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ANALYSIS OF GROUP SIZE, COMPOSITION AND
ACTIVITIES, OF BOTTLENOSE DOLPHIN
(*TURSIOPS TRUNCATUS*) IN THE REGION OF
SADO ESTUARY

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RESUMO

O efectivo e a composição dos grupos animais são aspetos importantes da organização social, podendo ser influenciados por diversos fatores ecológicos, e afectando as interações entre os indivíduos. Os grupos podem ser constituídos por indivíduos do mesmo sexo ou idade, geralmente envolvidos na mesma actividade. Estudos de estrutura social utilizam informações sobre padrões de associação entre indivíduos, essenciais para o conhecimento da dinâmica das populações e para a sua gestão e conservação.

A comunidade de golfinhos residentes na região do Sado é pequena e envelhecida, composta por 19 adultos, 6 juvenis e 2 crias, e apresenta uma estrutura social dinâmica e fluida.

Os dados mostram que os grupos desta comunidade têm tamanho médio de 11,6 indivíduos, sendo grupos maiores e mais frequentes compostos por adultos, juvenis e crias. O tamanho do grupo também foi analisado em termos do grau de dispersão e dos padrões de atividade dos animais do grupo sendo, em ambos, semelhante.

Os padrões de associação foram analisados no SOCPROG 2.7. As associações entre as classes de idade e sexo, e dentro das classes, são “preferidas a curto prazo”, e o coeficiente médio de associação na comunidade é 0,25. Estes golfinhos vivem numa sociedade de fissão-fusão, detetada pela prevalência de associações “preferidas a curto prazo” e pelo baixo coeficiente médio de associação.

Considerando estudos anteriores desta comunidade, a estrutura social e os padrões de associação poderão ter sofrido alterações recentes, possivelmente devido a remoção de alguns indivíduos (por morte ou emigração) que estiveram presentes na comunidade durante décadas.

Palavras-chave: *Tursiops truncatus*, estrutura social, composição de grupos, grau de dispersão, comportamento

ABSTRACT

Group size and composition are important aspects of social organization, and can be influenced by several ecological factors, affecting interactions between individuals. Groups can be composed by individuals of the same sex or age that are generally engaged in the same activity. Studies of social structure rely on data on association patterns between individuals, and are essential for the knowledge of population dynamics and its management and conservation.

The resident bottlenose dolphin community of the Sado region is small and aged; 19 are adults, 6 are subadults and 2 are calves, and it has a dynamic and fluid social structure. Data show that groups in this community have a mean size of 11.6 individuals, with larger and most frequent groups composed by adults, subadults and calves. Group size was also analyzed in terms of the spreading degree and activity patterns of animals in the group and, in both analyses, mean group size was similar.

The association patterns were analyzed with software SOCPROG 2.7. Associations between age and sex classes, and within classes, are *short-term preferred* and a mean coefficient of association of 0.25 was obtained for this community. These dolphins live in a fission-fusion society, as is expressed by the prevalence of short-term preferred associations and the low mean coefficient of association.

Considering previous studies of this community, social structure and association patterns might have changed recently, possibly due to the removal of some individuals (by death or migration) that were present in the community for decades.

Keywords: *Tursiops truncatus*, social structure, group composition, spreading degree, behavior

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I. INTRODUCTION

1.1 Studies of social structure in cetaceans

Some animals, considered “social”, live in groups, characterized by dynamic, complex and nonrandom patterns of social interactions (Hasenjager & Dugatkin, 2015).

When in groups, individuals may benefit from increased foraging efficiency and mating encounters, improved locomotory ability, alloparental care, maintenance of physiological parameters, as well as decreased individual risk of predation (Semeniuk & Rothley, 2008). However, in bigger groups, foraging efficiency decreases (Gazda, Iyer, Killingback, Connor & Brault, 2015); competition for resources, especially when limited, may increase; and parasites and diseases are more rapidly spread within groups. Large groups are also more easily attracted by predators (Ritz, Hobday, Montgomery & Ward, 2011; Thiel, 2011).

Group size is one of the main aspects of social organization, more frequently studied (Gibson & Mann, 2008) and, together with persistence of groups, might be affected by ecological factors, such as variations in local resources (Louis *et al.*, 2015).

Groups may be composed by individuals of the same sex, age, kin affiliation, or by individuals engaged in the same general behavior. Also, foraging strategies and habitat preferences may shape group composition. Group size and composition, and group dynamics, affect sociality, which is expressed by the nature of interactions between individuals (Titcomb, O'Corry-Crowe, Hartel & Mazzoil, 2015). Group composition and its stability, as well as the patterns of associations between individuals and reproductive strategies, are adapted in order to maximize the individuals' fitness under certain ecological conditions (Quintana-Rizzo & Wells, 2001).

Interactions, which are characterized as elementary aspects of social structure, involve at least two individuals, one or more types of behavior, and they occur in a limited period of time. When interactions are extended in time, or following sequences of interactions, the two individuals involved may begin to recognize each other. Sequences of interactions between two individuals known to each other are described as relationships. Since individuals are familiar to each other, previous interactions will have influence in the nature and course of future interactions between these individuals. Relationships are also characterized by the pattern of interactions, i. e., the frequency of interactions, when they take place, and how interactions affect individuals. The patterns, quality and nature of relationships will express the social structure of a given community (Hinde, 1976).

Interactions, which are also characterized as actions affecting the behavior of another individual, can be difficult to observe, and the majority of interactions takes place among individuals in association. Consequently, analyses of social structure are performed using data on associations between pairs of individuals (Whitehead, 2009). Throughout the last 25 years, various association indices were used to measure the strength of associations between individuals, particularly in social vertebrates (Cairns & Schwager, 1987; Bejder, Fletcher & Bräger, 1998). Before analyzing associations between dyads, described as pairs of individuals, it is essential to define them in a sampling period. Associations are considered when two individuals are observed together in the same group during a given sampling period, and may depend on the proportion of time and number of groups in which the pair was observed together (Whitehead, 2009).

An association between a pair of individuals is, usually, summarized in an association index, which can be described as an estimate of the proportion of time a pair of individuals has spent together (Whitehead, 2009). Association indices, calculated for each dyad, in a given population, are used to measure the strength of an association between a pair of individuals (Bejder *et al.*, 1998). The most used indicator is the half-weight index (Cairns & Schwager, 1987; Whitehead & Dufault, 1999), which accounts for biases created when not all individuals are present (Dungan, Wang, Araújo, Yang & White, 2015). This index comprises values between 0 and 1, in which values closer to 1 represent higher association levels (Bejder *et al.*, 1998).

Studies of association patterns between pairs of individuals are very common with several species (e.g. Connor, Wells, Mann & Read, 2000; Simpson, Rands & Nicol, 2012; Wakefield, 2013; Dungan *et al.*, 2015; Fedutin, Filatova, Mamaev, Burdin & Hoyt, 2015; Gero, Gordon, & Whitehead, 2015), and social structure varies from stable groups with fixed associations to fluid and dynamic societies (Fedutin *et al.*, 2015).

The analysis of social structure is fundamental for the study of population biology (Whitehead, 2008a). It has variations across communities, which are defined as groups of individuals of the same species that occur in space and time, with opportunities to interact with each other (Louis *et al.*, 2015).

Studying social structure and habitat use among clusters, defined as sets of individuals in which the majority of associations occur, may play an important role in their conservation (Louis *et al.*, 2015), especially in species with strong bonds between individuals and where local traditions may affect movements or mating patterns (Augusto, Rachinas-Lopes & dos Santos, 2012).

Social structure can be shaped by specializations in the diet and by the techniques used to capture prey (Blasi & Boitani, 2014), by ecological factors, such as prey availability, and by oceanographic or factors intrinsic to the population, such as shared knowledge and behavioral

strategies (Louis *et al.*, 2015). Studying social structure can offer important insights into social dynamics of populations (Lusseau & Newman, 2004) and may have important implications in management and conservation (Whitehead, 2009; Dungan *et al.*, 2015) of a given species or population.

Social structure, interactions and social behavior within a population or species may affect persistence via its effects on reproduction or survival. For instance, mating systems influence a population's genetic structure, and, therefore, will affect population viability (Blumstein, 2010).

Many cetaceans live in social groups, whose composition changes over hours or days. In this dynamic and fluid organization, known as fission-fusion societies (Würsig & Würsig, 1977; Symington, 1990), individuals change their associations frequently. Communication, defense, feeding and reproduction are facilitated in fission-fusion societies (Foley, McGrath, Berrow & Gerritsen, 2010). In these social systems, associations may be adjusted in response to fluctuations in resource availability (Louis *et al.*, 2015).

In most studies of this type of societies, data on associations are based on the “Gambit of the Group”, in which it is assumed that all individuals in a group are associating with each other (Gazda *et al.*, 2015).

Cetaceans are a group with special conservation concerns, that present a large variety of complex social behaviors. In this particular group of marine mammals, the terms “pods” and “herds” represent temporary congregations of individuals, in the same area and often engaged in similar activities (Reynolds III, Wells & Eide, 2000). Pods are primary groups, composed by small social groups, that remain intact for a long period of time (days and weeks), whereas herds are temporary aggregations of primary groups of cetaceans, only lasting for minutes or hours (Ritz *et al.*, 2011).

1.2. The common bottlenose dolphin

The common bottlenose dolphin, *Tursiops truncatus* (Montagu 1821), in particular, is one of the most studied cetacean species worldwide, due to the existence of many populations close to the shore, which allowed long-term studies. Offshore and coastal ecotypes have been described for this species, with ecological, morphological and physiological variations (Connor *et al.*, 2000; Mattos, Rosa & Fruet, 2007).

The bottlenose dolphin is an aquatic mammal, classified in the order Cetartiodactyla, infraorder Cetacea, parvorder Odontoceti and family Delphinidae (Reynolds III *et al.*, 2000). This

species is found from tropical to temperate waters, occurring in both coastal waters, including bays and estuaries, as in open waters (Connor *et al.*, 2000). In the European Union, the common bottlenose dolphin is being protected under the Habitats Directive (92/43/22C), and listed in Annex II, given that its conservation requires the establishment of Special Areas of Conservation, and in Annex IV, due to its need of strict protection (Louis *et al.*, 2015).

In anatomic terms, in adults, body size varies between 2 and 4 meters of length, depending on the geographic location (Reynolds III *et al.*, 2000), and there's no evident sexual dimorphism, making sex determination difficult. The subadults are independent dolphins, usually measuring less than 249 cm (230 cm for females) and calves are small dolphins, frequently accompanied by larger dolphins, assumed to be their mothers (Wells, Scott & Irvine, 1987).

Males reach sexual maturity between the ages of 8 and 13, and females between the ages of 5 and 13. Females can live longer than 50 years old, and males longer than 40, making bottlenose dolphin, a long-life species. (Connor *et al.*, 2000). In *Tursiops truncatus*, gestation lasts for 12 months, with females giving birth to a single calf, which can stay associated with its mother for several years. Birth interval varies between 2 and 6 years, depending on the geographic location. Bottlenose dolphins are carnivores, feeding on a large variety of fish species, cephalopods and, less frequently, crustaceans (Connor *et al.*, 2000).

In bottlenose dolphin populations, the mean size group varies between 5 and 140 individuals, depending on the geographic location (Connor *et al.*, 2000). Structural units can be constituted by mother-calf pairs; single and mixed sex groups of subadults; female bands, with their calves; and male pairs or trios (alliances) (Pryor & Norris, 1991).

Individuals from the bottlenose dolphin community of Moray Firth (Scotland) are mostly observed in mixed-sex groups (Eisfeld & Robinson, 2004). In the community of Doubtful Sound the most abundant groups are composed only by males and mixed-sex groups are the least frequent (Lusseau *et al.*, 2003). On the other hand, in the community of Sarasota Bay, mixed-sex groups, and female bands, are the most frequent, whereas male alliances are the least abundant (Wells *et al.*, 1987). Female bands and male alliances are the most abundant groups in the community of Shark Bay (Gero, Bejder, Whitehead, Mann & Connor, 2005).

Social structure in this species is most likely affected by predation risk, prey distribution, habitat structure, as well as male competition, breeding success and risk of infanticide, and with cultural transmission as a likely mechanism influencing social structure (Blasi & Boitani, 2014).

The bottlenose dolphin community of the Sado region is the only resident community found in continental Portugal, and one of the few in Europe (Augusto *et al.*, 2012). Additionally, is one of the smallest known communities of bottlenose dolphin worldwide (dos Santos,

Coniglione & Louro, 2007). This community is being studied since the beginning of the 80's (dos Santos, Louro, Couchinho, & Brito, 2005; dos Santos *et al.*, 2007), and many studies about its demography, movement patterns, home range, habitat use (Harzen, 1998), as well as emissions of acoustic signals (dos Santos *et al.*, 2007; Luís, Couchinho & dos Santos, 2014; Luís, Couchinho & dos Santos, 2016) have been carried out since then. Previous studies indicated an average group size of 7.75 ± 6.37 and a typical group size of 12.97 for this community. Mean group size has variations among classes, and groups composed by adults, subadults and calves have the largest average group size in this community (Augusto *et al.*, 2012).

This is a fragile community due to its apparent isolation, low recruitment and ageing. Also, there was a 10-year period without the survival of any calf (Augusto *et al.*, 2012). In addition, it inhabits an area of elevated impact due to the proximity of Setúbal, a large urban center (Ferreira, 2010). This species is listed as “Least Concern” in the IUCN Red List. However, the status of “Critically Endangered” might be attributed to locally isolated populations of bottlenose dolphins. Given the condition of the local community in the Sado region, an Action Plan was approved in 2009 by ICNF (*Instituto da Conservação da Natureza e das Florestas*), for the protection and monitoring of this community of bottlenose dolphins (Augusto *et al.*, 2012). At the moment, these actions are being revised for a new edition of the plan.

Based on studies carried out in the study area (dos Santos & Lacerda, 1987; dos Santos *et al.*, 2007), individuals mainly feed on mullets, cuttlefish, octopus, twaite shad, european eel and squid.

Since there is limited information about demography and behavior of this population, a continuing analysis of its social structure will be beneficial to assess its conservation status (Augusto *et al.*, 2012). Given that social structure can influence the conservation of bottlenose dolphins, by affecting its persistence through effects on reproduction or survival (Blumstein, 2010) studies of grouping and association patterns might be beneficial for the management of this fragile community.

1.3 Objectives

This study intends to follow up monitoring work and studies of activities, group size and composition of the bottlenose dolphin resident population of Sado region. Its objectives are to:

- Determine the effective community size, through a complete photographic census;
- Follow up the work of determining sex and age structure of the individuals of this community;
- Analyze size and age structure of the observed groups;
- Calculate mean group size and analyze its variations;
- Analyze group size according to the observed activity patterns;
- Determine spreading degree of the social units in different activity contexts and according to group size;
- Calculate coefficients of association between dolphin pairs;
- Calculate mean coefficient of association of the community;
- Perform hierarchical analysis of coefficients of associations and create dendrograms;
- Compare social structure from the sampling period between 2007 and 2010, with the sampling period of 2015 and 2016.

II. MATERIALS AND METHODS

2.1. Study Area

The Sado estuary, the 2nd biggest of Portugal, with an approximate area of 240 km² (Caeiro *et al.*, 2005) and a width of 4 km (Martins, Leitão, Silva & Neves, 2001), is located on the western continental coast of the country (Caeiro *et al.*, 2005).

This estuary has an average depth of 8m and a maximum depth of 50 m in the river mouth (Freitas *et al.*, 2008). There are two channels in the lower estuary, divided by sand and mud banks. The south channel, delimited by Península of Tróia, is deeper, wider and has a stronger water flow. In contrast, the north channel, delimited by the city of Setúbal, has a weaker current (Caeiro *et al.*, 2005), and it is strongly influenced by the city, its harbor and industrial areas (Caeiro, Goovaerts, Painho & Costa, 2003).

