K -squared = 0.14; $df = 1$; $p = 0.7$). Then, the Student's t -test was performed and no significant difference of group size in different group compositions was shown ($t = -2.3$; $df = 3.7$; $p = 0.08$).

Coastal subareas (Cabo Frio and Rio de Janeiro subareas)

T. truncatus truncatus groups varied from 2 to 120 individuals in CF subarea (mean = 37.94, $SD = 30.37$) while group sizes in RJ subarea ranged from 1 to 80 dolphins (mean = 39.33, $SD = 27.36$) (Figure 6). Pooling both areas, group size observed ranged between 1 and 120 individuals (mean = 36.42, $SD = 28.70$).

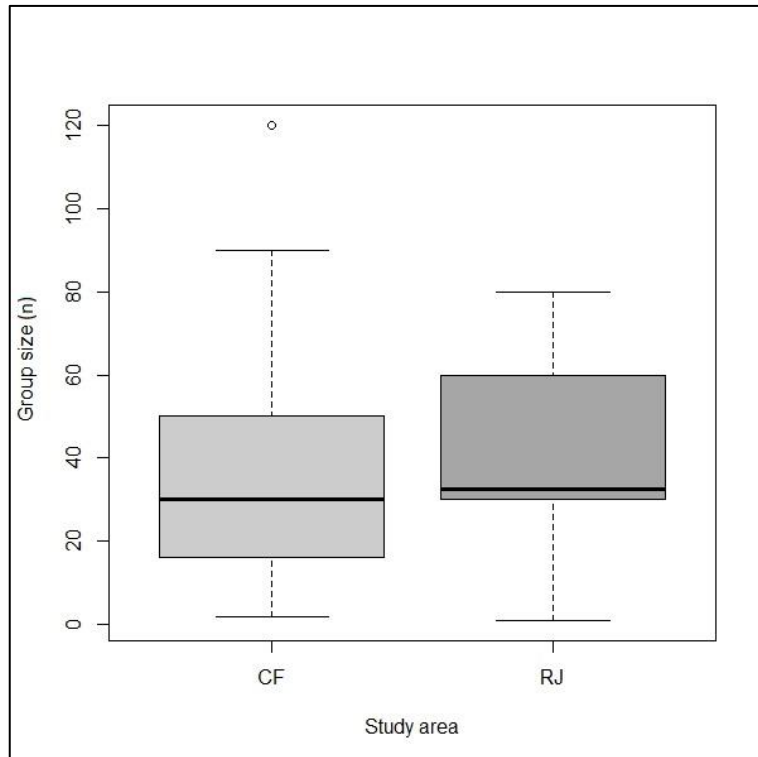


Figure 6 – *T. truncatus truncatus* group size in the two studied subareas. CF = Cabo Frio; RJ = Rio de Janeiro. Bottom dashed line = first quartile; below thick line = second quartile; thick line = median; above thick line = third quartile; top dashed line = fourth quartile; white point = outlier.

There was not significant difference in group size between CF and RJ subareas ($W = 48$; $p = 0.7$).

Group size ranged from 2 to 120 individuals (mean = 28.29, SD = 41.57) during summer. During fall, group size varied of 30 to 90 (mean = 50.63, SD = 23.97), while winter ranged from 1 to 50 (mean = 35.11, SD = 19.46). Although there was no significant difference of group size among seasons ($H = 13.5$; $df = 13$; $p = 0.4$), groups observed during summer tended to be smaller than those sighted during fall and winter (Figure 7).

