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Distribution and habitat use of bottlenose dolphin (*Tursiops truncatus*) in Central and South West of Portugal mainland

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Resumo:

Perceber a relação entre a distribuição das populações e o meio ambiente é fundamental para desenvolver medidas de gestão e de conservação. A conservação das espécies deve ser principalmente desenvolvida a nível local, no sentido de ir ao encontro dos requisitos ecológicos das populações. Os ambientes marinhos são dinâmicos e são influenciados por fatores oceanográficos e topográficos. Esta heterogeneidade influencia temporalmente a distribuição das espécies marinhas, como por exemplo os cetáceos. O golfinho-roaz (*Tursiops truncatus*), pertencente ao grupo dos cetáceos, é um mamífero marinho com uma distribuição cosmopolita. Contudo em algumas áreas costeiras, as estimativas populacionais têm vindo a diminuir. As populações desta espécie são bastante dinâmicas e o uso do habitat por parte destas é influenciado por diversos fatores ambientais. Estudar os grupos de golfinho-roaz em vários locais, pode contribuir para uma melhor compreensão do uso do habitat por parte destes. Em Portugal, os estudos sobre o golfinho-roaz têm sido principalmente focados na população residente do Estuário do Sado.,. Porém, grupos costeiros também se encontram presentes na costa portuguesa, mas a informação existente sobre estes é escassa. Perceber como os golfinhos-roazes costeiros utilizam a costa portuguesa a um nível local e como se movimentam ao longo da costa é uma lacuna no estudo desta espécie, em Portugal continental. Para além disso, o golfinho-roaz é uma espécie de interesse comunitário, no âmbito da Diretiva Habitats e por isso é obrigatória a implementação de Zonas Especiais de Conservação (ZEC) para esta espécie. Recentemente, foram propostas novos Sítios de Importância Comunitária em Portugal continental nomeadamente em Sesimbra e Sagres, tendo por base dados de census aéreos. O objetivo deste estudo é compreender o uso do habitat do golfinho-roaz, através da sua ecologia comportamental, na zona Centro e Sudoeste de Portugal continental, em Sesimbra e Sagres, respetivamente, através da estimação da abundância relativa da população, avaliação dos padrões de fidelidade e de residência, análise dos padrões de comportamento das características de grupo e da estrutura social, como também a identificação movimentos entre as duas regiões e de preferências de habitat, em ambas as áreas. Dois conjuntos de dados foram analisados através de dados recolhidos em saídas de mar durante o período de 2007 a 2014, em Sesimbra e Sagres, através de saídas dedicadas e de uma plataforma de oportunidade, respetivamente. Em cada saída, a data, hora e trajeto foram registados. Em cada avistamento foram registados vários parâmetros, tais como a espécie, posição geográfica, tamanho e composição do grupo, comportamento do grupo, bem como o registo fotográfico. As fotografias foram utilizadas para foto-identificação dos indivíduos. Métodos de captura-recaptura foram utilizados para estimar a abundância relativa da população, em cada área. A avaliação do tempo de residência e o tipo de associações sociais dos indivíduos reavistados foram realizados através do programa de análise SOCPROG. A influência da composição e tamanho do grupo no comportamento assim como a influência da composição do grupo na dimensão do grupo foram estatisticamente testadas. Os movimentos entre as duas áreas de estudo foram identificados através de comparação de catálogos de foto-identificação. Por fim, a identificação das preferências de habitat e de áreas mais adequadas para o golfinho-roaz em Sesimbra e Sagres foram efetuadas através de modelação de máxima entropia. Foram realizadas 136 Saídas de mar, em Sesimbra, resultando em 29 avistamentos e 2160 saídas de mar, em Sagres, resultando em 227 avistamentos de golfinho-roaz. A análise dos dois catálogos de foto-identificação, um para cada área, culminou na identificação de 148 indivíduos em Sesimbra e 303 indivíduos em Sagres. Como o esforço de amostragem não foi regular ao