In 1980, with the main purpose of protecting species diversity and sources of biological productivity, a Nature Reserve was created (Harzen, 1998). Despite its partial conservation status, the Sado estuary houses several industries, most of them on the northern side (Caeiro *et al.*, 2005; Lillebø, 2011), with decades of industrial pollutants, herbicides and pesticides accumulation in the water, and with contaminated sediments (Gil & Vale, 2001; Caeiro *et al.*, 2005).

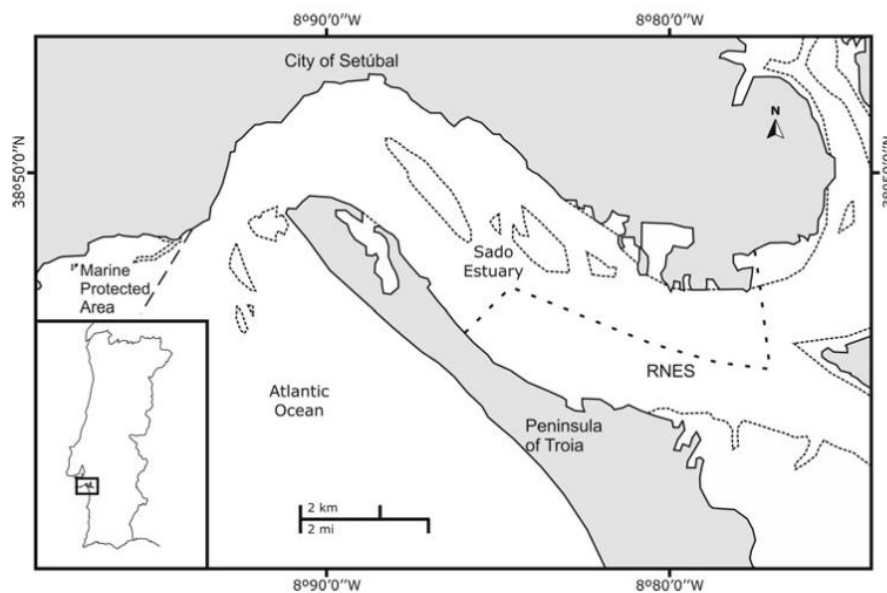


Figure 1. Map of the study area, located on the central western coast of Portugal. The broken lines represent a marine protected area and Reserva Natural do Estuário do Sado (RNES), whereas the small dotted lines correspond to mud banks (Retrieved from Augusto *et al.*, 2012).

2.2 Data collection

Social structure and group composition analyses were performed using records of activity patterns, through direct observations, video cameras, recording sheets (see Appendix VI) and photographs. Data collection was conducted between June 2015 and June 2016, during 16 sampling days, with approximately 68 hours of observation effort. These records were registered on board of a cabin boat, “Darwin”, with a length of 8.4 meters.

Data collection was performed by two observers. One was in charge of photo and video recordings and the other of annotations of activity patterns. When possible, a third element would register the exact distance of the individuals to the boat, using a rangefinder, Newcon Optik LRM 2000PRO. Photographs were collected with two cameras, a Canon EOS 450D (90-300mm or 18-300mm lens), in JPEG format with a resolution of 4272x2848 pixels, and a Nikon D7200 (70-300mm lens), also in JPEG format with a resolution of 6000x4000 pixels. Videos were recorded with a Canon Powershot A1200, in MOV format with a resolution of 1280x720 pixels, or a Canon, LEGRIA HF R606, in MP4 format with a resolution of 1920x1080 pixels. The video camera was installed on a bike helmet (Figure 2), worn by the observer in charge of photographic records, in order to ensure simultaneous records of the activities and photographic data. Spreading degree of each observed group was scored, in a scale of I to V (see below).

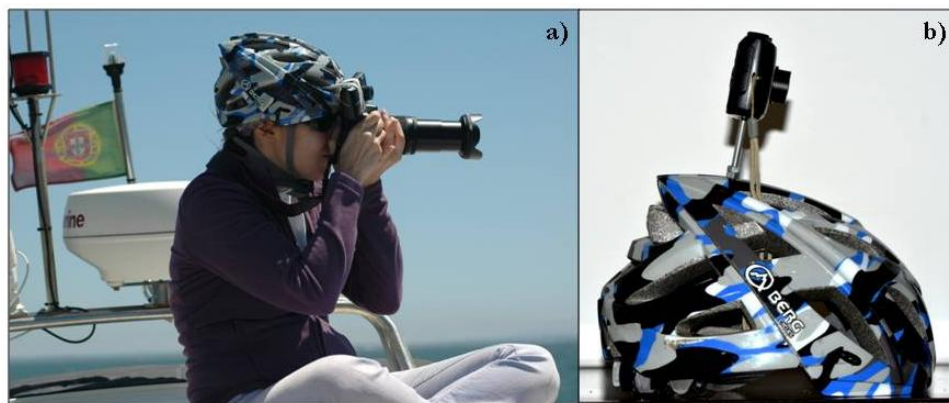


Figure 2. Materials used for photographic and video records, particularly a) the method used and b) the improved equipment for video records. Figure 2a was taken by Paulo Marques.

Water depth and GPS positions of the boat, direction of movements and activities of the observed dolphin group were also recorded.

Records started at the moment of first sighting of individuals and each group was accompanied until data collection of all individuals was complete. Data collection was performed with minimum disturbance to the dolphins and, at any sign of discomfort, data collection was

suspended. Distance to the animals was managed in a way to avoid behavioral change, usually above 50 m, except when the dolphins spontaneously approached the boat.

2.3 Data analysis

Individuals were distinguished through the photo-identification method. Photographs were taken during each sampling period and, subsequently, analyzed to identify individuals, through natural marks, like cuts and scars, on their dorsal fins (Würsig & Würsig, 1977). This method of individuals' identification is non-invasive and provides information about group structure and movement patterns of a population (Pryor & Norris, 1991). To identify individuals, these photographs were compared to existent catalogues, initiated in 1981 (dos Santos & Lacerda, 1987).

The determination of the sex of the individuals through photos capturing the genital area was also attempted. Adults are considered to be, at least, 6 years old, whilst subadults are 3 to 5 years old and calves younger than 3 years old. Adults frequently observed with the same calf, are assumed to be adult females and with high probability of being the mother (Wells *et al.*, 1987), since it is known that females strongly associate with calves throughout the first years (Campbell, Bilgre & Defran, 2002) and adult male interactions with calves are known to be rare (Connor *et al.*, 2000).

2.3.1. Group analysis

Groups were defined as the total of individuals within an area of 100-m radius and involved in similar behavioral activities (Louis *et al.*, 2015). In each group, the number of individuals and their identification was determined. Percentages of each age structure and sex, as well as mean group size and its variation (Standard Deviation, SD) were calculated.

Groups were then categorized according to the age structure of the individuals present in each group (Adapted from Félix, 1997).

- All adults
- All subadults
- Adults and subadults
- Adults and calves

- Adults, subadults and calves
- Subadults and calves

For each category, group size was determined, and total number of groups and mean group size for each category were calculated.

2.3.1.1. Group size according to observed activity patterns

Based on Shane (1990), and previous studies in the Sado estuary (e.g. Augusto, 2007), four main activity patterns were defined.

Travel - Constant movements in one direction, with directed and synchronized diving;

Foraging and feeding – Diversity of behaviors, distinguished by sequences of dives in different directions, fish kicks and fish tossing, among others, like feeding circles or feeding splashes;

Socialize – Some or all members of the group in physical contact with one another; constant displays of surface behaviors; absence of forward movement or prey;

Rest – Individuals closed to each other, with very slow movements or drifting in one direction at the surface.

For each activity pattern, group size was analyzed, and total number of groups and mean group size for each activity pattern were calculated.

2.3.1.2. Spreading degree of social units (in different activity contexts; according to group size)

Groups were then categorized according to their spreading degree:

- I, very tight, or aggregated, individuals
- II, tight individuals
- III, loose individuals
- IV, dispersed individuals
- V, very dispersed individuals

“Very tight” aggregation means a separation between individuals with less than one body length apart; “loose”, separation greater than one body length and less than five body lengths;

“widely dispersed”, group members spread greater than five body lengths apart (as in Shane, 1990).

For each spreading degree, group size was analyzed, and total number of groups and mean number of individuals in each group were calculated.

Within each activity pattern, groups were categorized according to spreading degree, group size was determined, and total number of groups and mean number of individuals in each group were calculated.

Results were analyzed using STATISTICA 7.0 (Statsoft, Inc.) and, for each type of group, its percentage in relation to the total number of groups, minimum and maximum sizes, as well as mean size and standard deviation (SD) were calculated.

In all analyses, with the purpose of determine differences in mean group sizes, an ANOVA, with a significance level of 0.05, was performed, where the null hypothesis is the equality of mean group sizes and alternative hypothesis the difference between mean group sizes. Data collected were subject to Shapiro-Wilk normality test and residuals analysis, to determine whether a parametric ANOVA (simple ANOVA) or non-parametric (Kruskal-Wallis ANOVA) should be performed (Zar, 1999).

2.3.2. Analysis of social structure

2.3.2.1. Software

Data analysis was performed using SOCPROG 2.7 (Whitehead, 2009), a software developed to analyze animal associations, in which data are recorded from observations of the social behavior on individually identifiable animals.

SOCProg is considered a reliable tool to analyze social structure, to develop relationship measures and to synthesize them into models and representations of social structure. This program makes use of data on the associations of identified individuals, providing analyses of social structure. These analyses are performed through association indices, which calculate approximately the amount of time spent by two individuals together at the surface, and can be easily repeated after changes in attributes, such as the length of sampling period, definition of association or restrictions (age or sex of the individuals, or season of the year) (Whitehead, 2009).

From the four known indices to analyze associations between dyads (simple ratio, half-weight, twice-weight and square root) (Cairns & Schwager, 1987), the Half-Weight Index (HWI) is the most commonly used in studies of bottlenose dolphin social structure, making comparisons among studies easier (Louis *et al.*, 2015).

SOCPROG is also used to perform hierarchical cluster analysis, from the association data. From the various options available the average-linkage method is usually the chosen (Whitehead, 2009) due to its higher likelihood to create dendrograms more approximated to the real social structure, when compared to the other methods available (Whitehead & Dufault, 1999).

2.3.2.2. Coefficients of association, being group the sampling unit

Individuals were considered in association when observed in the same sighting group and engaged in the same behavior (Dungan *et al.*, 2015). Coefficients of association between dyads (pairs of individuals) were calculated using the Half-Weight Index (HWI):

$$HWI = x / [x + yAB + 0.5(yA + yB)]$$

where x is the number of sampling periods in which A and B were observed in association, yAB is the number of times A and B were both observed, but not associated, yA the number of times when only A was observed, and yB the number of times when only B was observed (Bejder *et al.*, 1998).

This index quantifies the strength of associations between pairs of individual dolphins (Louis *et al.*, 2015). However, due to the limited observation time and the fact that presence of individuals in a group might not always represent real associations, data collected may only be an approximation of the entire social structure of the community, leading to biased data. Using a weighted association index removes some sampling bias, since it filters out weak associations (Gazda *et al.*, 2015).

In SOCPROG, the half-weight index is the default index for associations defined as the number of groups, or weighted groups, in which a pair of individuals was observed (Whitehead, 2009). In order to help guarantee that individuals can be reidentified, only those seen at least 5 times during the study period are included in the analysis (Bejder *et al.*, 1998). In other studies with bottlenose dolphin populations, only individuals observed at least 5 times were included in the analysis (e.g. Lusseau *et al.*, 2006; Louis *et al.*, 2015), which was why this was the number used

in the present study. Additionally, in order to avoid demographic effects, such as death or migration, a daily sampling period was used (Bejder *et al.*, 1998).

As in Quintana-Rizzo & Wells (2001), the obtained association indices were distributed by 5 categories: low associations (0.01 – 0.20), moderate-low (0.21 – 0.40), moderate (0.41 – 0.60), moderate-high (0.61–0.80), and high (0.81 – 1.00).

To ensure that associations haven't occurred randomly, and that some associations are preferred or avoided, permutations tests, with variations introduced by Manly (1995) and Bejder *et al.* (1998), were performed (Whitehead, Bejder, & Ottensmeyer, 2005). Analyses were carried out using simulated data sets, involving the same number of individuals and groups as in the observed data, randomly generated so that important features of the original data are retained. In this analysis, dyads for which the association index is higher than expected from random association, are highlighted (Bejder *et al.*, 1998).

In these tests, given that new random matrices differ slightly from the previous ones, random data sets are dependent of each other, and even of the real data. As a result, and since the real matrix is the initial matrix, p-values are biased to extreme values and the number of permutations does not designate an exact p-value. To ensure that the test is not conservative and p-value is accurate, the number of permutations must be increased until stabilization of the p-value is guaranteed. The method introduced by Manly and Bejder generates flips (trials per permutation), in which intersections of 2 rows and 2 columns are sequentially inverted, in a 1:0 matrix. According to simulations performed, 1000 flips is the optimal value in the majority of cases (Whitehead, 2009).

Groups were permuted within samples, since this option accounts for situations in which not all members of the community are found (such as birth, death or emigration). In this option, the null hypothesis is that there are no preferred or avoided association, given the number of groups in which each individual was seen in the sampling period. For short-term associations, the null hypothesis is rejected when the mean of real associations is significantly lower than the permuted data, whereas for long-term associations, the null hypothesis is rejected if the SD of the real associations is significantly high, in comparison to the permuted associations (Whitehead, 2009). Finally, to ensure that the p-value is stable, this test was executed 3 more times (Louis *et al.*, 2015).

Furthermore, analyses were also conducted between age and sex classes. To perform these tests, “from” and “to” sets of individuals were chosen, in each class, where the null hypothesis is that there are no preferred associations between individuals of category “from” and category “to”.

The null hypothesis is, for example, that males have no preferred or avoided associations with particular females, and vice-versa, and adults have no preferred or avoided associations with particular subadults, and vice-versa (Whitehead, 2009). Calves were excluded of these analyses due to their high associations with their presumed mothers.

Differences in overall gregariousness were also tested. In this test, SOCPROG evaluates if there are individuals consistently found in larger or smaller groups than other individuals or if they all have similar typical group sizes, which is the mean group size individuals experience (Whitehead *et al.*, 2005). The null hypothesis that all individuals have similar typical group sizes is rejected when the p-value is higher than 0.95.

In order to guarantee that this representation of social structure is reliable, a measure of social differentiation, or coefficient of variation (CV) of association indices estimated using maximum likelihood, was calculated (Louis *et al.*, 2015). Social differentiation measures variability in social structures, and is defined as the coefficient of variation of the calculated association indices, which is the proportion of time that pairs spent together. Social differentiation less than 0.3 indicates homogeneous societies, greater than 0.5 well differentiated societies, and social differentiation greater than 2.0 indicates extremely differentiated societies (Whitehead, 2009).

2.3.2.3. Mean coefficient of association of the population

After calculating the association coefficients between pairs of individuals of the population, an association matrix is produced, containing the association coefficients between all identified individuals (Whitehead, 2009). Each association index represents the relationship of each dyad, whereas the matrix of association indices among individuals of a population represents the social structure of that population (Whitehead, 2008b).

2.3.2.4. Hierarchical analysis of coefficients of associations (to create dendrograms)

A hierarchical analysis of clusters by average linkage, for the coefficients of association of the population, was performed, resulting in a dendrogram (a graphic representation of the social organization of the population) (Augusto *et al.*, 2012).

In hierarchical cluster analyses, the cophenetic correlation coefficient, defined as the correlation between the clustering levels in the dendrogram and the actual indices of association, is also calculated by SOCPROG. Coefficients with values of 0.8, or above, are considered to effectively represent the social structure of a population (Whitehead, 2009).