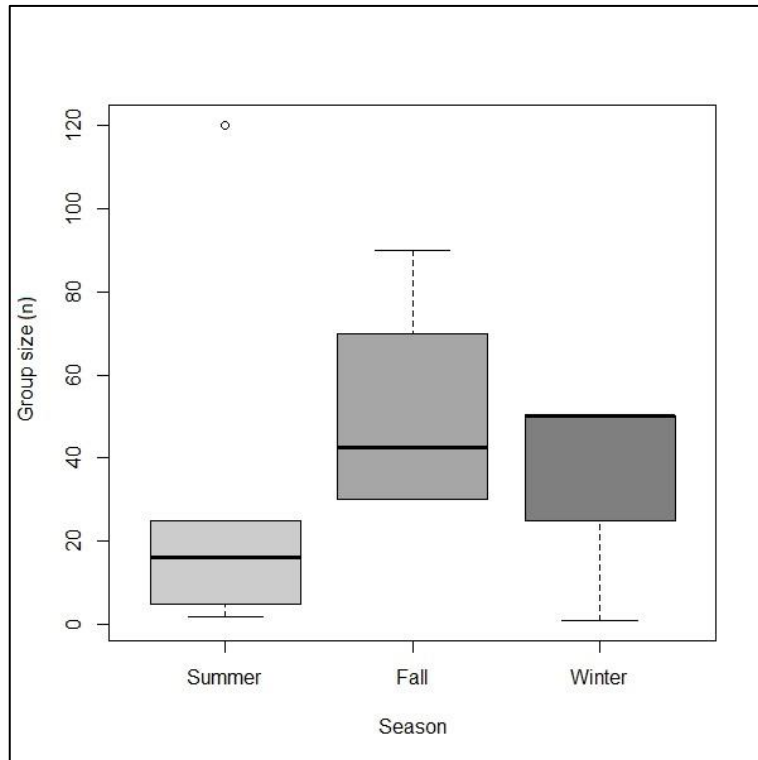


Figure 7 – *T. truncatus truncatus* group size in the different seasons grouping both studied subareas. Bottom dashed line = first quartile; below thick line = second quartile; thick line = median; above thick line = third quartile; top dashed line = fourth quartile; white point = outlier.

The size of groups with calves ($n = 21$) ranged from 2 to 120 individuals (mean = 40.86, SD = 29.80), while groups without calves ($n = 3$) presented groups of 1 to 30 individuals (mean = 20.33, SD = 16.74) (Figure 8).

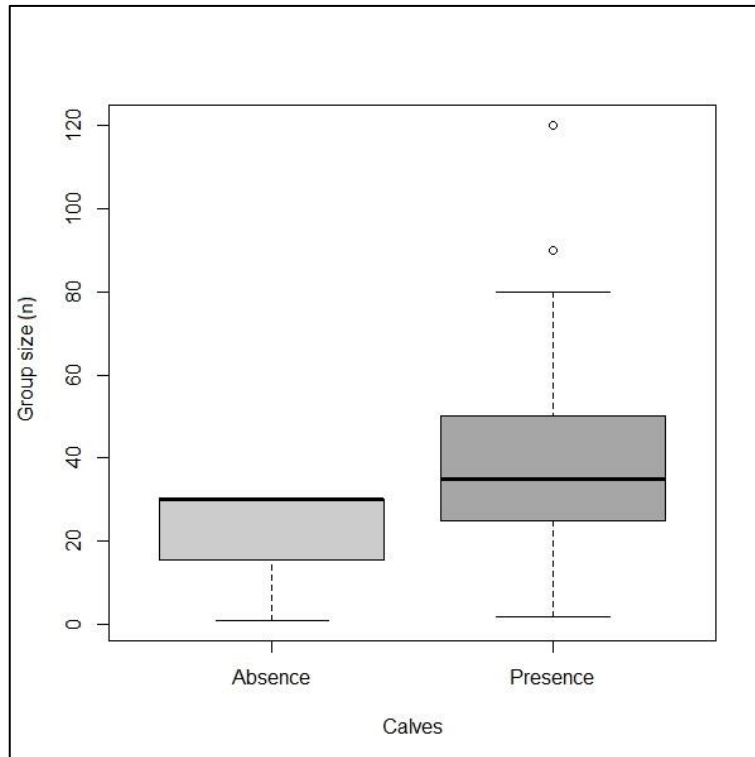


Figure 8 – *T. truncatus truncatus* group size without and with calves. Bottom dashed line = first quartile; below thick line = second quartile; thick line = median; above thick line = third quartile; top dashed line = fourth quartile; white points = outliers.

Group size shows evidence that it does not follow normal distribution ($W = 0.9$; $p = 0.03$) and was confirmed equal variance in group size between groups with and without calves (Bartlett's K-squared = 0.8; $df = 1$; $p = 0.4$). Then, it was possible to observe that group size varied regardless of group composition ($W = 18$; $p = 0.2$).

Group composition showed significant difference between the coastal subareas ($p = 0.009$). CF subarea present a high frequency of groups with calves when compared to RJ subarea.

Oceanic subarea

In the oceanic subarea, all 3 groups (100.0%) were just sighted during spring. A statistical test could not be performed due to data limitation.