longo de todo o período de amostragem nas duas áreas, as estimativas da abundância relativa da população apenas foram feitas para o período de amostragem de 2009 e 2013, em que um esforço de amostragem foi superior e o número de animais identificados também foi mais elevado. Os dados sugerem, através do programa SOCPROG, a existência de uma população aberta de 354 (95%-IC: 156.7- 797.8) indivíduos, para área de estudo de Sesimbra e 350 (95%-IC: 184.7-662.4) indivíduos para a área de estudo em Sagres. Por outro lado, através do Programa MARK, os dados sugerem a existência de 167 (95 % IC:145.2-192.7) indivíduos para a área de estudo de Sesimbra e de 817 (95 % IC 459.6-1458.7) indivíduos para a área de estudo de Sagres. Através do histórico de re-avistamentos de todos indivíduos e da definição utilizada para a fidelidade do local, foram identificados, “não-residentes” (Sesimbra=82%; Sagres=65%), “transientes” (Sesimbra=11%; Sagres=24%), “residentes” (Sesimbra = 7%; Sagres = 11%). Os resultados dos padrões de residência revelam que eventos de emigração ocorrem em Sesimbra e eventos de emigração e de re-imigração ocorrem em Sagres. Relativamente à análise comportamental, o comportamento mais observado em Sesimbra foi de deslocação e em Sagres foi de alimentação. Segundo as análises estatísticas realizadas para ambas as áreas, apenas a composição do grupo influencia a dimensão do grupo, em Sagres. Em relação à análise da estrutura social, o valor médio de associação entre os indivíduos que ocorrem em Sesimbra é de 0.21 e para os indivíduos que ocorrem em Sagres é de 0.05. O padrão das associações entre os indivíduos ajustou-se a um modelo teórico composto por “conhecidos casuais”. Foram identificados 28 indivíduos que se deslocaram entre Sesimbra e Sagres, percorrendo em média 158 quilómetros (SD= 3.5) com uma mínima variação temporal de 11 dias e uma máxima variação temporal de 1465 dias. Os modelos de máxima entropia para o golfinho-roaz obtidos apresentam um valor médio de AUC de 0.77 para a área de Sesimbra e de 0.628 para a área de Sagres. As variáveis ambientais mais importantes que influenciaram a distribuição do golfinho-roaz consistiram no tipo de habitat, distância à costa, aspeto do fundo oceânico e a concentração de clorofila-a, mas com contribuições diferentes para Sesimbra e Sagres. As áreas perto da costa apresentam uma maior probabilidade de ocorrência para esta espécie, tanto em Sesimbra como Sagres. Uma zona mais afastada da costa na área de Sagres, também apresenta elevada adequabilidade para a ocorrência do golfinho-roaz. As características observadas através dos padrões de residência, análise comportamental e social são as esperadas para as populações de golfinho-roaz, que ocorrem em águas costeiras. Estes animais são bastante dinâmicos e móveis, apresentando uma combinação de fidelidade local com movimentos de média distância. De acordo com as análises comportamentais e das características de grupo, Sesimbra e Sagres parecem ser áreas importantes para atividades relacionadas com hábitos alimentares. A variabilidade de movimentos entre as duas áreas pode estar relacionada com a disponibilidade de recursos ou dispersão de indivíduos para efeitos de acasalamento. De facto, numa perspetiva regional, alguns animais parecem apresentar alguma fidelidade na região sudoeste de Portugal, pois foram vistos várias vezes, num período de quatro anos. As áreas propostas como sítio de importância comunitária, em Sesimbra e Sagres, poderão beneficiar o estado de conservação das populações de golfinho-roaz, pois estas áreas foram onde a maioria dos indivíduos foram identificados e apresentaram habitats adequados para espécie. Este estudo pretende contribuir para uma melhor compreensão do uso do habitat do golfinho-roaz em Portugal continental e poderá servir de informação base para o desenvolvimento de medidas de conservação adequadas das populações costeiras desta espécie. Por último, este estudo veio demonstrar a importância dos estudos locais e da comparação de dados entre diferentes regiões, abordagem que poderá ser usada de futuro para compreender melhor espécies móveis como são os cetáceos.