Through cluster analysis, performed using complete average linkage (Benmessaoud, Chérif & Bejaoui, 2013), the existence of specific social groups within the population can be inferred, if pairs have relatively high values of coefficients of association (Bejder *et al.*, 1998).

In the resulting dendrogram, the individuals are arranged on one axis and their degree of association on the other, in order to examine relationships between all photo-identified dolphins.

III. RESULTS

During the sampling period, dolphins were found in the Sado estuary, around the peninsula of Tróia, as shown in Figure 3.

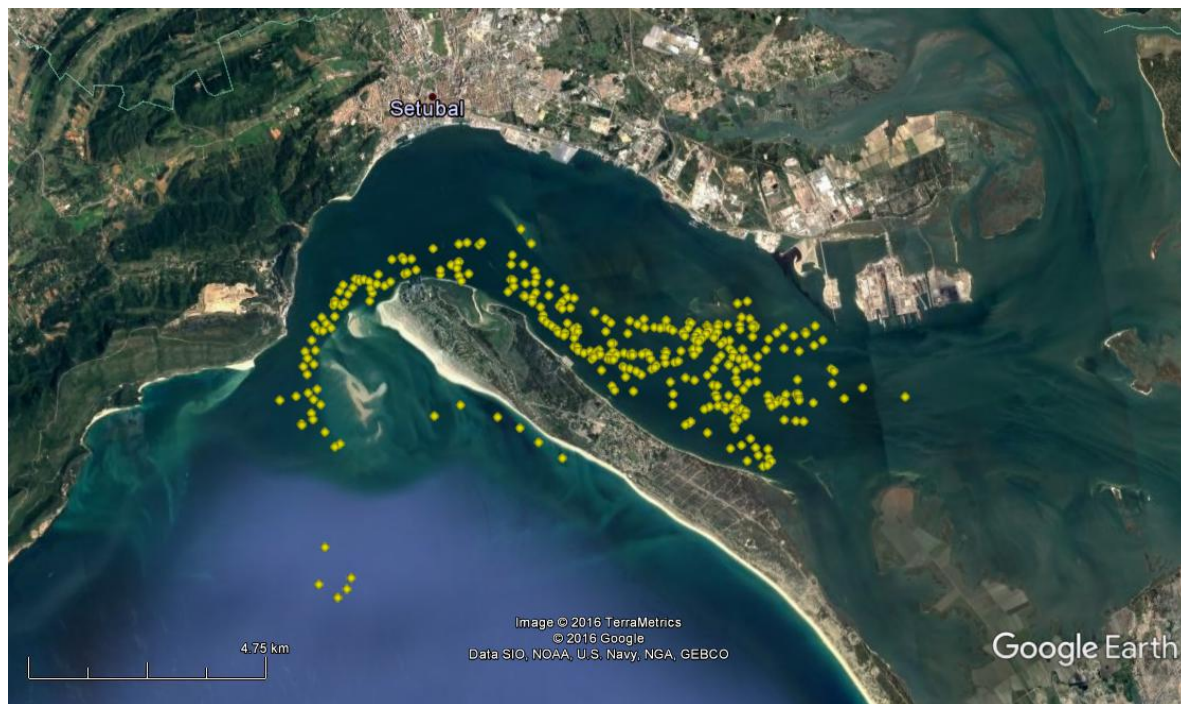


Figure 3. Image showing all the locations of the individuals during the sampling period (N = 96)

3.1. Resident community of Sado estuary

The bottlenose dolphin resident community of the Sado region is made up by 27 individuals (Table 1), in which 7 are considered females, 3 are presumed males, and the sex of the remaining dolphins (17) is undetermined (Fig. 4a). There are 19 (70.37 %) adults, 6 (22.22%) are subadults, and at the time of this sampling there are only two calves, one born in 2014 and the other in 2015, corresponding to 7.41% of the total of individuals (Fig. 4b).

Table 1. Community of bottlenose dolphins of Sado estuary, individual age class and presumed sex (Following Augusto, 2007).

ID	ESTIMATED AGE	AGE CLASS	SEX
AGU	40+	Adult	Presumed female
APA	26	Adult	Unknown
BOM	5	Subadult	Unknown
BUM	40+	Adult	Presumed female
CLU	17	Adult	Presumed male
DAR	10	Adult	Presumed male
ELE	40+	Adult	Presumed female
FAC	38+	Adult	Presumed female
GOR	37+	Adult	Presumed female
HIG	4	Subadult	Unknown
HUX	9	Adult	Unknown
LAM	11	Adult	Unknown
MAR	1	Calf	Unknown
MED	11	Adult	Unknown
MID	16	Adult	Unknown
MIS	4+	Subadult	Unknown
MUR	40+	Adult	Presumed male
POS	6	Subadult	Unknown
QUA	37+	Adult	Presumed female
SAL	2	Calf	Unknown
SPI	16+	Adult	Unknown
TAI	6	Subadult	Unknown
TAL	38+	Adult	Unknown
THO	38+	Adult	Unknown
TRO	5	Subadult	Unknown
TRU	36+	Adult	Presumed female
ZOE	23+	Adult	Unknown

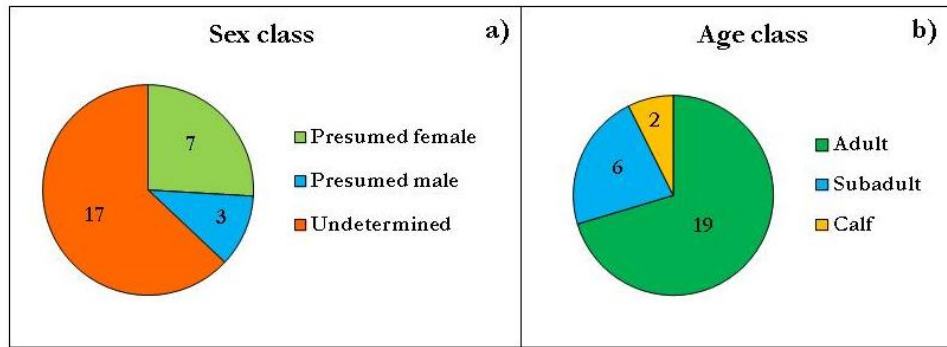


Figure 4. Abundance of each class, classified by a) age and by b) sex .

3.2 Group composition

During the sampling period, 96 groups were observed, varying between 1 and 26 individuals. The mean group size in this community is 11.61 dolphins, with a SD of ± 5.72 (Table 2).

The most frequent group class was composed by adults, subadults and calves, whereas the least frequent classes were subadults only, and adults and calves. No groups composed by subadults and calves were found during the sampling period (Fig. 5).

Table 2. Minimum and maximum sizes, and number of groups, for each group category in the community.

Category	Minimum size	Maximum size	No. groups	Mean group size	SD
Adults	1	10	7	4.40	3.82
Subadults	2	2	1	2	-
Adults + subadults	2	19	40	9.50	4.72
Adults + subadults + calves	6	26	47	14.80	4.62
Adults + calves	4	4	1	4	-
Total			96	11.61	5.72

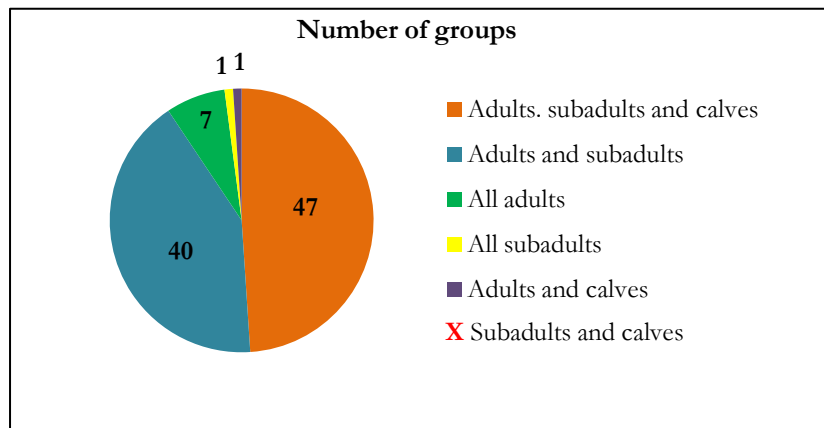


Figure 5. Number of groups for each age category.

Group sizes for each age category do not follow a normal distribution, according to the Shapiro-Wilk test for normality ($W = 0.75; p < 0.001$). For this reason a non-parametric ANOVA (Kruskal-Wallis ANOVA) was performed.

Since the null hypothesis was rejected ($H_{(4, N=96)} = 35.77; p < 0.001$), there are differences in the mean group sizes among distinct age class categories.

3.3. Group size according to activity patterns

During the sampling period, travelling was the most observed activity, following by search for prey and feeding, socialization and, for last, resting (Table 3 & Fig. 6).

Table 3. Number of groups, minimum and maximum sizes, mean group size and SD, for each activity pattern.

Activity pattern	No. groups	Minimum size	Maximum size	Mean group size	SD
Travelling	71	1	26	11.92	5.90
Search of prey and feeding	14	6	20	10.71	4.36
Socialization	9	2	22	11.33	5.85
Resting	2	1	16	8.50	10.61
Total	96			11.61	5.72

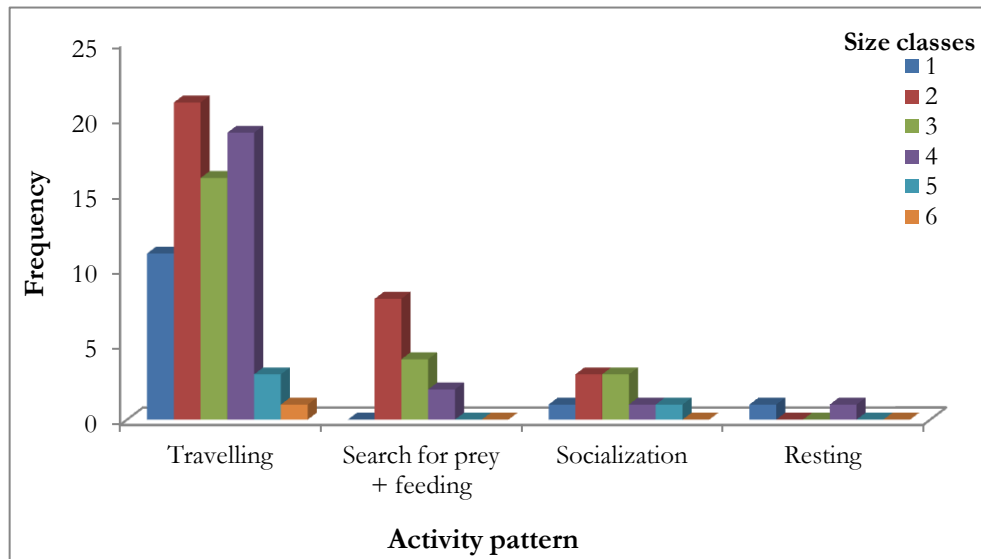


Figure 6. Frequency of group sizes, for each activity pattern. Class 1 of size represents groups from 1 to 5 individuals; class 2 groups from 6 to 10 individuals; class 3 groups from 11 to 15 individuals; class 4 groups from 16 to 20 individuals; class 5 groups from 21 to 25 individuals; and class 6 groups from 26 to 30 individuals

Once more, the mean size of groups among activity patterns does not follow a normal distribution ($W = 0.59$; $p < 0.001$). There are no differences in the mean group sizes, between activity patterns ($H_{(3, N=96)} = 0.98$; $p = 0.807$), therefore the null hypothesis was accepted.

3.4. Group size for each to spreading degree

Groups were observed predominantly in the spreading degree II (individuals separated by about 3 body lengths). Individuals, in groups, are less frequently found in the spreading degrees V (Table 4 & Figure 7).

Table 4. Minimum and maximum sizes, number of groups, and mean size group and standard deviation, for each spreading degree.

Spreading degree	Minimum size	Maximum size	No. Groups	Mean group size	SD
I	2	18	16	8.94	4.96
II	3	26	39	12.36	5.76
III	4	20	22	12.36	4.78
IV	4	24	12	14.75	5.40
V	6	16	4	9.50	4.51

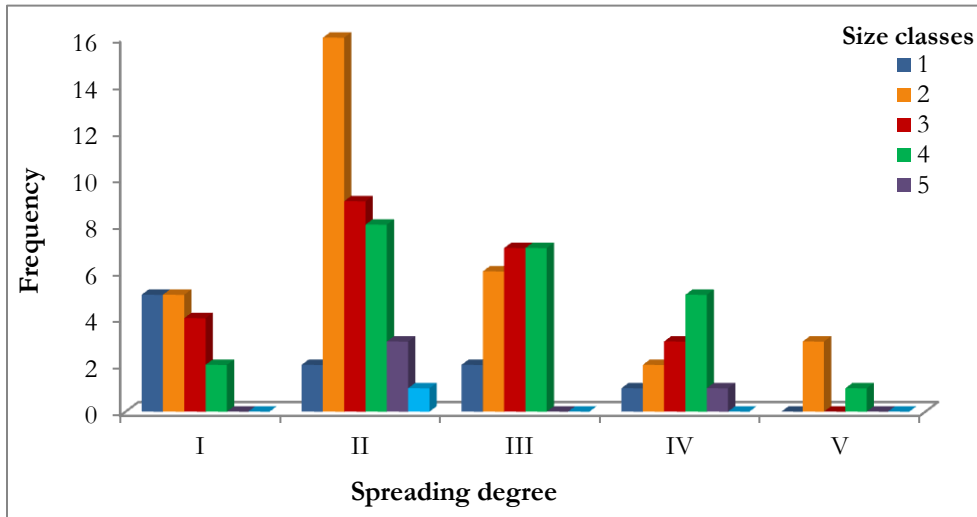


Figure 7. Frequency of groups, for each spreading degree. Class 1 of size represents groups from 2 to 5 individuals; class 2 groups from 6 to 10 individuals; class 3 groups from 11 to 15 individuals; class 4 groups from 16 to 20 individuals; class 5 groups from 21 to 25 individuals, and class 6 groups from 26 to 30 individuals

According to the Shapiro-Wilk normality test ($W = 0.88$; $p < 0.001$), mean group sizes for each aggregation degree do not follow a normal distribution. Therefore a non-parametric ANOVA (Kruskal-Wallis ANOVA) was performed. In spite of the higher observations of groups in spreading degree II, the null hypothesis that there are no significant differences between mean group sizes for each spreading degree was accepted ($H_{(4, N=93)} = 8.71$; $p = 0.069$).

3.5. Group size for each spreading degree within each activity pattern

The most frequently observed groups were in a tight aggregation (spreading degree II), while travelling. No groups were found in very tight aggregation while search for prey and feeding, nor dispersed groups (spreading degree V) during socialization (Fig. 8).