1.5.1 Photo-identification

A total of 475 individuals of *T. truncatus truncatus*, from 18 groups, were photo-identified on the coast of Cabo Frio. In the city of Rio de Janeiro, 110 individuals were

photo-identified from 6 sighted groups. For the oceanic data, 45 individuals were recorded belonging 3 sighted groups. Thus, 614 individuals were photo-identified in this study.

A total of 16 individuals were sighted in more than one study area (Table 1 and Figure 9).

Table 1 – Individuals sighted in more than one study area. ¹ = Sightings in Cabo Frio subarea; ² = Sightings in Rio de Janeiro subarea.

| Identification | Sighting | | Resightings | | | |
|----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|--|
| | 0 | 1 | 2 | 3 | 4 | |
| #001 | 04/16/11 ¹ | 04/19/14 ² | | | | |
| #002 | 04/16/11 ¹ | 04/19/14 ² | | | | |
| #003 | 12/21/11 ¹ | 04/19/14 ² | | | | |
| #004 | 02/08/12 ¹ | 03/09/12 ¹ | 04/19/14 ² | | | |
| #005 | 02/08/12 ¹ | 05/02/18 ² | | | | |
| #006 | 02/08/12 ¹ | 03/09/12 ¹ | 06/05/12 ¹ | 08/29/12 ¹ | 04/19/14 ² | |
| #007 | 03/09/12 ¹ | 06/05/12 ¹ | 04/19/14 ² | | | |
| #008 | 03/09/12 ¹ | 05/02/18 ² | | | | |
| #009 | 03/09/12 ¹ | 05/02/18 ² | | | | |
| #010 | 03/09/12 ¹ | 03/10/17 ² | 05/02/18 ² | | | |
| #011 | 03/09/12 ¹ | 04/19/14 ² | | | | |
| #012 | 03/09/12 ¹ | 05/02/18 ² | | | | |
| #013 | 03/09/12 ¹ | 04/19/14 ² | | | | |
| #014 | 04/03/14 ² | 02/14/17 ¹ | 02/15/17 ¹ | | | |
| #015 | 04/03/14 ² | 03/05/16 ¹ | | | | |
| #016 | 08/17/16 ¹ | 11/05/17 ² | | | | |



Figure 9 – Example of individual sighted in more than one study area.

Pairs of adult individuals were recorded together three times on three different occasions (Table 2) within a minimum interval of 31 days and maximum interval of 802 days (mean interval = 326.33, SD = 181.42), being two pairs recorded together in both subareas. Every time a pair was sighted, it belonged to a group with calves.

Table 2 – Pairs of *T. truncatus truncatus* and dates on which they were sighted associated in different subareas. CF = identification of CF subarea catalog; RJ = identification of RJ subarea catalog.

| Pairs | Dates |
|---------------|--------------|
| CF#176/RJ#035 | 02/08/12 |
| CF#215/RJ#034 | 03/09/12 |
| | 04/19/14 |
| CF#202 | 02/08/12 |
| CF#215/RJ#034 | 03/09/12 |
| | 08/29/12 |
| CF#215/RJ#034 | 03/09/12 |
| CF#222/RJ#037 | 06/05/12 |
| | 04/19/14 |

1.5.3 Movements

Within CF subarea, individuals were recaptured at a distance between 1.2 and 18.1 km (mean = 9.6, SD = 4.5), while within RJ the distance ranged from 15.2 to 16.2 km (mean = 15.7, SD = 0.6). Between coastal subareas, the distance between recaptures varied from 112.7 to 137.6 km (mean = 126.5, SD = 6.8) (Figure 10). All individuals sighted in both subareas were first seen in Cabo Frio subarea and later in Rio de Janeiro subarea, except for one individual who was seen first in Rio de Janeiro subarea.