Palavras-chave: Golfinho-roaz; Uso do habitat; Métodos captura-recaptura; Conservação de Cetáceos

Abstract:

Understand the relationship between the distribution of populations and the environment is fundamental to develop management and conservation measures. Species conservation should be primarily developed at the local level, in order to meet the ecological requirements of populations. Studying the habitat use of bottlenose dolphin in different locations can contribute to a better understanding of this species. In Portugal mainland, the study of the bottlenose dolphin has been mainly focused on the resident population of the Sado Estuary. However, coastal groups of bottlenose dolphin are also present in Portuguese coast, but the available information on these groups is scarce. Moreover, bottlenose dolphin is a Species of Community interest under the Habitats Directive and therefore is mandatory the implementation of Special area of Conservation (SAC's) for this species. Recently, Sites of Community Importance were proposed for this species in the Portuguese coast based on aerial surveys data, particularly in Sesimbra and Sagres. The aim of this study is to understand the habitat use and the dynamics of coastal bottlenose dolphins in two different regions of mainland Portugal, Sesimbra and Sagres, through estimate of population size (relative abundance), assessing the site fidelity and residency patterns, analyse of the behaviour patterns, group characteristics and social structure of coastal bottlenose dolphin in the two areas, identify movements of individuals between the two areas, compare habitat preferences and predict suitable areas for the occurrence of bottlenose dolphins in Sesimbra e Sagres. Two datasets were used through data collected from boat-surveys during the period from 2007 to 2014, in Sesimbra and Sagres. Mark-recapture methods were used to estimate population size. The analyses of residence patterns and social structure of the re-sightings individuals were performed through the SOCPROG software. The influence of group composition and group size on the behaviour as well as the influence of group composition on group size were statistically tested. The movements between the two study-areas were identified through photo-identification catalogues matching. Finally, the identification of habitat preferences and suitable areas for bottlenose-dolphins in Sesimbra and Sagres were carried out through a maximum entropy modelling. Each photo-identification catalogue, culminated in the identification of 148 individuals in Sesimbra and 303 individuals in Sagres. Since the sampling effort was not regular throughout the sampling period in both areas, population size estimates were only made for 2009-2013 sampling period. The data suggest through the SOCPROG software the existence of an open population of 354 (95% -IC: 156.7- 797.8) individuals, for Sesimbra region and 350 (95% -IC: 184.7-662.4) individuals for Sagres region. On the other hand, through the MARK software, data suggest the existence of 167 (95% CI: 145.2-192.7) individuals for Sesimbra and 817 (95% CI 459.6-1458.7) individuals for Sagres. Through the history of re-sightings of all individuals, it were identified "Non-residents" (Sesimbra = 82%, Sagres = 65%), "Transients" (Sesimbra = 11%, Sagres = 24%) and "Residents" (Sesimbra = 7%, Sagres = 11%). The analysis of residence patterns reveals that emigration events may occur in Sesimbra and events of emigration and re-immigration may occur in Sagres. According to the behavioural analysis, the most observed behavioural pattern in Sesimbra was Travelling and in Sagres was Feeding. Regarding social analysis, the mean value of association among individuals occurring in Sesimbra was 0.21 and for individuals occurring in Sagres was 0.05. It was identified 28 individuals, which travelled between the two areas, travelling on average 158 km (SD = 3.5) with a minimum time variation of 11 days and a maximum temporal variation of 1465 days. The maximum entropy models for the bottlenose-dolphin obtained have an average AUC value of 0.77 for the Sesimbra area and 0.628 for the Sagres area. The most important environmental variables that influenced the distribution of bottlenose dolphin were habitat type, distance to the coast, seabed_aspect and chlorophyll-a. The areas near coast seems to be important for this species, in both study-areas. These animals are very dynamic and mobile, presenting a combination of site fidelity with mid-movements. According to behaviour analysis and group characteristics analyses Sesimbra and Sagres seem to be important areas for feeding habits. The variability of movements between the two areas may be related with food resources or individual dispersion for mating purposes. In fact, from a regional perspective, some animals seem to have some fidelity in the southwestern region of Portugal mainland, since they were observed several times within four years sampling period. The areas proposed as Sites of Community Importance, in Sesimbra and Sagres may contribute to the conservation of bottlenose dolphins, since the majority of the individuals were observed in these areas and the most suitable habitats were identified. This study intends to contribute to a better understanding of the habitat use of bottlenose dolphin in Portugal mainland and might serve as base information for the development of effective conservation measures of coastal populations of this species. Finally, this study highlighted the importance of local studies and the comparison of data from different regions, an approach that can be used in the future to better understand mobile species like cetaceans.