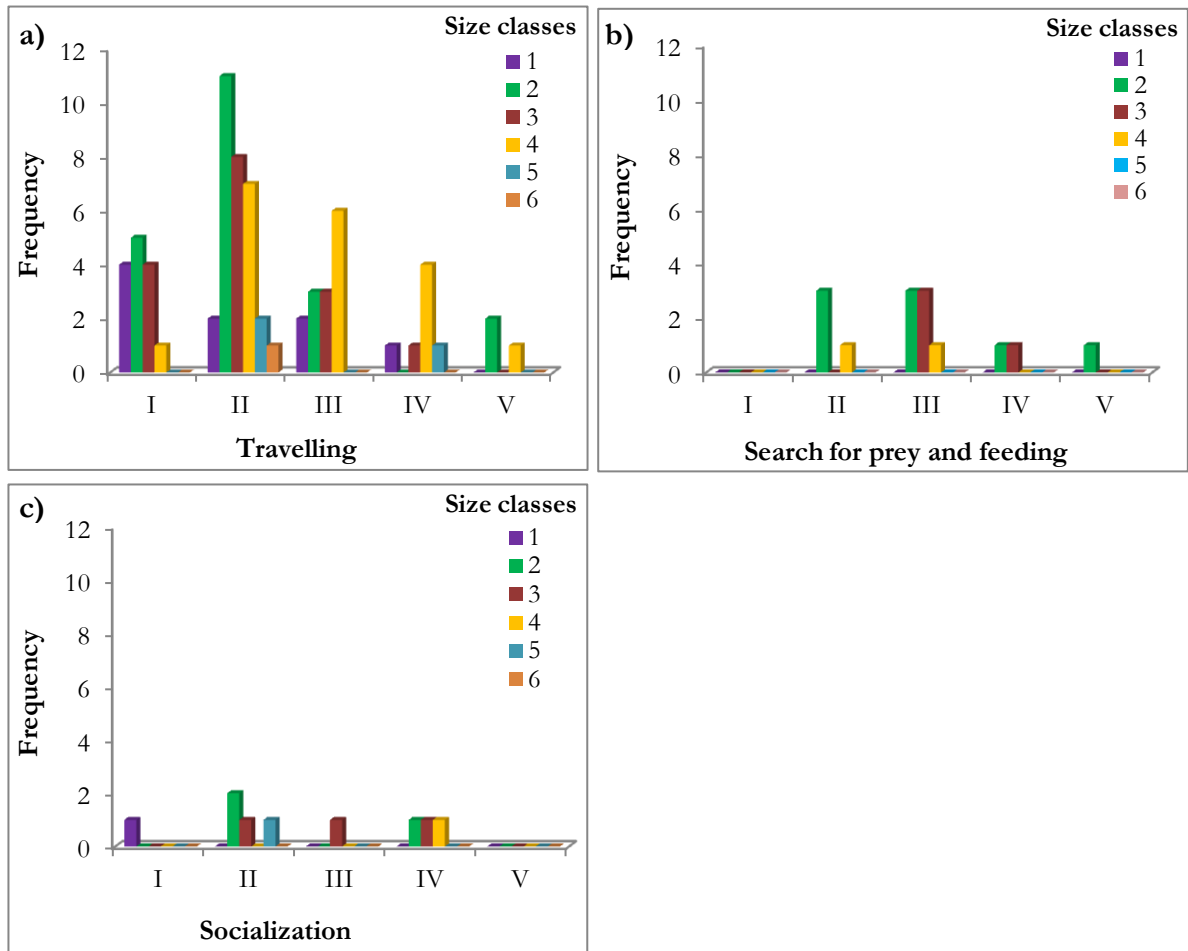


Figure 8. Frequency of group sizes, for each spreading degree, a) during traveling b) during search for prey and feeding; c) socialization. Class 1 of size represents groups from 2 to 5 individuals; class 2 groups from 6 to 10 individuals; class 3 groups from 11 to 15 individuals; class 4 groups from 16 to 20 individuals; class 5 groups from 21 to 25 individuals, and class 6 groups from 26 to 30 individuals.

Individuals tend to travel in a tight aggregation (spreading degree II), and travel less in very dispersed groups (spreading degree V) (Table 5).

Table 5. Minimum and maximum sizes, number of groups, and mean size group and standard deviation, for each spreading degree, during travelling.

Spreading degree	Minimum size	Maximum size	No. Groups	Mean group size	SD
I	2	18	14	8.93	4.57
II	3	26	31	12.55	5.74
III	4	20	14	13.14	5.32
IV	4	24	7	16.29	6.24
V	7	16	3	10.67	4.73

According to the Shapiro-Wilk normality test ($W = 0.87$; $p\text{-value} < 0.001$), group sizes for different spreading degrees do not follow a normal distribution. Consequently a non-parametric ANOVA (Kruskal-Wallis ANOVA) was performed. The null hypothesis that there are no significant differences in the mean group sizes, for different spreading degrees, was also accepted ($H_{(4, N=69)} = 8.90$; $p = 0.064$).

While feeding and searching for prey, groups were mostly found in a loose aggregation (spreading degree III). No groups were found in a very tight aggregation (spreading degree I) (Table 6).

Table 6. Minimum and maximum sizes, number of groups, and mean size group and standard deviation, for each spreading degree, during search for prey and feeding.

Spreading degree	Minimum size	Maximum size	No. Groups	Mean group size	SD
I	0	0	0	0	0
II	6	20	4	10.75	6.29
III	7	17	7	10.86	3.80
IV	10	15	2	12.50	3.54
V	6	6	1	6	-

According to the Shapiro-Wilk normality test ($W = 0.85$; $p = 0.020$), group sizes according to spreading degree do not follow a normal distribution. As a result a non-parametric ANOVA (Kruskal-Wallis ANOVA) was performed.

Since the null hypothesis was accepted ($H_{(3, N=14)} = 2.921$; $p = 0.404$), within the category “Feeding and search for prey”, there are no differences in the mean group size, for different aggregation degrees.

During socialization activities, groups were essentially found in tight and dispersed aggregations degrees (II and IV, respectively). No groups were found in a very dispersed aggregation degree (V) (Table 7).

Table 7. Minimum and maximum sizes, number of groups, and mean size group and standard deviation, for each aggregation degree, during socialization.

Spreading degree	Minimum size	Maximum size	No. Groups	Mean group size	SD
I	2	2	1	2.00	0.00
II	7	22	4	12.50	6.86
III	12	12	1	12.00	0.00
IV	8	16	3	12.67	4.16
V	0	0	0	0.00	0.00

According to the Shapiro-Wilk normality test ($W = 0.84$; $p = 0.065$), group sizes according to spreading degree follow a normal distribution. As a result a parametric ANOVA (One-way ANOVA) was performed.

The Bartlett test for homogeneity of variances was performed and the null hypothesis that there are no differences between variances was accepted ($\chi^2_{(1)} = 0.45$; $p = 0.504$). Once again, in the “socialization” category, the null hypothesis that there are no differences in the mean group sizes for different spreading degrees was accepted ($F_{(3)} = 0.93$; $p = 0.489$).

During resting, only one group, in a very tight aggregation (spreading degree I) was observed (Table 8). For this reason, statistical analysis was not conducted.

Table 8. Minimum and maximum sizes, number of groups, and mean size group and standard deviation, for each spreading degree, during resting.

Spreading degree	Minimum size	Maximum size	No. Groups	Mean group size	SD
I	16	16	1	16	-
II	0	0	0	0	0
III	0	0	0	0	0
IV	0	0	0	0	0
V	0	0	0	0	0

3.6. Social structure

During the sampling period, 20700 photographs were obtained, of which 15201 (73.76%) were used for the associations' analysis. Nearly half of the association indices between pairs are moderate-low and less than 10% are moderate-high to high association indices.

The present sampling of this community produced a mean coefficient of association of 0.25 (± 0.09), and the matrices of association and standard errors associated to the analysis, using the HWI and having group as sampling unit, are both presented in appendices (III and IV). The matrix of standard errors (SE) was obtained using the method "Bootstrap replicates", with 1000 permutations.

Most of the associations are moderately-low (51%), and less than 5% are high associations (Fig. 9).

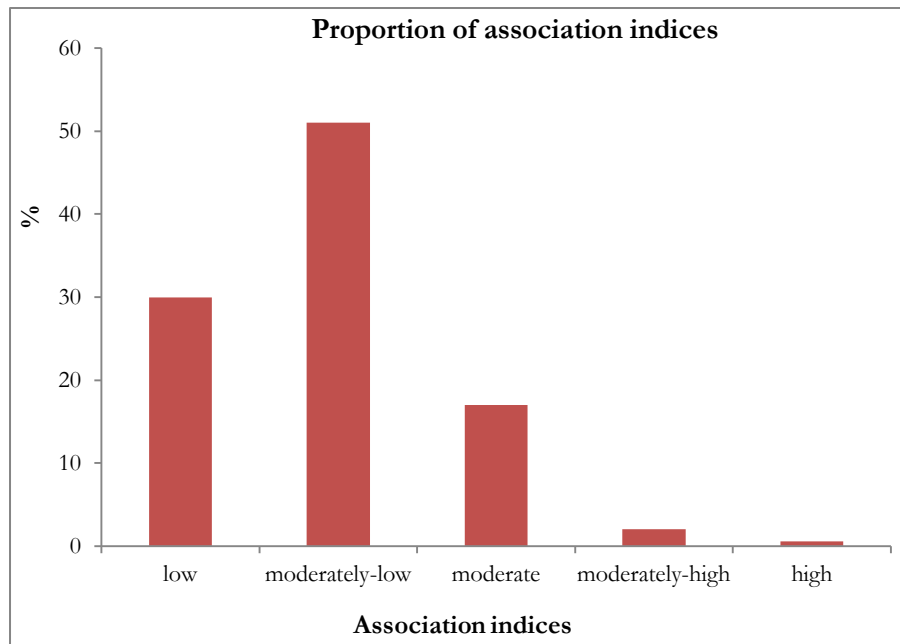


Figure 9. Proportion of association indices for each category. Low - 0 to 0.2; Moderately-low - 0.21 to 0.4; Moderate - 0.41 to 0.6; Moderately-high - 0.61 to 0.8; High - 0.81 to 1.0 (According to Quintana-Rizzo & Wells, 2001).

3.6.1. Association matrices

Table 9. Matrix of associations between presumed females.

AGU	1.00								
BUM	0.08	1.00							
ELE	0.46	0.31	1.00						
FAC	0.31	0.08	0.54	1.00					
GOR	0.50	0.25	0.33	0.67	1.00				
HUX	0.52	0.17	0.17	0.17	0.19	1.00			
LAM	0.59	0.15	0.37	<u>0.81</u>	0.40	0.42	1.00		
QUA	0.27	0.27	0.18	0.27	0.30	0.21	0.35	1.00	
TRU	0.40	0.32	0.16	0.40	0.35	0.36	0.54	0.38	1.00
	AGU	BUM	ELE	FAC	GOR	HUX	LAM	QUA	TRU

Table 10. Matrix of associations between subadults.

BOM	1.00					
HIG	0.36	1.00				
MIS	0.08	0.22	1.00			
POS	0.36	0.47	<u>0.00</u>	1.00		
TAI	0.36	0.53	0.30	0.67	1.00	
TRO	0.37	0.21	0.08	0.34	0.48	1.00
	BOM	HIG	MIS	POS	TAI	TRO

Table 11. Matrix of associations between males

CLU	1.00		
DAR	0.07	1.00	
MUR	0.22	0.29	1.00
	CLU	DAR	MUR

Table 12. Matrix of associations between presumed females and calves.

AGU	0.32	0.25
BUM	0.08	0.17
ELE	0.32	0.00
FAC	0.40	0.17
GOR	0.17	0.18
HUX	0.27	<u>0.95</u>
LAM	<u>0.92</u>	0.32
QUA	0.19	0.00
TRU	0.25	0.26
	MAR	SAL

Table 14. Matrix of associations between presumed females and subadults.

AGU	0.31	0.43	0.08	0.43	0.50	0.37
BUM	0.08	0.07	<u>0.00</u>	0.14	0.07	0.37
ELE	0.23	0.36	<u>0.00</u>	0.43	0.43	0.30
FAC	0.08	0.36	<u>0.00</u>	0.29	0.43	0.52
GOR	0.33	0.31	0.17	0.62	0.23	0.72
QUA	0.00	0.17	<u>0.00</u>	0.17	0.17	0.26
TRU	0.40	0.37	0.08	0.30	0.37	0.77
	BOM	HIG	MIS	POS	TAI	TRO

Table 13. Matrix of associations between presumed males and presumed females.

CLU	0.31	0.31	0.15	0.31	0.17	0.36	0.00
DAR	0.59	0.22	0.37	0.30	0.56	0.17	0.38
MUR	0.30	0.15	0.37	0.37	0.32	0.35	0.31
	AGU	BUM	ELE	FAC	GOR	QUA	TRU

Most of the associations indices among presumed females are moderately-low, and there is one high association indice, FAC and GOR, with an association indice of 0.81 (Table 9). Among subadults there are no high association indices and one pair of individuals was not found is association, POS and MIS with an association indice of 0.00 (Table 10). Presumed males only have low and moderately-low association indices between them (Table 11).

Although LAM and MAR, and HUX and SAL have the highest association indices, the majority of association indices are low and moderately-low (Table 12). There are no moderate or moderately-high associations between presumed females and calves, and one pair of individuals (ELE and SAL) was not found associated (association indice of 0.00). There are no high association indices between presumed females and subadults, and MIS was found associated with only 3 presumed females (Table 13). Additionally, no high or moderately-high associations were found between presumed males and presumed females (Table 14).

3.6.2. Permutations tests

In the permutation tests for random associations, p-values started to stabilize at 10000 permutations, with 1000 flips (trials per permutation) and a significance level of 0.05. Null hypothesis are rejected when p-values for the mean (short-term preferred associations) and for SD (long-term preferred associations) are higher than 0.95 (1-sided tests) and p-values for which null hypothesis of random associations was rejected are written in bold.

For the test of sociality (1-sided), null hypotheses are rejected when the p-value of the SD of typical group size is higher than 0.95 (Table 15).

Table 15. Values of the mean, standard deviation (SD), proportion mean/SD (CV) and SD for typical group size, for the real coefficients of association, permuted data, and corresponding p-values. Results for the entire community, between adults (From: Adult To: Adult), between subadults (From: Subadult To: Subadult) and between adults and subadults (From: Adult To: Subadult; From: Subadult To: Adult)

		Mean	SD	CV	SD (Typical group size)
Community	Real	0.28	0.17	0.60	0.23
	Permuted	0.41	0.18	0.16	0.16
	<i>p-value</i>	1.000	0.968	<0.001	<0.001
Community (after 3 repetitions)	Real	0.28	0.17	0.60	0.23
	Permuted	0.40	0.18	0.44	0.16
	<i>p-value</i>	1.000	0.992	<0.001	<0.001
From: Adult To: Adult	Real	0.27	0.16	0.57	0.21
	Permuted	0.41	0.16	0.43	0.17
	<i>p-value</i>	1.000	0.999	<0.001	<0.001
From: Adult To: Subadult	Real	0.29	0.17	0.61	0.10
	Permuted	0.35	0.18	0.52	0.05
	<i>p-value</i>	1.000	0.89	<0.001	0.034
From: Subadult To: Adult	Real	0.29	0.17	0.61	0.09
	Permuted	0.37	0.18	0.49	0.06
	<i>p-value</i>	1.000	0.841	<0.001	<0.001
From: Subadult To: Subadult	Real	0.34	0.16	0.47	0.08
	Permuted	0.41	0.19	0.45	0.04
	<i>p-value</i>	1.000	0.895	0.372	0.013

The null hypothesis was rejected in all permutation tests. There are preferred associations and most of them are short-term associations (Mean, $p = 1.000$). Among adults there are also long-term preferred associations among adults (SD, $p = 0.999$).

In the tests for sociality, none of the null hypotheses was rejected. All individuals experience similar typical group sizes.

Permutation tests were also performed between and within sexes, with the null hypothesis stating that all associations are random (Table 16).

Table 16. Values of the mean, standard deviation (SD), proportion mean/SD (CV) and SD for typical group size, for the real coefficients of association, permuted data, and corresponding p-values. Results for the entire community, between males (From: Male To: Male), between females (From: Female To: Female) and between males and females (From: Male To: Female; From: Female To: Male)

		Mean	SD	CV	SD (Typical group size)
From: Male	Real	0.19	0.10	0.50	0.02
	Permuted	0.28	0.12	0.41	0.01
	<i>p-value</i>	0.998	0.610	0.276	0.359
To: Male	Real	0.32	0.12	0.37	0.02
	Permuted	0.43	0.13	0.31	0.02
	<i>p-value</i>	1.000	0.861	0.068	0.512
From: Female	Real	0.32	0.12	0.37	0.03
	Permuted	0.39	0.13	0.34	0.03
	<i>p-value</i>	1.000	0.824	0.245	0.554
To: Female	Real	0.33	0.14	0.44	0.06
	Permuted	0.47	0.13	0.28	0.04
	<i>p-value</i>	1.000	0.270	<0.001	0.067

In all tests, the null hypothesis that there are no preferred or avoided associations was rejected. Also, preferred associations between and within sex classes are short-term and long-term preferred associations were not found.