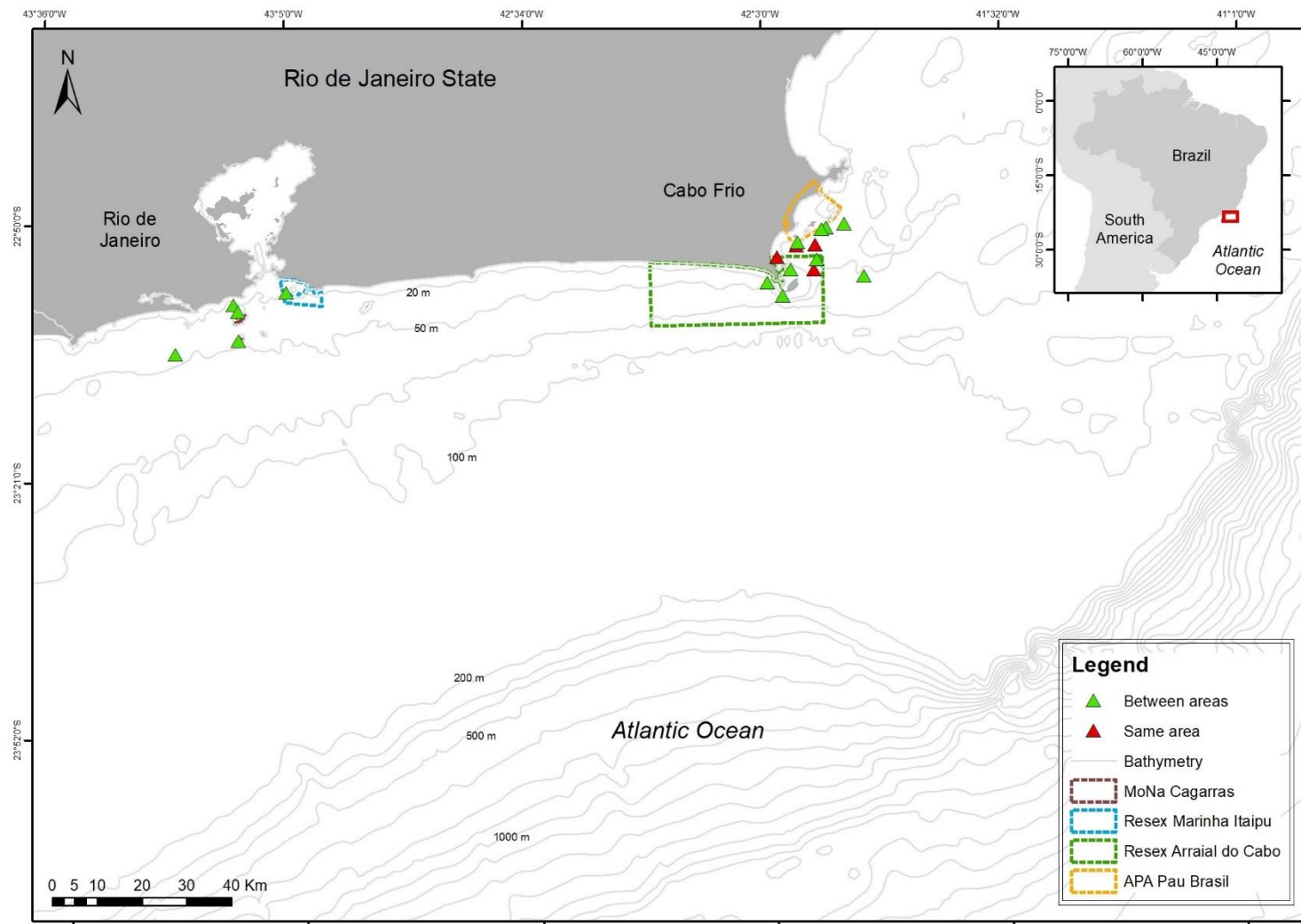


Figure 10 – Study area plotting the groups with individuals recaptured at least once. Conservation units within the boundaries of the study area highlighted in dotted lines.

1.5.4 Residency

Cabo Frio subarea

Of the 429 individuals catalogued in CF subarea, 41 (9.6%) were recaptured at least once and used for residency analyzes.

Individuals were recaptured 1 (82.9%) to 3 (2.4%) times. The interval ranged from 1 to 416 days (mean = 104, SD = 85). A total of 27 (65.8%) presented a low residency degree, seven individuals (17.1%) presented a medium residency degree and other seven individuals (17.1%) were classified as high residency degree (Figure 11). CCC value of 0.84 indicated that dissimilarities of the data from CF area was also well represented.

Four individuals were recorded together in two different occasions, and one pair was also recorded together for twice. Intervals ranged from 1 to 86 days (mean = 37.33, SD = 43.82).

Rio de Janeiro subarea

Only two individuals were recaptured, each in one occasion only, within Rio de Janeiro subarea. Interval ranged between 419 and 1,475 days (mean = 947.00, SD = 746.70). It was not possible to perform the AHC in the RJ subarea because the low recapture number.