Key words: Bottlenose dolphin; Habitat use; Mark-recapture methods; Cetaceans conservation

The research included in Chapter 2 has been presented in the following Congress:

Almeida, D., Martinho, F., Magalhães, S. Brito, C., Carvalho, I. (2017, May) Movements of coastal bottlenose dolphins between two areas along the coast of South Portugal mainland. Proceedings of the Twentieth Annual Conference of the European Cetacean Society, Middelfart, Denmark. (Winning the 1st place for the Under-graduated best poster apresentation)

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CHAPTER 1: Introduction

Introduction

The common bottlenose dolphin

One of the most iconic marine mammal and top predator is the common bottlenose dolphin (*Tursiops truncatus,* Montagu, 1821). This species have a wide distribution from all temperate to tropical waters inhabiting in rivers, lagoons, estuaries, oceanic islands and offshore waters (Wells and Scott, 2002). Through genetic, morphological and ecological differences were identified two distinct ecotypes, the pelagic-oceanic and the coastal ecotype (Hoelzel et al., 1998; Mead and Potter, 1995). The pelagic-oceanic ecotype is primarily distributed in deep offshore waters (Wells et al., 1999) and in oceanic islands, like Azores (Silva et al., 2008), São Tomé (Pereira et al., 2013) and Hawaii (Baird et al., 2009), forming large groups with very large home-range. Otherwise, coastal ecotype is distributed in coastal and inshore waters (Torres et al., 2003) forming groups more restricted and sometimes resident (Shane et al., 1986).

Residence and site fidelity of bottlenose dolphin populations varies, within a full spectrum of patterns, ranging from resident to migratory groups (Wilson et al., 1999) with seasonal site fidelity (Barco et al., 1999) or to transient groups, showing no site fidelity (Defran et al., 1999). Normally, individuals living in sheltered inshore areas, like lagoons or estuaries, show higher site fidelity (Bearzi et al., 2008) and sometimes form resident populations with home-ranges well defined, where individuals are repeatedly seen (Barros and Wells, 1998). These populations are found in Shannon Estuary, Ireland (Ingram and Rogan, 2002), Moray Firth, Scotland (Wilson et al., 1997) Sado Estuary, Portugal (dos Santos et al., 2005) and Sarasota bay, USA (Barros and Wells, 1998), for example. Whilst, individuals living in less protected areas, such as open coastal areas, form large and dynamic populations, which changes in terms of group size and composition. These coastal populations are constituted by individuals with different levels of residence and site fidelity, which some of them are transients and may travel hundreds of kilometres (Bearzi, 2005; Defran et al., 1999).

Bottlenose dolphins live in groups composed by few individuals to thousands and are organized as a fission-fusion society (Read et al., 2003), which individuals associate and form social units whose composition change over time and space. Some associations between individuals last years and others only one-day (Wells et al., 1987). Due to these differences observed, studies have shown that social structure is influenced by several factors, such as anthropogenic activities (Constantine et al., 2004; Louis et al., 2015), environmental changes (Lusseau et al., 2004) or behaviour patterns within the group (Gero et al., 2005; Sargeant et al., 2007).