In the tests for sociality, the null hypotheses that all individuals have similar typical group sizes were accepted. Therefore, there are no individuals found in preferentially larger or smaller groups compared with other individuals, and individuals in the class “From” associate with the same number of individuals in the class “To”.

The coefficient of variation is 0.50 (SE = 0.09), meaning that this is a well differentiated community. The correlation between calculated and estimated association indices is of 0.67 (SE = ± 0.04), which indicates a very good estimate of the real social structure for this community.

3.6.3. Hierarchical cluster analysis

The following dendrogram (Fig. 10), based on the matrix of associations, has a cophenetic correlation coefficient of 0.80.

In this dendrogram, individuals are organized in a large group, with exception for MID, MIS and TAL. Apart from these dolphins, all individuals have association indices greater than

0.20, and at this point it is possible to distinct two subgroups. One constituted by BUM, QUA, MED, CLU and APA, and the other subgroup by the remaining individuals. The strongest associations correspond both to calves and their mothers - SAL and HUX, MAR and LAM. There is also another significant cluster, composed by MED, CLU and APA, in which the three individuals are associated together, with the same association indice, composing a tryad (association indice of about 0.60).

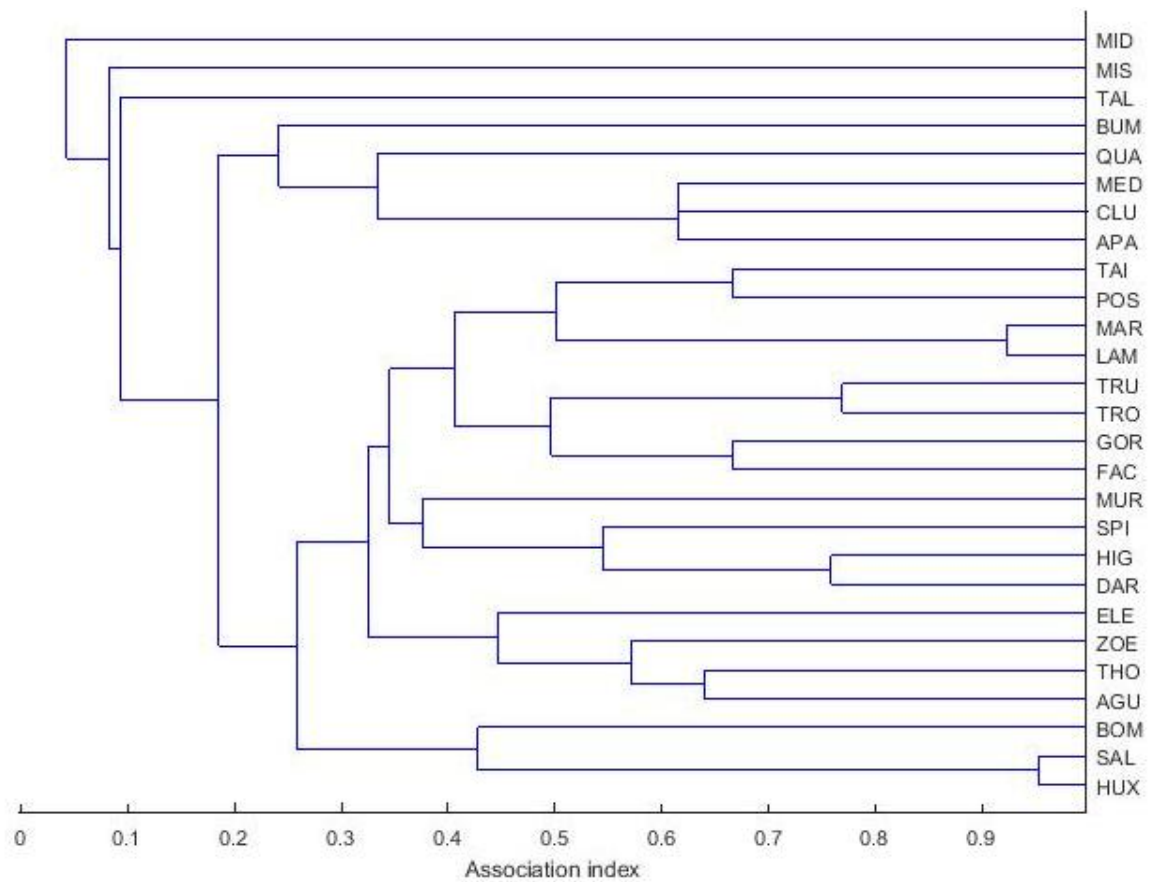


Figure 10. Dendrogram of all associations of the entire community, through hierarchical cluster analysis. In the vertical axis, there are represented the individuals of the community, whereas the horizontal axis represents the association indices between each pair of individuals

IV. DISCUSSION

The resident bottlenose dolphin community of the Sado estuary is composed by 27 individuals, in which more than half of them are adults. In this study, group composition and size, as well as the social structure of the community were analyzed. These parameters are important in terms of assessment of population viability, and to develop strategies for the management and conservation of this community.

4.1. Census of the community

The small size of this community of the Sado region makes it possible to carry out a complete census. Censuses were made through photo-id, which is a frequently used method in studies of social structure. Although this is a common technique, it has some constraints. It is rarely possible to photograph individuals from different groups at the same time, which may lead to biased data collection. Also, ID might not be possible due to out-of-focus photographs or individuals photographed at unfavorable angles. Also, calves and subadults do not usually have very distinguishable marks on their dorsal fins, making their identifications difficult. Additionally, indices are calculated only based on associations at the surface, and it is not possible to observe how the animals move while underwater.

To prevent these constraints, it is necessary to increase the sampling period, as well as the number of photographs of the individuals.

During the sampling period, groups were mostly found in the south channel, generally around Tróia, and between “Canal da Comporta” and LISNAVE. This might be due to the fact that the south channel, in comparison to the north channel, has more prey abundance and diversity (dos Santos & Lacerda, 1987; Harzen, 1998) and it is less polluted due to the lack of industries there (Caeiro *et al.*, 2009).

There were no records of interactions with non-resident bottlenose dolphins, during the sampling period. For these reasons, this community appears to be philopatric and closed (Augusto, 2007; Augusto *et al.*, 2012), however it is necessary to collect more data, throughout the years, to assess the permanence of this situation.

This small community is also aged, since almost $\frac{3}{4}$ of the individuals are adults, and about 53% of them are older than 35. The age of the majority of adult individuals is probably

underestimated, given that it was predicted based on the first year of sighting, when individuals were already adults and assumed to be at least 5 years old. The real age is only known for 14 individuals.

In other studies worldwide, the age of most individuals is also undetermined. In Moray Firth, only 36 individuals (of 182 photo-identified dolphins) are positively identified as adults (19 females and 17 males) (Eisfeld, 2003). From the 163 identified dolphins in the community of Sarasota Bay, 85 are adults and 62 are subadults (Wells, 2014).

Additionally, sex is also undetermined for most individuals of this community, similarly to other communities worldwide. In the community of Doubtful Sound, from the 83 identified dolphins, 36 are known females and 37 are males (Lusseau *et al.*, 2003), whereas in the community of Cedar Keys (Florida), sex is only known for 36 individuals (27 females and 9 males), from 233 identified dolphins (Quintana-Rizzo & Wells, 2001).

At the moment, this community is composed by 6 subadults and 2 calves. Given that there was a 10-year period where no calves had survived, the survival of these individuals is a positive aspect for the community.

In nature, individuals can live longer than 40 years old (Connor *et al.*, 2000) and, comparing this value with the ages in the community it is expected that half of the individuals from the Sado community will disappear during the next years. On the other hand, given that there is no indication of reproductive senescence for this species, females can stay reproductively active after their early forties (Reynolds *et al.*, 2000; Eisfeld, 2003).

4.2. Group structure

In this study, mean group size is similar to previous works (dos Santos & Lacerda, 1987; Augusto, 2007; Augusto *et al.*, 2012), whereas typical group size is lower (Augusto *et al.*, 2012).

Other bottlenose dolphin communities worldwide have similar mean group sizes, although this is a higher mean group size in comparison to other estuarine communities (see table 1 in *Review of literature*). Different definitions of “group” have been used (Connor *et al.*, 2000; Benmessaoud *et al.*, 2013; Titcomb *et al.*, 2015) so it is not easy to make comparisons among distinct studies.

Groups composed by all members of the community were not found during the sampling period, which is consistent with the definition of fission-fusion society, where groups constituted by all individuals together are rarely found (Connor, Smolker & Richards, 1992).

Groups composed by all ages were the most frequently observed during the sampling period, which is consistent with previous studies with this community (Augusto, 2007; Augusto *et al.*, 2012) and with other communities (Félix, 1997; Pereira, Martinho, Brito, & Carvalho, 2013). As in Augusto *et al.* (2012) the largest groups are composed by adults, subadults and calves, similarly to other studies (Félix, 1997; Campbell *et al.*, 2002; Augusto, 2007; Blasi & Boitani, 2014), which might correspond to a calf protection strategy (Gibson & Mann, 2008).

However, in previous studies in this community, groups composed by subadults and calves were found, whereas groups composed by subadults were absent (Augusto, 2007; Augusto *et al.*, 2012), contrary to the current study. Similarly, other communities' groups composed only by adults and only by subadults are rare (e.g. Félix, 1997), which seems to be typical of communities of bottlenose dolphins.

Group size might have seasonal variances (Campbell *et al.*, 2002; Gowans, Würsig & Karczmarski, 2007; Vermeulen & Cammareri, 2009; Benmessaoud *et al.*, 2013). However, no data collection was made from December to March, so it was not possible to analyze influences of seasonality in grouping patterns.

4.2.1. Group size for different activity patterns and spreading degrees in groups

As in other studies (Bearzi, 2005; Blasi, Giuliani & Boitani, 2015), “travelling” was the most frequent activity pattern recorded, followed by search for prey and feeding, and socialization. Small groups, composed by 6 to 10 individuals, were the most frequent during foraging and feeding. In socialization, most of the groups had intermediate sizes, composed by 6 to 15 individuals.

Mean group size was similar in the four main activity patterns, as reported by a previous study (Augusto, 2007), and in all spreading degrees. However, it is contrary to what has been reported in earlier studies of this community (dos Santos & Lacerda, 1987), as well as in other studies worldwide (Bouveroux & Mallefet, 2009; Vermeulen & Cammareri, 2009; Durden, Stolen & Stolen, 2011). The most frequent spreading degree was II, followed by spreading degree III. Generally, individuals do not tend to be very dispersed or in a very tight spreading degree, which is an expression of their fluid and dynamic social system.

In previous works (Bouveroux & Mallefet, 2009; Vermeulen & Cammareri, 2009; Durden *et al.*, 2011), mean group size was larger during search for prey and feeding and, in this activity pattern, spreading degree III was the most common. Differences of group size (Durden *et al.*,

2011; Blasi & Boitani, 2014) and spreading degree (Bearzi, 2005; Gowans *et al.*, 2007) of groups might be connected to distinct foraging strategies of the individuals.

While travelling, spreading degree II was the most frequent, particularly in groups composed by 6 to 10 individuals. During feeding and search for prey, there were no differences in the mean group size, for different spreading degrees and, when socializing, individuals were found in a tight aggregation (spreading degree II) or dispersed (spreading degree IV).

Different spreading degrees might be associated to different activity patterns and/or different group sizes. However, there might be some constraints associated with the analyzes of spreading degree of groups. This was the first study of this community where spreading degree of groups was measured, and it was only estimated based on visual observations of the groups at the surface. Therefore, it might not be a very accurate measure of the real aggregation/spreading patterns of groups.

There are no significant differences in the mean group sizes for different spreading degrees or in the spreading degrees of “travelling” groups. However, increasing the sampling period and, thus, the number of groups in different spreading degrees and activity contexts, could reveal significant variation in mean group sizes.

4.3 Social structure

The mean association indice for the entire community is lower than the previously obtained (Harzen, 1995; Augusto, 2007; Augusto *et al.*, 2012). However, it is in the same range of the most studies with common bottlenose dolphin, whose association indices vary between 0.1 and 0.3 (e.g. Connor *et al.*, 2000; Quintana-Rizzo & Wells, 2001; Vermeulen & Cammareri, 2009; Pereira *et al.*, 2013). Since these association patterns are found in many communities of bottlenose dolphin worldwide, they seem to be characteristic of the species.

In the last study of social structure (Augusto *et al.*, 2012), this community was composed by 24 individuals, and groups had a mean size of 7.75 (\pm 6.37). The mean association indice of the community was 0.45 (\pm 0.15), with a social differentiation of 0.38. The community is now constituted by 27 individuals, the mean group size obtained is higher (11.6 \pm 5.72), as well as the social differentiation measure (0.50). However, the mean CoA of the community had decreased (0.25 \pm 0.09). From the beginning of the last study (Augusto *et al.*, 2012) until now, 7 individuals have disappeared of the community (CAL, LIN, LUA, RED, TIP, TUD and WAL), by death or migration, and 7 have been born since then (BOM, HIG, MAR, MIS, POS, SAL and TRO). Also,

long-lasting associations among individuals have become absent, and only short-term preferred associations were found.

In previous studies (Harzen, 1995; Augusto, 2007; Augusto *et al.*, 2012) the mean coefficient of association for this community varied between 0.38 and 0.45, higher than the obtained in this study. This result might be due to the existence of a period of about 10 years without survival of the calves, leading to an increased protection of the existing calves and subadults and, consequently, higher coefficients of association in this study.

Most association indices were low and moderately-low, and only a small percentage was high. These values are similar to coefficients of association found in other communities of bottlenose dolphin (Vermeulen & Cammareri, 2009; Benmessaoud *et al.*, 2013; Pereira *et al.*, 2013) and are characteristic of fission-fusion societies, composed by highly fluid groups whose composition changes throughout short periods of time.

Moreover, indices of association might be influenced by group sizes, given that in larger groups several potential associations between individuals can be found (see e.g. Pereira *et al.*, 2013). On the other hand, some individuals seem to have stable associations over time, since a small number of dyads has moderately-high to high association indices.

According to Whitehead (2008a), the mean association indice for a community is better estimated by the ratio between typical group size and community size, minus 1. For this reason, association indices are affected by both community size and typical group size and, in smaller communities, with a small typical group size, the mean association indice will also be low.

Similarly to the community of Moray Firth (Eisfeld, 2003), no alliances between males were found during the sampling period, contrary to the communities of Sarasota Bay, Shark Bay (Connor *et al.*, 1992; Connor *et al.*, 2000) and Doubtful Sound (Lusseau, 2007), for example. Community size or habitat characteristics might influence alliance formation, given that in small communities (Connor *et al.*, 2000; Brusa, Young & Swanson, 2016) and in communities inhabiting open estuarine systems (e.g. Quintana-Rizzo & Wells, 2001), male alliances appear to be absent. Also, in larger communities there is increased competition between males over females, supporting formation of male alliances in these communities (Connor *et al.*, 2000). However, it is not possible to discuss these possibilities with this particular community due to the scarcity of positive identifications of males.

The majority of associations among presumed females was low to moderately-low. Only one high association was found (LAM and FAC), which indicates a strong affiliation between these two presumed females. However, HUX and LAM, which are supposedly in similar reproductive conditions, have a moderate association index, contrary to what was expected, given

that in some communities females in similar reproductive status condition tend to have stronger associations (Blasi & Boitani, 2014). These patterns of association among females are also found in other communities (e.g. Sarasota Bay, Wells *et al.*, 1987). Contrary to other studies (e.g. Félix, 1997; Blasi & Boitani, 2014), females of this community do not appear to form bands, due to the high number of low and moderately-low associations indices. Due to inner-birth intervals, strength of associations among females might change through the years (Blasi & Boitani, 2014), as females might preferentially associate with other females in the same reproductive condition (Shane, Wells & Würsig, 1986; Connor *et al.*, 2000).