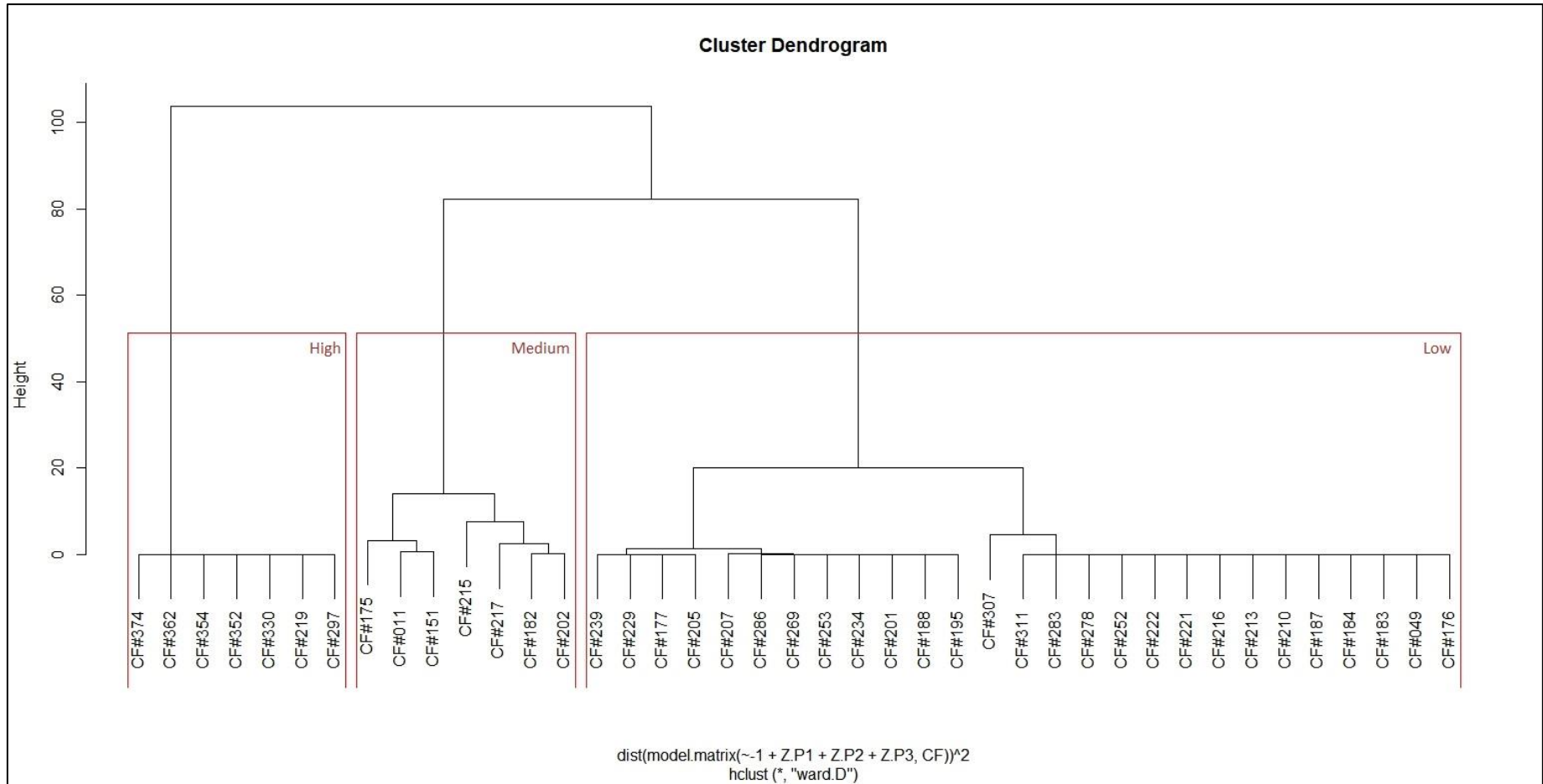


Figure 11 – Agglomerative Hierarchical Clustering (AHC) dendrogram of *T. truncatus truncatus* in the Cabo Frio subarea. CF = identification of CF subarea catalog; RJ = identification of RJ subarea catalog.

Coastal subareas (Cabo Frio and Rio de Janeiro subareas)

Of the 614 individuals catalogued, 57 (9.3%) were recaptured at least once and used for residency analyzes.