Females have more varied and stronger associations than males, as observed in communities of Shark Bay and Sarasota Bay (Connor *et al.*, 2000; Connor & Krützen, 2015). These distinct association patterns may be related to different uses of resources or their availability (Connor *et al.*, 2000), or reciprocal support strategies.

Most of the associations among presumed males and presumed females are moderately-low association indices. This pattern of association is generally dependent on the females' reproductive state, but it might also be affected by anthropogenic impacts and relatedness of the individuals (Eisfeld & Robinson, 2004).

HUX and LAM were considered females due to the high association indices with calves (HUX and SAL – 0.95; LAM and MAR – 0.92) (following Connor *et al.*, 2000; Benmessaoud *et al.*, 2013). In this community there are strong associations between females and their dependent calves, which is consistent to long-term studies in other bottlenose dolphin communities worldwide (Shark Bay, Gibson & Mann, 2008; Sarasota Bay, Connor *et al.*, 1992; Connor *et al.*, 2000; Wells *et al.*, 1987; Moray Firth, Eisfeld, 2003), and they are known to be the strongest bonds among bottlenose dolphins (Wells *et al.*, 1987).

There are long-term preferred associations among adults, and associations are primarily “short-term preferred”, within and between both sex and age classes, as in previous studies (e.g. Augusto, 2007). However, bottlenose dolphins within the same community tend to have stronger and long-term preferred associations (Quintana-Rizzo & Wells, 2001).

Given the social differentiation measure of 0.5, relationships in the community are heterogeneous. Social differentiation of the resident community of Sado estuary is similar to other communities (Blasi & Boitani, 2014; Titcomb *et al.*, 2015) yet, its higher than previously obtained for this community (Augusto *et al.*, 2012) Also, there are differences in gregariousness, with some adults being in significantly larger or smaller groups than others.

This community lives in a large-mixed group, with the exception of three individuals that were not found associated with any of the other individuals. There is no clear division in subunits

however, two groups of individuals tend to spend more time together than with other individuals, which is not usual for bottlenose dolphin communities. This type of organization is also found in the Doubtful Sound community (Lusseau *et al.*, 2003) and it might be related to geographic isolation of these communities.

Moreover, it might be relevant to determine whether the removal (by death or emigration) of older individuals, that have lived in the community for a long time (LUA, for example), has influence in the social structure and existence of preferred or avoided companionships in this community. Individuals that used to be associated with LUA and with each other in 2012 (FAC, TRU, AGU, CLU and BUM) (Augusto, 2007; Augusto *et al.*, 2012), were not found associated together in the present study. After LUA's death, these individuals were found dispersed throughout the community, being associated with other animals.

The removal of individuals from a particular community has varied consequences in terms of social stability (Blumstein, 2010), its size, and might have influence in the functional roles of each individual, and the structural properties of the entire community (Wiszniewski, Lusseau & Möller, 2010).

In addition, Lusseau & Newman (2004) consider that distinct individuals have different associations within communities and their removal might have great impacts on the communities. Association patterns might be particularly important, especially in communities with small size.

Social structure and association patterns of the resident bottlenose dolphins in Sado estuary have changed. Mean group size increased and mean association indice decreased, in comparison to previous studies, which suggests that a reorganization of the social system of the resident community is underway. Moreover, the number of long-term preferred associations decreased and short-term preferred associations prevailed (Augusto, 2007; Augusto *et al.*, 2012).

It would be interesting to investigate how environmental factors, like prey availability and habitat degradation, and on the other hand intrinsic factors (e.g. leadership and dominance) have influence in the social structure, particularly in the association patterns and group dynamics.

Moreover, social structure studies should be taken into account in the management and effective conservation of a given community of dolphins, which should consider impacts of human activities. It is necessary to understand social relationships between individuals in order to delineate target management plans for communities, particularly small and closed communities. Also, group composition should be considered for models of population dynamics, especially if trends in abundance or population viability are evaluated (Lusseau *et al.*, 2006).

4.5 Final considerations

The bottlenose dolphin resident community in the Sado estuary lives in a fission-fusion society, which is detected by the low mean association index and the prevalence of short-term preferred associations.

This community was subject to a period of 10 years without the survival of any calf. At the moment, it is composed by a high number of adults, 6 subadults and 2 calves. Due to the survival of the subadults during their first years, it's highly expected they reach adult age and become reproductively mature.

Even though this community is being studied since the early 80's, detailed work on its social structure and group composition only dates from the late first decade of 2000. It is essential to implement a continuous monitoring effort of this community, especially in the south channel of the estuary and near “canal da Comporta”, where individuals were mainly found during the sampling period.

Efforts in sex determination should be continued, since only a few individuals are identified as presumed females or males. Given this low gender identification, some particular association patterns might be masked and, thus, the representation of social structure may be inaccurate.

Further research, with increased data sets, is fundamental for a better understanding of the aspects involved in the establishment and maintenance of these associations. For future research, more intensive data collection is necessary to obtain sufficient data to analyze group composition according to different behavioral categories. Additionally, it would be interesting to determine whether there are preferred or avoided associations in different behavioral categories, similarly to Gero *et al.* (2005) and López and Shirai (2008).

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VI. APPENDICES

According to the regulations of ISPA-IU, dissertations include a literature review, commonly known as “state of the art”, about the theme of the dissertations, which will be presented below.

I. REVIEW OF LITERATURE

1.1. Group formation

Group living in animals is adaptive, in the sense that it increases survival and reproductive success of each individual of the group (Alexander, 1974; Gowans, Würsig & Karczmarski, 2007).

Group formation occurs as a strategy that responds to food dispersion, predator avoidance, fitness and reproduction strategies (Titcomb, O’Corry-Crowe, Hartel & Mazzoil, 2015). Groups, and their relationships, are more likely to be maintained and stabilized if fitness gains outweigh the costs (Louis *et al.*, 2015). In groups, individuals are less susceptible to predators, have improved access to resources and gregariousness is promoted by the distribution of resources. However, group living might lead to increased predation and transmission of parasites and diseases; also, foraging becomes less efficient and reproductive opportunities might become scarce (Gowans *et al.*, 2007).

Group size might influence social behavior and reproductive success of individuals. (Gowans *et al.*, 2007). An increase of the group size is thought to have both benefits and costs associated. Benefits include improved detection and defense against predators, which provides better protection to the group (Campbell, Bilgre & Defran, 2002; Gowans *et al.*, 2007) and an increased success in competition between groups. On the other hand, costs comprise larger vulnerability to parasites, and an increase in within-group competition for both mating partners and food (Majolo, Aureli & Schino, 2012). Moreover, large groups are more easily attractive and detected by predators, which might lead to increased predation risk (Gowans *et al.*, 2007).

Group composition can be influenced by several factors including sex, age, kinship and behavior of the individuals. In addition, groups are composed by animals with similar foraging strategy and habitat preferences. Sociality, or interactions between individuals, is marked by size, composition and temporal dynamics of social units (Titcomb *et al.*, 2015). Group composition and its stability, as well as associations between individuals and reproductive strategies, are

adapted in order to maximize the individuals' fitness under certain ecological conditions (Quintana-Rizzo & Wells, 2001).

In marine environments, several types of groups can be found. Swarms are groups of evenly spaced members, although not polarized (aligned in the same direction), whereas schools designate groups, usually of fish, in which members are polarized, and display synchronized movements (Ritz, Hobday, Montgomery & Ward, 2011); Swarms and schools are contained in *shoals*, larger groups composed of unrelated individuals, assorted by species and body length (Krause, Butlin, Peuhkuri, & Pritchard, 2000). Shoals ranging from ten to millions of individuals can be found in many species of crustaceans and are, usually, monospecific (Thiel, 2011). Various coral reef fish species form *aggregations* during spawning ("FSAs", *Fish Spawning Aggregations*) season, that last from days to a few months, every year (Grüss, Robinson, Heppel, Heppell & Semmens, 2014).

Pods and herds, respectively, designate group of cetaceans. Pods are primary groups of cetaceans, composed by a small number of individuals, and lasting for a period of some weeks, whereas herds are secondary groups, composed by aggregations of pods, and lasting for minutes or hours (Ritz *et al.*, 2011).

Social and ecological influences may determine an individual's pattern of social relationships. Ecological patterns might affect the available mating strategies of males, whereas resources distribution has influence in the patterns of grouping and sex-specific associations. Females' reproduction, as well as their grouping patterns and relationships, are more limited by resources' distribution. Additionally, females' relationships and grouping patterns might be more affected by predation and fights with other females over access to resources. Also, distribution of females influences mating strategies of males, which in turn, will affect females' grouping patterns (Connor, Wells, Mann & Read, 2000).

In associations that last for a long time, individuals tend to interact frequently with each other, establishing relationships between them, such as dominance, cooperation in foraging and mating alliances. As a result, the social structure of a given group results from the total of relationships in that group. In conclusion, relationships are based on interactions among individuals, and social structure is based on the quality and pattern of these relationships (Gowans *et al.*, 2007).

1.2. Social structure

Social structure characterizes ecological relationships among all individuals of a particular community, such as competition and cooperation over resources, dominance and care of offspring. Also, it has influence in gene flow, spatial patterns and scale of movements, and in the effects of predation or exploitation by humans. For these reasons, social structure is considered a fundamental component of population biology (Whitehead, 1997).

Hinde defined a framework for the study of social structure of social animals, which is divided in 3 major levels: interactions, relationships, and social structure, where each level influences and is influenced by the other levels.

In interactions, individuals act together or an individual directs actions towards other individual, and relationships are formed by frequent interactions over time among two individuals (Whitehead, 1997; Hasenjager & Dugatkin, 2015). Interactions between two specific individuals are dependent on various aspects, such as their age, sex or kinship (Kappeler, Barrett, Blumstein & Clutton-Brock, 2013; Hasenjager & Dugatkin, 2015).

Relationships also include the nature and patterns of interactions between two individuals. The former comes from the behavior of the individuals involved in an interaction, and the latter is defined by the frequency and duration of each interaction, and the effects that one interaction might have on another. (Whitehead, 1997; Kappeler *et al.*, 2013; Hasenjager & Dugatkin, 2015).

In sum, social structure, is characterized by the total of all social relationships, such as competition, cooperation and dominance, in a population, In social structure, the quality and patterns of interactions between its members describe each pair of social relationships (Whitehead, 1997; Kappeler *et al.*, 2013; Hasenjager & Dugatkin, 2015).

Social structure of a population is established by the interactions among all its individuals and it might also have influence in the individuals' fitness, information flow, disease transmission patterns, as well as genetic structure and viability of populations. Therefore, to understand a population's ecology and fitness, might be important to assess why are animals are social and how (Titcomb *et al.*, 2015).

In order to study the social structure of a population, it's essential to collect data of interactions between identified animals, to describe relationships from observational data and, finally, to compile measures of relationship into models of social structure. Since interactions, which may be defined as actions affecting the behavior of another individual, can be difficult to observe, it's easier to monitor associations for studies of social structure, especially if the majority

of interactions occur between individuals in association (Whitehead, 2009). Additionally, given that the frequency with which two individuals associate is central to all aspects of their social interactions, associations can be described as the frequency with which two individuals are observed together in the same social unit (Cairns & Schwager, 1987).

Studies of association patterns are performed using records of group composition during short encounters of individuals, as well as groups' predominant activity in each encounter and possibly relevant environmental data. Repeated records over days and years might provide short or long-term pictures of an individual's association patterns (Connor *et al.*, 2000).

In most studies of social structure, only the presence or absence of association is measured. Usually, data collected are used to compute an association index for each pair of animals, which estimates the proportion of time a pair of individuals is observed in association, or amount of time observing individual A, when associated with individual B (Whitehead & Dufault, 1999).

However, if it is more likely to detect A in association with B, than without it, the association index will be biased and the association index of A with B will be different from the index of B with A. Yet, the real proportion of time that A and B spent associated will remain the same, independently of how individuals are distributed (Whitehead & Dufault, 1999).

Normally, symmetric association indices, such as the Half-Weight Index, are calculated (Whitehead & Dufault, 1999). The Half-Weight Index, also known as Dice's, Sorensen's or the Coherence Index, is the most popular among behavioral scientists. This index reduces biases, especially in cases where it's more likely to find two individuals when separate than when together (Cairns & Schwager, 1987).

In fission-fusion societies, there's reduced intra-group competition, through fission in periods of increased competition and, during group fusion, cooperative effects are increased, especially if it's more benefic to live in groups, or when the ecological costs of sociality are decreasing (López & Shirai, 2008).

Several populations of estuarine cetacean species inhabit in close proximity to areas with high human density, and are more exposed to anthropogenic pressures. Therefore, they become of particular importance in terms of conservation research. Studies with this particularly susceptible group of cetaceans might give opportunities to investigate impacts of anthropogenic disturbances and consequent responses from the populations. Additionally, they can be used in conservation and management initiatives, since particular individuals with important roles in a

given population may have disproportionate influences in social structure, requiring increased management attention (Wang *et al.*, 2015).

1.2.1. Importance of the study of social structure in marine mammals

It's important to include analysis of social structure in predictive models of populations, and in analyses of population viability, given that social structure is affected by environmental changes. However it is also essential to understand how social structure is affected by environmental changes, in a matter of conservation management (Gowans *et al.*, 2007).

Effective conservation of communities of cetaceans require knowledge of social relationships and behavior of individuals (Connor *et al.*, 2000). For example, the existence of different foraging strategies in many species makes them more vulnerable to habitat changes (Connor *et al.*, 2000).

Many studies have included social structure in the analysis of community viability, particularly in marine mammal communities. In these studies, territoriality, group formation and effective availability of mates are analyzed allowing for a framework where important aspects of social structure can be included into demographic analyzes and improve management practices (Gowans *et al.*, 2007).

1.2.2. Social structure in cetaceans

In cetaceans, pods and herds represent temporary congregations of individuals, in the same area and often engaged in similar activities (Reynolds III, Wells & Eide, 2000). Pods are primary groups, composed by small social groups, that remain intact for a long period of time (days and weeks), and herds are temporary aggregations of primary groups of cetaceans, that only last for minutes or hours (Ritz *et al.*, 2011).

Group sizes and social structures vary among cetaceans. Some species, like Hector's dolphins, are found in small and fluid groups, others occur in large fluid groups, such as Hawaiian spinner dolphins, and there are even some species found in highly structured and permanent groups, like resident killer whales. In addition, different groups of the same species, as killer whales, have notorious differences in behavior, diet, and social structures (Gowans *et al.*, 2007).

While some cetacean populations present weak and variable associations, such as humpback dolphin populations around the world (Dungan, Wang, Araujo, Yang & White, 2015), other populations, like the population of killer whales in the Strait of Gibraltar are described as having stable and hierarchically structured social units and a strong natal philopatry. Individuals tend to associate with specific individuals, and do not have random associations with one another. Also, associations among individuals within a pod are both strong and long-term (Esteban *et al.*, 2016).

Pilot whales (*Globicephala* spp.) (Mahaffy, Baird, McSweeney, Webster, & Schorr, 2015) and killer whales (Esteban *et al.*, 2016), for example, are known to exhibit natal group philopatry, a variety of social structure characterized by a lack of dispersal of male and female offspring from the natal group. Baird's beaked whales have stable and long-term associations, lasting for several years (Fedutin, Filatova, Mamaev, Burdin & Hoyt, 2015).

On the other hand, in fission-fusion societies, like the common bottlenose dolphins' society, studies of group composition can reveal important insights about social relationships, since at a given time, individuals might have the opportunity to associate in small groups or to travel alone (Connor *et al.*, 2000). In this type of society, associations are formed between individuals of the same sex and/or age structure, and the most common associations are female-calf pair, juveniles, adult males, young adult subgroups and male-female pairs (Pryor & Norris, 1991).

1.3. The common bottlenose dolphin

1.3.1. General characteristics

The common bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821), an aquatic mammal, classified in the order Cetartiodactyla, infraorder Cetacea, parvorder Odontoceti and family Delphinidae (Reynolds III *et al.*, 2000), is one of the best known of all living cetacean species, since it has been studied intensively in various places around the world (Bearzi, Fortuna & Reeves, 2008).

This species can be found in tropical and temperate waters, worldwide, and is as common in coastal waters, including bays and estuaries, as in open waters. (Reynolds III *et al.*, 2000 ; Connor *et al.*, 2000; Campbell *et al.*, 2002). Some populations, such as the one from the Atlantic coast of the United States, are known to carry out limited migrations, most probably to avoid stressful temperatures (Reynolds III *et al.*, 2000). Populations of the Mediterranean, for example, can be found inhabiting a large diversity of habitats, from lagoons and closed seas to the waters around archipelagos and islands (Bearzi *et al.*, 2008).

Bottlenose dolphins have a fusiform body and, unlike terrestrial mammals, they do not have hair, external ears or hind limbs. In adults, body size varies between 2 and 4 meters of length, depending on the geographic location. Regularly, larger and more robust individuals are found in higher latitudes and in open waters, when compared to lower latitudes and inshore waters.

There's no evident sexual dimorphism in this species, which makes sex determination more difficult. Males reach sexual maturity between the ages of 8 and 13, and females between the ages of 5 and 13. Females can live longer than 50 years old, and males longer than 40, making bottlenose dolphin, a long-life species. (Connor *et al.*, 2000). Individuals have a 12-month gestation period, giving birth to a single calf, which can stay associated with its mother for several years. Birth interval varies between 2 and 6 years, depending on the geographic location (Connor *et al.*, 2000), and there is no evidence of reproductive senescence in this species, as females may be reproductively active until their late forties (Augusto *et al.*, 2012).

Bottlenose dolphins are opportunistic predators, feeding on a large variety of fish species, cephalopods and, less frequently, crustaceans (Connor *et al.*, 2000). They make use of many feeding strategies, primarily depending on habitat, group dynamics, prey type (Reynolds III *et al.*, 2000), prey availability and abundance (Bearzi, 2005). Dolphins use echolocation clicks to search for demersal species, such as spotted sea trout (*Cynoscion nebulosus*), pinfish (*Lagodon rhomboids*), striped mullet (*Mugil cephalus*) and oyster toadfish (*Opsanus tau*) (Reynolds III *et al.*, 2000), as well

as european conger (*Conger conger*), red mullets (*Mullus barbatus* and *Mullus surmuletus*), flathead mullet (*Mugil cephalus*), common cuttlefish (*Sepia officinalis*) and common octopus (*Octopus vulgaris*) (Bearzi *et al.*, 2008). The abundance, distribution and access to resources may influence group size and composition, sex ratios as well as other social factors (Reynolds III *et al.*, 2000).

Bottlenose dolphins recognize their surrounding environment mainly through auditory or acoustic stimuli. For this reason, they have extremely developed acoustic regions of the brain that might reflect the importance of high-frequency echolocation clicks (Reynolds III *et al.*, 2000).

Table 17- Sounds produced by bottlenose dolphins. Retrieved from Reynolds III *et al.* (2000)

Sound type	Frequency range	Function
Clicks	0.2-150 kHz	Echolocation
Whistles	0.2-24 kHz	Individual recognition Group cohesion
Low frequency, narrowband	0.3-0.9 kHz	Unknown
Rasps, grates, mews, barks, yelps	0.2-16 kHz	Communication?

The two most studied dolphin sounds are echolocation clicks and signature whistles. Signature whistles, once established, remain practically untouched for the rest of the dolphin's life and are used to help maintain group cohesion for long periods of time. Echolocation, defined as the capacity to produce high-frequency sounds and to detect and analyze echoes of those sounds, constitutes an useful tool to detect bottom topography, prey type and availability, and presence of predators (Reynolds III *et al.*, 2000).

Bottlenose dolphins' behavior is connected to the habitat in which they are living. Their behavior appears to be shaped by feeding habits, particularly, and it seems that bottlenose dolphins' diet and foraging behavior depend largely on the location or season of the year. Also, prey preferences and foraging techniques might differ largely between geographically contiguous groups (Bearzi *et al.*, 2008).

1.3.2. Studies in the wild

According to their location, different populations of common bottlenose dolphin can show distinct group sizes (Table 1). For example, the population of Sarasota Bay, Florida is composed by larger groups than the bottlenose dolphin population of Argentina, which might be a result of different feeding strategies and of different types of feeding (Pryor & Norris, 1991).

Table 18. Mean size of bottlenose dolphin groups, and respective standard deviation, in worldwide studies. ND represents non-available data and SD standard deviation (adapted from Eisfeld, 2003).

Location			Environment	Mean size (SD)	Reference
Bahía San Antonio, Patagonia, Argentina			Shallow bay	5.4 (ND)	Vermeulen & Cammareri, 2009
Turneffe Atoll, Central America		Belize,	Coastal	3.8 (SD = \pm 3.55)	Campbell <i>et al.</i> , 2002
Santa Monica Bay, California			Offshore	15.0 (SD = \pm 12.05)	Bearzi, 2005
Santa Monica Bay, California			Coastal	8.8 (SD = \pm 5.31)	Bearzi, 2005
St. Andrew Bay, Florida			Estuary	4 - 5 (ND)	Bouveroux & Mallefet, 2009
Sarasota Bay, Florida			Enclosed shallow bays	7.04 (SD = \pm 6.0)	Wells <i>et al.</i> , 1987 <i>in</i> Eisfeld, 2003
Sanibel Island, Florida			Open bays, with seagrass beds	2.4 (SD = \pm 1.51)	Shane, 1990 <i>in</i> Eisfeld, 2003
Northeastern coast of Tunisia			Coastal	5.17 (SD = \pm 2.89)	Benmessaoud, Chérif & Bejaoui, 2013
Filicudi Island; Aeolian Archipelago, Sicily, Italy			Coastal	5.22 (SD = \pm 2.21)	Blasi & Boitani, 2014
Outer Moray Firth, Scotland			Coastal	11.07 (SD = \pm 7.93)	Eisfeld, 2003
Inner Moray Firth, Scotland			Exposed estuary	6.45 (SD = \pm 0.31)	Wilson, 1995 <i>in</i> Eisfeld, 2003
Shannon Estuary, Ireland			Narrow and steep sided estuary	6.54 (SD = \pm 3.03)	Duguid, <i>in prep.</i> <i>in</i> Eisfeld, 2003
Shark Bay, Western Australia			Enclosed shallow bay	4.8 (SD = \pm 2.7)	Smolker <i>et al.</i> , 1992 <i>in</i> Eisfeld, 2003
Doubtful Sound, New Zealand			Deep coastal	17.2 (ND)	Lusseau <i>et al.</i> , 2003 <i>in</i> Eisfeld, 2003

In order to study the behavior of a species, particularly bottlenose dolphins, it's essential that individuals are clearly identified, that they are tracked over time, and that attributes of those individuals are known (age, sex, reproductive status, for example) (Reynolds III *et al.*, 2000). Würsig & Würsig (1977) developed a photographic technique to record and discriminate individuals by their natural marks. In bottlenose dolphins, photographs of their dorsal fins are used, which have different sizes and shapes (Reynolds III *et al.*, 2000), and are very thin and tattered throughout the individuals' life. Additionally, tissue of dorsal fins does not regenerate and prominent scars and nicks lasted for more than a couple of years can be seen in almost every animal (Würsig & Würsig, 1977).

Groups, often fluid, are defined by age and sex, and the most commonly recognized include female bands (or nursery groups), subadult groups and male pairs. Female bands include adult females and their calves and are often composed by more than two generations (Reynolds III *et al.*, 2000). Larger calf-group sizes thus appear to be a generalized characteristic of coastal bottlenose dolphins. In some cases, larger calf-groups could provide greater protection for the young against aggressive male conspecifics, as well as the benefits of social learning for young members (Campbell *et al.*, 2002).

Bottlenose dolphin group size varies according to biogeographic region, activity, prey availability, and other factors (Bearzi *et al.*, 2008). Additionally, in many places of the world, mean group size has annual and seasonal variations, larger in the fall, and smaller in the spring and summer (Campbell *et al.*, 2002). Groups with calves are often bigger than groups without them (Campbell *et al.*, 2002; Blasi & Boitani, 2014). Variations in mean group and population sizes in several locations suggest that habitat differences may influence bottlenose dolphins' behavioral ecology (Campbell *et al.*, 2002).

Social structure can be influenced by specializations in the diet, as well as by techniques used in the search of prey (foraging). Human activities may also have impacts on the social structure, through changes in the distribution of food resources, for example. Moreover, aquaculture farms and trawlers can alter the behavior of bottlenose dolphins by modifying the habitats, changing predation pressure and vary food distributions and availability, which might influence social interactions and the demography of dolphin population (Blasi & Boitani, 2014).

Usually, associations between individuals are weak and fluid, with individuals having short-term associates and a smaller amount of constant companions. Bottlenose dolphin populations also show high variations in relationships between males, females, and among males and females at both inter- and intra-population levels (Louis *et al.*, 2015).

Association patterns might be mediated by different reproductive strategies (Bouveroux & Mallefet, 2009). Bottlenose dolphins have preferential associations with members of the same sex, which might reflect the different reproductive strategies of males and females. Males may form long-term alliances, to better compete for females, whereas females are known to form bands, and frequently associate with other females in the same reproductive conditions (Pryor & Norris, 1991). Preferred associations among different communities might also be connected to distinct predation risks or availability of resources (Connor *et al.*, 2000).

Females tend to occur in larger groups than when their calves are older, and mothers and their calves are more sociable during the calves' first year, when mortality rate is the highest (Gibson & Mann, 2008). This might happen due to the suggestion that predation risk can lead to increase the size of groups (Bearzi, 2005). Moreover, females might prefer or favor groups larger than the optimal size, to provide protection and alloparental care for their offspring (Benmessaoud *et al.*, 2013).

Distinct communities of common bottlenose dolphin have different association patterns and distinct social systems. Bottlenose dolphin populations in the Black sea are relatively sedentary, settled animals, and consist of local subpopulations (Pryor & Norris, 1991). In the bottlenose dolphin population of the Aeolian Archipelago, Italy, association indices are higher for females than for males (Blasi & Boitani, 2014).

The population of bottlenose dolphins of Sarasota Bay, Florida, appears to be based on four main structural units: mixed and single sex groups of subadults; mother-calf pairs; bands of females with their calves, and adult males, as individuals, or in strongly bonded pairs or trios (Pryor & Norris, 1991). However, In Filicudi Island (Aeolian Archipelago, Sicily), social structure of bottlenose dolphin population has a different pattern. It is constituted by two distinct groups, hierarchically structured, without mixing, sub-divided in smaller groups, and both composed by preferred and long-term associations (Blasi & Boitani, 2014).

Bottlenose dolphins of Doubtful Sound live in a small and relatively closed population (Lusseau, 2007). In this population, long-term associations are predominant and a strong element, as well as focal schools with large average size, contrary to other populations worldwide. Long-term associations are observed within and between sexes, and for this reason, Doubtful Sound population considered a fission-fusion society, or fission-fusion, having particularly large numbers of strong and long-term associations (Lusseau *et al.*, 2003).

In the population in the waters near Panama City, Florida, the fission-fusion model is well illustrated, with individuals presenting short-term associations and rapid dissociations, over short periods of time, usually in a daily basis (Bouveroux & Mallefet, 2009).

The bottlenose dolphin population of the inner Moray Firth lives in a fission-fusion society that is predominantly composed of short-term acquaintances, lasting a few hours to a few days. Longer-lasting associations form an integrated network, which is composed of two social units largely explained by the ranging patterns of individuals. These two units have limited interactions through few common individuals (Lusseau *et al.*, 2006).

Movement patterns, such as residency and migrations, have influence in the associations of bottlenose dolphins, making them more complex (Quintana-Rizzo & Wells, 2001). Within populations of common bottlenose dolphins particular types of associations are normally observed.

1.3.2.1. Associations between males

When males reach 10 or 15 years of age, they tend to associate more in smaller groups, with strongly bonded young adults (presumably related males), and less with younger subadults. (Pryor & Norris, 1991).

Associations between adult males are named alliances, which are strong, stable and, usually, long-term associations (Bouveroux & Mallefet, 2009), and they are formed so that individuals can obtain access to, or defend, females. Interestingly, males may also join in attacks to rival alliances, in order to help a third alliance to obtain a female, instead of obtaining the female for themselves (Connor *et al.*, 2000).

Alliances are formed between pairs or trios of males (Bouveroux & Mallefet, 2009), being maintained for decades (Lusseau, 2007) and their sizes varying between areas, and among alliances in the same area (Whitehead & Connor, 2005). This pattern of association is very common in bottlenose dolphin populations of Shark Bay, Australia; Sarasota Bay, Florida (Connor *et al.*, 2000; Lusseau, 2007; Bouveroux & Mallefet, 2009) and Panama City (Florida), and it is frequently observed during prey search, mating and social activities (Bouveroux & Mallefet, 2009).

In Shark-bay, in particular, bottlenose dolphin males are known to form two types of alliances. “First-order alliances”, with aggressive herding of females, are formed between two or

three males (dyads and triads) to capture a female for reproductive purposes, and “second-order alliances”, which are composed by two or more first-order alliances in order to aggressively capture females from other alliances (Connor, Smolker & Richards, 1992; Connor *et al.*, 2000). Such a complex social system is very difficult to document unless long-term, detailed data from a clear-water habitat is obtained.

In Sarasota Bay, males also form strong bonds with other males, in pairs. These pairs are crystallized at sexual maturity and are known to last as long as 20 years, until the loss of one of the members of the pair (Connor *et al.*, 2000).

1.3.2.2. Associations between males and females

Males and females form very strong, temporary associations, which are related to the female’s reproductive state. Associations between males and females are much higher in years when females are cycling than when they are pregnant, and are much more frequent during mating season (Connor *et al.*, 2000).

The bottlenose dolphin population of St. Andrew Bay, Panama City, Florida consists of small groups, of 2 or 3 associations, of both males and females, which can be compared to *first order alliances*, described by Connor *et al.* (1992). Regular associations with other dyads or trios are found in this kind of alliances, in which, dyads and triads form regular associations with each other. Sometimes, they are associated in bigger groups, for reproduction purposes, defense against predators or as a strategy to search for prey (Bouveroux & Mallefet, 2009).

1.3.2.3. Associations between females

Young females interact mostly with other subadults until the birth of their first calf (about 8 to 12 years of age), after which they join bands of adults and young females (Pryor & Norris, 1991). Bands, in social terms, are groups of females, with strong and stable associations among them. These strong bonds can be found in the populations of Sarasota Bay (Connor *et al.*, 2000; Blasi & Boitani, 2014), Shark Bay (Blasi & Boitani, 2014), and are formed to obtain cooperative defense against predators and male harassment, in competitions with other females over resources, and vigilance (Connor *et al.*, 2000).

Associations between females usually rely on their reproductive status, and females can be associated both with related and unrelated females (Blasi & Boitani, 2014).

In the populations of Shark Bay and Sarasota Bay, some females present a large network of associates whereas other females do not associate in bands (Connor *et al.*, 2000). On the other hand, in some populations, (e.g. Filicudi Island, Italy) females have preferred associations and live in bigger groups, in comparison to males of the same population (Blasi & Boitani, 2014).