At regional scale, in Rio de Janeiro state, a total of 16 individuals (28.1%) were recaptured between coastal subareas. Individuals were recaptured between 1 (78.9%) and 4 (1.8%) times (mean = 2.25; SD = 0.54) in a minimum interval of 1 and maximum of 2,275 days (mean = 429, SD = 590). Of the 16 individuals recaptured in both subareas, five were also recaptured within the same subarea, while another 41 individuals (71.9%) were recaptured only within the same subarea.

Among the 57 recaptured dolphins, a total of 39 individuals (68.4%) presented a low residency degree, 7 individuals (12.3%) presented a medium residency degree and 11 individuals (19.3%) were classified in high residency degree (Figure 12). CCC value of 0.73 indicated the dissimilarities among collected data were well represented by the clusters in the dendrogram.

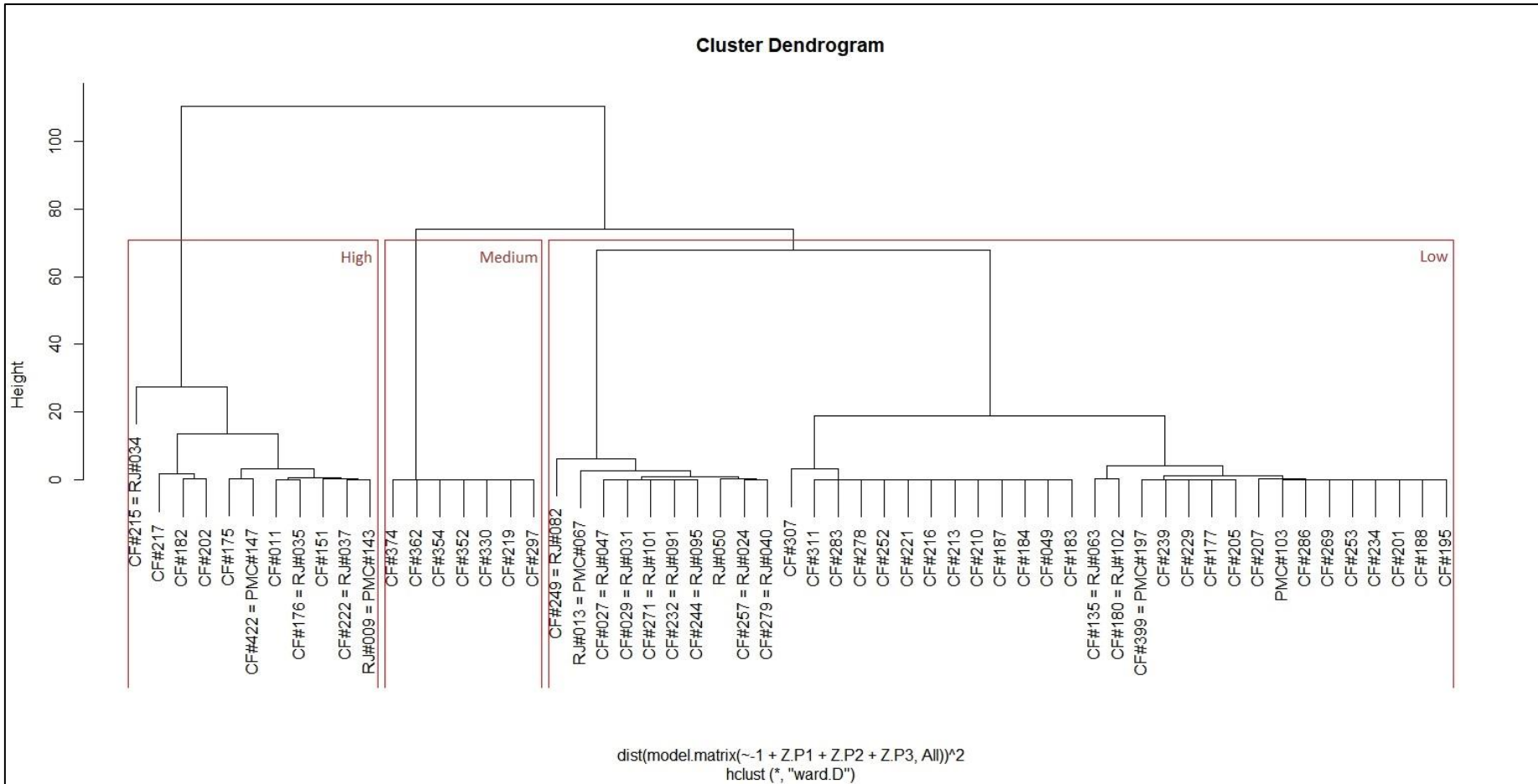


Figure 12 – Agglomerative Hierarchical Clustering (AHC) dendrogram of *T. truncatus truncatus* in Rio de Janeiro state. CF = identification of CF subarea catalog; RJ = identification of RJ subarea catalog.