1.3.2.4. Associations between mothers and calves

Females and their calves form very strong bonds. Calves remain with their mothers for 3 to 6 years, well beyond their age at weaning, 18 to 20 months (Pryor & Norris, 1991; Connor *et al.*, 2000). Calves may still associate with their mothers, from time to time, after separation. At that period, young dolphins join mixed groups of subadults, where males form strong bonds with other males of similar age, which might be maintained at least into early adulthood (Pryor & Norris, 1991). In Sarasota Bay, in particular, calves and their mothers form strong bonds with other females in the same reproductive status (Blasi & Boitani, 2014).

Calf survivorship might be related to group size, since larger groups with calves, who appear to be typical of coastal populations, might provide protection for the young, against either male conspecifics or predators (Campbell *et al.*, 2002). Additionally, in larger groups, there are more opportunities to rest, socialize and for calf care and learning (Blasi & Boitani, 2014).

Calf-groups size tend to decrease as calves age, over three or four years and, additionally, associations between adult males and females with their calves are rare, as well as interactions among calves and adult males (Connor *et al.*, 2000).

1.3.2.5. Associations with other species

Associations with other cetacean species are not frequent (Bearzi *et al.*, 2008). Interspecific associations might occur because of foraging benefits and predator avoidance, as well as social factors, such as territory defense, reproduction and dominance. Usually, agonistic behaviors are the predominant activity in interspecific interactions, with larger species dominant over smaller species (Elliser & Herzing, 2016).

Although interspecific associations are unusual, bottlenose dolphins have been documented associated with common dolphins (*Delphinus delphis*), Risso's dolphins (*Grampus griseus*), common minke whales (*Balaenoptera acutorostrata*) (Bearzi, 2005), short-finned pilot whales (*Globicephala macrorhynchus*), Atlantic spotted dolphin (*Stenella frontalis*) (Connor *et al.*, 2000), as well as with short-beaked common dolphins and long-finned pilot whales (*Globicephala melas*) (Bearzi *et al.*, 2008).

There are also records of social interactions, most probably aggressive behavior, among bottlenose dolphins and tucuxi dolphins (*Sotalia fluviatilis*) (Acevedo-Gutiérrez, DiBerardinis, Larkin, Larkin & Forestell, 2005).

1.3.2.6. Associations with humans

Bottlenose dolphins are also known to interact with human activities (artisanal fisheries, in particular) (Reynolds III *et al.*, 2000). These interactions are benefic for both parts and have been documented in Mauritania (Wells & Scott, 2009) and in Laguna, Brazil, during mullet fishing season (Pryor & Lindbergh, 1990; Reynolds III *et al.*, 2000; Wells & Scott, 2009; Daura-Jorge, Cantor, Ingram, Lusseau & Simões-Lopes, 2012). In both locations, dolphins are known to cooperatively drive fish schools towards fishermen (Reynolds III *et al.*, 2000), and execute stereotyped signals (head or tail slaps) to indicate when and where nets can be thrown by fishermen (Daura-Jorge *et al.*, 2012).

Additionally, in many parts of the world, dolphins feed on discarded fish from shrimp trawls and purse seines, or steal fish from several types of fishing gear (Wells & Scott, 2009).

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II. NUMBER OF IDENTIFICATIONS OF EACH INDIVIDUAL IN EACH SAMPLING DAY

ID	08/06/ 2015	15/06/ 2015	30/07/ 2015	07/10/ 2015	14/10/ 2015	03/11/ 2015	06/04/ 2016	07/04/ 2016	20/04/ 2016	21/04/ 2016	26/04/ 2016	27/04/ 2016	28/04/ 2016	20/05/ 2016	23/06/ 2016	30/06/ 2016	TOTAL
AGU	27	27			5	47	30	36	37	33	18	30		9	71	16	386
APA	20	17	18	5		24	12	7	25	28	8	40		15		8	227
BOM	1	9	10		5	27	13	35	15	18	3	28		3	50		217
BUM	14	9			1	34	5	10	12	36	17	36		6	1	11	192
CLU	1	8	34		1	16	11	4	13	18	8	35		22		13	184
DAR	24	43	31		19	108	47	38	19	28	20	34		12	23	19	465
ELE	29	34	60		1	34	3	32	11	7	8	40			4	14	277
FAC	9	15	32		5	29	32	32	6	14	25	41			8	10	258
GOR		16	23		16	69	33	26	7	29	23	27				10	279
HIG	56	26	33	1	15	27	42	40	13	77	28	43		5	25	7	438
HUX	5	13			12	68	47	9	25	21				48	119		367
LAM	10	13	112		22	42	44	32	66	44	40	70		42	5	14	556
MAR			41		10	19	19	19	37	17	9	41		29	5	9	255
MED	22	13	17			21	21	7	13	55	10	32		40	1	17	269
MID	1									1	1	19	69		2		93
MIS	2	4	19	2		26	1	1		5	4	7		1	2		74
MUR	35	30	30		18	43	2	4	10	46	24	41		8	11	23	325
POS	26	23	46	1	5	52	34	29	28	36	8	17		33	53	1	392
QUA	3					48	4		30	36	25			3	1	17	167
SAL	3	13	3		15	43	40	11	38	29		56			97		348
SPI	17	22	16	1	8	46	21	31	8	36	12	37				8	263
TAI	27	28	69	4	15	67	33	29	28	50	10	33		11	28	1	433
TAL	1	1	5		1	26	6	1	25	10				18	6	10	110
THO	18	37	37		9	22	17	4		19	17	19		8	83		290
TRO	7	20	58		14	44	17	12	13	11	10	30		21	3	12	272
TRU	4	11	34		23	25	14	18	38	25	17	24				21	254
ZOE	36	34	19		3	44	8		1	21	13	17		1	64		261

III. MATRIX OF ASSOCIATION, USING THE HWI, HAVING GROUP AS SAMPLING UNIT

AGU	1.00																												
APA	0.23	1.00																											
BOM	0.31	0.23	1.00																										
BUM	0.08	0.23	0.08	1.00																									
CLU	0.31	0.62	0.00	0.31	1.00																								
DAR	0.59	0.22	0.37	0.22	0.07	1.00																							
ELE	0.46	0.08	0.23	0.31	0.15	0.37	1.00																						
FAC	0.31	0.23	0.08	0.08	0.31	0.30	0.54	1.00																					
GOR	0.50	0.08	0.33	0.25	0.17	0.56	0.33	0.67	1.00																				
HIG	0.43	0.36	0.36	0.07	0.14	0.76	0.36	0.36	0.31	1.00																			
HUX	0.52	0.00	0.52	0.17	0.17	0.33	0.17	0.17	0.19	0.40	1.00																		
LAM	0.59	0.22	0.30	0.15	0.30	0.36	0.37	0.81	0.40	0.41	0.42	1.00																	
MAR	0.32	0.08	0.16	0.08	0.16	0.15	0.32	0.40	0.17	0.30	0.27	0.92	1.00																
MED	0.54	0.62	0.08	0.15	0.62	0.22	0.08	0.31	0.17	0.43	0.17	0.30	0.16	1.00															
MID	0.11	0.00	0.00	0.00	0.11	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.11	0.00	1.00														
MIS	0.08	0.08	0.08	0.00	0.00	0.15	0.00	0.00	0.17	0.22	0.09	0.00	0.08	0.08	0.00	1.00													
MUR	0.30	0.52	0.07	0.15	0.22	0.29	0.37	0.37	0.32	0.62	0.08	0.43	0.15	0.37	0.10	0.08	1.00												
POS	0.43	0.14	0.36	0.14	0.21	0.48	0.43	0.29	0.62	0.47	0.40	0.41	0.52	0.14	0.10	0.00	0.14	1.00											
QUA	0.27	0.36	0.00	0.27	0.36	0.17	0.18	0.27	0.30	0.17	0.21	0.35	0.19	0.27	0.00	0.00	0.35	0.17	1.00										
SAL	0.25	0.00	0.33	0.17	0.17	0.24	0.00	0.17	0.18	0.23	0.95	0.32	0.35	0.08	0.00	0.17	0.08	0.54	0.00	1.00									
SPI	0.31	0.23	0.31	0.08	0.15	0.52	0.15	0.31	0.42	0.57	0.09	0.37	0.32	0.15	0.11	0.16	0.22	0.36	0.27	0.08	1.00								
TAI	0.50	0.36	0.36	0.07	0.00	0.34	0.43	0.43	0.23	0.53	0.48	0.55	0.52	0.43	0.10	0.30	0.34	0.67	0.17	0.38	0.50	1.00							
TAL	0.00	0.08	0.08	0.00	0.08	0.08	0.08	0.08	0.17	0.07	0.00	0.15	0.17	0.08	0.00	0.00	0.08	0.22	0.10	0.35	0.08	0.07	1.00						
THO	0.64	0.08	0.08	0.16	0.16	0.46	0.40	0.32	0.35	0.30	0.18	0.31	0.08	0.32	0.00	0.08	0.15	0.37	0.10	0.09	0.32	0.37	0.00	1.00					
TRO	0.37	0.07	0.37	0.37	0.07	0.43	0.30	0.52	0.72	0.21	0.17	0.57	0.31	0.07	0.20	0.08	0.29	0.34	0.26	0.32	0.22	0.48	0.15	0.15	1.00				
TRU	0.40	0.24	0.40	0.32	0.00	0.38	0.16	0.40	0.35	0.37	0.36	0.54	0.25	0.24	0.00	0.08	0.31	0.30	0.38	0.26	0.24	0.37	0.00	0.25	0.77	1.00			
ZOE	0.56	0.08	0.16	0.08	0.00	0.23	0.48	0.32	0.35	0.44	0.27	0.23	0.00	0.16	0.00	0.08	0.31	0.15	0.10	0.17	0.16	0.37	0.08	0.58	0.31	0.17	1.00		
	AGU	APA	BOM	BUM	CLU	DAR	ELE	FAC	GOR	HIG	HUX	LAM	MAR	MED	MID	MIS	MUR	POS	QUA	SAL	SPI	TAI	TAL	THO	TRO	TRU	ZOE		

IV. MATRIX OF STANDARD ERRORS ASSOCIATED TO THE ANALYSIS OF THE HWI, HAVING GROUP AS SAMPLING UNIT

AGU	0.00																											
APA	0.12	0.00																										
BOM	0.12	0.12	0.00																									
BUM	0.07	0.11	0.07	0.00																								
CLU	0.13	0.13	0.00	0.13	0.00																							
DAR	0.13	0.11	0.13	0.11	0.07	0.00																						
ELE	0.14	0.07	0.12	0.12	0.10	0.13	0.00																					
FAC	0.13	0.11	0.07	0.07	0.13	0.12	0.13	0.00																				
GOR	0.14	0.08	0.14	0.12	0.10	0.13	0.13	0.13	0.00																			
HIG	0.13	0.12	0.12	0.07	0.10	0.11	0.13	0.13	0.13	0.00																		
HUX	0.15	0.00	0.14	0.11	0.11	0.14	0.11	0.11	0.12	0.13	0.00																	
LAM	0.13	0.11	0.12	0.10	0.13	0.13	0.13	0.10	0.13	0.13	0.14	0.00																
MAR	0.13	0.07	0.10	0.07	0.11	0.10	0.13	0.13	0.12	0.12	0.13	0.05	0.00															
MED	0.13	0.13	0.08	0.10	0.13	0.11	0.07	0.13	0.10	0.13	0.11	0.12	0.11	0.00														
MID	0.09	0.00	0.00	0.00	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.09	0.10	0.00	0.00													
MIS	0.07	0.08	0.07	0.00	0.00	0.10	0.00	0.00	0.11	0.11	0.09	0.00	0.08	0.08	0.00	0.00												
MUR	0.12	0.13	0.07	0.10	0.11	0.12	0.13	0.13	0.13	0.13	0.08	0.14	0.10	0.13	0.09	0.07	0.00											
POS	0.13	0.09	0.12	0.09	0.11	0.13	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.09	0.08	0.00	0.09	0.00										
QUA	0.13	0.14	0.00	0.13	0.13	0.11	0.11	0.13	0.14	0.10	0.13	0.13	0.12	0.14	0.00	0.00	0.13	0.10	0.00									
SAL	0.13	0.00	0.13	0.10	0.11	0.12	0.00	0.11	0.12	0.12	0.05	0.13	0.14	0.08	0.00	0.11	0.07	0.13	0.00	0.00								
SPI	0.12	0.12	0.12	0.07	0.10	0.13	0.10	0.13	0.14	0.13	0.08	0.13	0.13	0.10	0.09	0.10	0.11	0.12	0.13	0.08	0.00							
TAI	0.13	0.13	0.12	0.07	0.00	0.12	0.13	0.13	0.12	0.13	0.13	0.13	0.13	0.13	0.08	0.12	0.13	0.12	0.11	0.13	0.13	0.00						
TAL	0.00	0.07	0.07	0.00	0.07	0.07	0.07	0.07	0.11	0.07	0.00	0.10	0.11	0.07	0.00	0.00	0.07	0.11	0.09	0.14	0.07	0.07	0.00					
THO	0.13	0.07	0.08	0.10	0.11	0.14	0.14	0.13	0.14	0.12	0.12	0.13	0.08	0.13	0.00	0.08	0.10	0.13	0.09	0.08	0.13	0.13	0.00	0.00				
TRO	0.12	0.07	0.13	0.13	0.07	0.13	0.12	0.14	0.12	0.11	0.10	0.13	0.12	0.07	0.12	0.07	0.12	0.12	0.13	0.13	0.11	0.13	0.10	0.10	0.00			
TRU	0.13	0.12	0.13	0.13	0.00	0.14	0.10	0.14	0.14	0.13	0.14	0.14	0.12	0.12	0.00	0.08	0.12	0.12	0.14	0.13	0.12	0.13	0.00	0.12	0.11	0.00		
ZOE	0.14	0.07	0.10	0.08	0.00	0.12	0.14	0.13	0.13	0.13	0.13	0.12	0.00	0.11	0.00	0.08	0.12	0.10	0.09	0.11	0.10	0.13	0.08	0.14	0.13	0.11	0.00	
	AGU	APA	BOM	BUM	CLU	DAR	ELE	FAC	GOR	HIG	HUX	LAM	MAR	MED	MID	MIS	MUR	POS	QUA	SAL	SPI	TAI	TAL	THO	TRO	TRU	ZOE	

V. BOTTLENOSE DOLPHIN COMMUNITY OF SADO ESTUARY – CATALOGUE OF DORSAL FINS

Photographs were taken by Patrícia Rachinas-Lopes and by students of Bachelor's degree in Biology and Master's degree in Marine Biology and Conservation, from ISPA-IU

1) AGU



2) APA



3) BOM



4) BUM



5) CLU



6) DAR



7) ELE



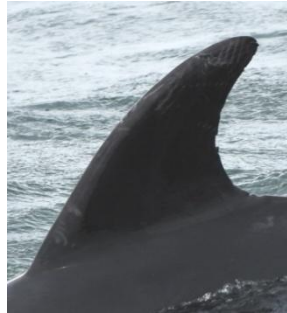
8) FAC



9) GOR



10) HIG



11) HUX



12) LAM



13) MAR



14) MED



15) MID



16) MIS



17) MUR



18) POS



19) QUA



20) SAL



21) SPI



22) TAI



23) TAL



24) THO



25) TRO



26) TRU



27) ZOE



VI. EXAMPLE OF A SAMPLING FORM

SAÍDA Nº _____	H INÍCIO _____	MARÉ _____	METEO _____	RC _____	TRIPULAÇÃO _____
DATA _____	H FIM _____	_____	_____	RF _____	_____
	T ESFORÇO _____	_____	BEAUFORT _____	RA _____	_____

HORA	LATITUDE (N)		LONGITUDE (W)		PROF. (m)	DIRECÇÃO	TAMANHO GRUPO	GRAU AGREGAÇÃO (I-V)	INDIVÍDUOS IDENTIF.	ACTIVIDADE	VELOCIDADE (rápido, médio, lento)	DISTÂNCIA (m)	AZIMUTE (°)	OBSERVAÇÕES
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				
	38°		8°							A B P D S R				