Oceanic subarea

It was not possible to perform the AHC in the Oceanic subarea because there was no recapture.

1.6 Discussion

1.6.1 Occurrence, group size and composition

In CF and RJ, coastal areas within Rio de Janeiro state, the group size observed in the current study ranged between 1 and 120 individuals (mean = 36.42, SD = 28.70). This result is corroborated by other studies performed in different coastal areas (e.g. Defran et al. 1999 – Southern California Bight; Hubard et al. 2004 – north-central Gulf of Mexico; Bouveroux et al. 2014 – northeastern Gulf of Mexico; Oudejans et al. 2015 – northwest Ireland; Cobarrubia-Russo et al. 2018 – north Venezuela). However, previous studies conducted along the continental shelf break of Southeastern Brazil reported groups of *T. truncatus truncatus* relatively smaller than groups of coastal areas (Di Tullio et al. 2016).

A tendency to increase group size towards deep and open waters is very common, but group size may vary according to habitat and activity patterns of the species (Shane et al. 1986). Shallow and coastal waters can provide relatively predictable and evenly distributed food resources. The existence of larger groups in deep and open water increase the probability of encountering enough food resources to feed the whole group as well as these areas seems to offer a relatively protection against predation (Norris & Dohl 1980; Wells et al. 1980; Würsig 1978). In contrast, if intraspecific competition is high, groups can be subdivided to reduce pressure on food resources (Cockcroft & Ross 1990).

The mean group size reported in oceanic areas was 18.83 individuals (SD = 4.31) (Di Tullio et al. 2016), indicating an increase in group size in coastal subareas (CF: mean = 37.94, SD = 30.37; RJ: mean = 39.33, SD = 27.36). In oceanic waters off the coast of Brazil, primary production is limited by extremely low phosphorus amount, making them oligotrophic (Mahiques et al. 2004; Gaeta & Brandini 2006). Therefore, low primary productivity can result in a decrease of food resources, hampering the occurrence of large groups in oceanic areas.

Although there was no significant difference between the group size found in both coastal areas, Cabo Frio showed a group size slightly larger than those found in Rio de Janeiro. This result is possible explained by the existence of some upwelling events which

occurs mainly in Cabo Frio subarea, but it can also reach Rio de Janeiro subarea with low intensity. This phenomenon results in local high primary productivity and consequently in high fish productivity (Mazzoil et al. 2008), supporting larger feeding groups.

In Cabo Frio, all groups contained calves, while only half of the groups found in Rio de Janeiro had calves. As the groups in Cabo Frio were slightly larger, it may indicate that they can provide more protection to calves through dilution and confusion effects (Landeau & Terborgh 1986; Turner & Pitcher 1986) as well as providing better behavioral development, which create more opportunities for social learning (Mann & Smuts 1999). Sensory-motor activities are essential to increase the survival chances of calves and can have different adaptive functions, such as learning foraging tactics, avoid predators and find their mother quickly (Mann & Smuts 1999).

Each season presents its own dynamic of fish stocks. In the Rio de Janeiro state, during summer it is common to find demersal species such as those of the Engraulidae and Trichiuridae families (Petrobras 2013). During fall and winter, pelagic species such as Brazilian sardine and Lebranche mullet can be observed (Paiva & Motta 2000, Lemos et al. 2016).

Although the common-bottlenose-dolphin (*T. truncatus*) show a generalist diet, it is possible to observe a feeding preference for some fish species belonging mainly to Clupeidae, Engraulidae, Mugilidae and Trichiuridae families, such as Brazilian sardine *Sardinella brasiliensis*, Anchovy *Pomatomus saltator*, Lebranche mullet *Mugil cf. liza*, White mullet *Mugil curema* and Largehead hairtail *Trichiurus lepturus* (e.g. Bearzi 2005, Di Benedetto 2001, Milmann et al. 2016, Moura et al. 2016).

In the Southwestern Atlantic Ocean, pelagic species are particularly abundant in the southeastern Brazil throughout the year (Muto et al. 2000), occurring on the continental shelf up to 350 m deep. The above data corroborate the presence of *T. truncatus truncatus* in coastal areas with the presence of their preys.

1.6.2 Photo-identification

In this study, there were not many associations, which can be explained by most individuals with a low residency degree, as reported in common-bottlenose-dolphin populations worldwide (e.g. Silva et al. 2008 – Azores Archipelago; Baird et al. 2009 – Hawaii Islands). The associations recorded are evidence of fluid relationships (Shane

2004) with fission-fusion dynamics (Connor et al., 2000) and may maintain high gene flow (Qu erouil et al. 2007).

1.6.3 Movements

Extensive movements (maximum = 137.6 km) between Cabo Frio and Rio de Janeiro subareas can be explained by the physiographic and oceanographic similarities between these subareas (Lodi et al. 2012). Similar results have been reported for *Steno bredanensis* (Lodi et al. 2012) and *Balaenoptera edeni* (Lodi et al. 2015), demonstrating the importance of the studied subareas not only for *T. truncatus truncatus*, but also for other cetaceans species. The low number of dolphins recaptured (9.3%) reported in this study may be related to a larger home range than our study area, which probably mean these areas does not have enough food resources to support resident populations (Tardin et al. – *in press*).

Long distance movements are reported for *T. truncatus* around the world, for example, California, UK and Ireland (e.g. Wells et al. 1990 – +600 km; Wood 1998 – +1,000 km; Robinson et al. 2012 – +1,000 km). In Rio de Janeiro, movements of approximately 100 km have already been recorded (Lodi et al. 2008).

These animals may be continuously moving around looking for food resources and not attracting predators to a particular area (Gowans et al. 2008).

1.6.4 Residency

A total of 9.3% (n = 57) individuals recaptured at least once shows that there was not a high residency degree in the study area. Several studies performed worldwide also showed populations with low residency degree. A total of 65.2% of individuals were sighted only once in north-central Gulf of Mexico (Hubard et al. 2004) and 51.0% were seen once or twice in southwest Florida (Shane 2004). In north Venezuela, more than half of the individuals (52.9%) were considered transient (Cobarrubia-Russo et al. 2018).

Although it was reported low residency degree, both in Cabo Frio and Rio de Janeiro, it was evidenced that both subareas can be used by the same animals. The low residency degree rate in the study area can be due to unknown ecological issues or a response to the high degree of anthropic impacts (e.g. maritime traffic, pollution and underwater noise), in order to avoid or minimize their effects on the groups.

Due to its clear waters and scenic beauty, Cabo Frio and Rio de Janeiro subareas present intense nautical tourism, mainly in the summer (TurisRio 2019). Fishing activity is

also intense in these subareas (Tubino et al. 2007; Petrobras 2013; Amorim & Monteiro-Neto 2016), especially in Cabo Frio because it is a region with a strong influence of the upwelling (Valentin 1984, Duarte & Viana 2007). In addition, Cabo Frio is in the Campos Basin, a place of constant oil exploration (Petrobras 2018).

Rio de Janeiro subarea, the capital of the state and one of the most populous cities in Latin America (IBGE 2018), is directly affected by the eutrophic waters of Guanabara Bay (SisBaHiA 2018) and is located in the Santos Basin, where there is also intense oil exploration. Although the activities of the Campos Basin have not yet begun, supply vessels may be in Guanabara Bay, passing through the subarea of Rio de Janeiro during the displacement.

No recaptures were recorded among individuals identified between coastal and oceanic areas. Although the number of sampling in oceanic areas were small, the results suggest that the *T. truncatus truncatus* does not perform longitudinal migrations, i.e., between the coastal and oceanic areas. Results such as this are common (e.g. Wells et al. 1999; Bearzi et al. 2009) and may be associated with oceanographic dissimilarities (Bearzi et al. 2009).

1.7 Conclusions

The results obtained in this study provide a better understanding of the occurrence, movements and residency of *T. truncatus truncatus*, which is necessary for the proposal of conservation measures, especially in regions subjected to anthropic impacts, such as oil and gas exploitation, fisheries and tourism, which are recurrent in both studied subareas.

Given the low degree of residence of most individuals, they were considered to belong to a metapopulation that is present in an area larger than the area covered in the present study. This metapopulation is also transient, only being present in each subarea studied on certain occasions.

1.8 Recommendations

Simultaneous sampling in all three subareas can provide more accurate movement results.

Ecological models may help to better understand the occurrence of *Tursiops truncatus truncatus* in the study area, in addition to identifying potential areas. For the paper

publication, habitat suitability and movement models will be generated to complement the results.

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