The wide variation of patterns in terms of residency, site fidelity, behaviour patterns and social structure exhibited by bottlenose dolphins is due to an environmental plasticity of this species. This permit that populations have site-specific adaptations (Henderson and Würsig, 2007). It seems that habitat use of populations is a complex mechanism caused by several factors, such as environmental features and intrinsic factors of populations, such as social learning, which all together change, temporarily and spatially. Due to this, making general assumptions of bottlenose dolphins should be avoided, especially for conservation purposes (Balance, 1992; Wilson et al., 1997). In order to study the habitat use and other patterns of these populations, it is more accurate conducting fine-scale studies, where populations are studied in a regional or local perspective (Ingram and Rogan, 2002). Also comparing bottlenose dolphins populations from different areas, permitted to gain a better insight into their habitat use and how environmental factors shape their behaviour and population dynamics (Wilson et al., 1997).

Bottlenose dolphin can be identified through natural markings and their movement patterns can be analysed by re-sightings of identified individuals, through photo-identification (Hammond et al., 1990; Würsig and Jefferson, 1990). In coastal waters of Greece, for example, it was analysed individual movements between three study-sites and was possible to find that nine individuals travelled across the areas, which are up to 265 km apart, and in terms of site fidelity patterns, it was observed that individuals considered to be residents in a given area can temporarily leave and move widely (Bearzi et al., 2011).

The photo-identification techniques are the most used to obtain information about site fidelity, individual and group movements in cetaceans, because of their relatively accessible and non-intrusive nature. It allow for observations of natural behaviour with minimal disturbance, the assessment of ranging patterns and habitat use (Baird et al., 2009), as well as analyse the social associations, and when in long-term perspective they can provide insights of life history and population dynamics (Wells et al., 1987). Using photo-identification catalogues from different sites allows looking into the patterns of different populations in a comparative and integrative approach. In Pelagos Sanctuary, Mediterranean Sea, data were analysed in order to estimate abundance, distribution and movements of bottlenose dolphins from ten different research groups. It was possible to realize that some individuals have high site fidelity and others move between different areas. This multi-site study allowed to understand the existence of two subpopulations that are related with physiographic and oceanographic features of the areas, which influence the foraging techniques of bottlenose dolphins, the results of the study led to propose a Special Area of Conservation, for this species in the region (Gnone et al., 2011).

Although multi-site studies are essential to understand the dynamic of cetacean populations, due to logistic and costs constraints it might be difficult to conduct scientific surveys in some regions and during long periods of time. In the last decades, several studies have been using data collected on opportunistic platforms like whale-watching companies, ferries lines or commercial ships lines (Azzellino et al., 2008; Correia et al., 2015; Ingram et al., 2007; Kiszka et al., 2007). The whale-watching companies, for example, are increasing worldwide, and this kind of operators can collect useful and ecological information from cetacean sightings during tourist boat journeys, which can be used for scientific purposes. Integrate information from opportunistic platforms and scientific research might be advantageous on studying cetacean's populations.

Describing and understanding the process that determine the distribution of organisms is a fundamental problem in ecology (Cañadas et al., 2005). The complexity and heterogeneity of habitat influence how animals distribute in a certain area by variations in abundance, distribution and availability of food resources (Balance, 1992). Therefore it is likely that certain areas that present the best conditions will be more used than others and, thus, have a greater importance to the occurrence of a species. Cetaceans species are highly mobile and may have a patchy distribution, which could difficult the understanding of habitat use of populations in a geographical range. Recently, Species Distribution Models (SMD) became a useful tool to identify key areas for cetaceans (Gregr and Trites, 2001; Pereira et al., 2013) and to assess the influence of environmental variables on species distributions (Phillips et al., 2006). Several studies have shown that oceanographic and topography factors, such water depth, oceans currents, sea surface temperature, seabed aspect (Blasi and Boitani, 2012; Hastie et al., 2005) have an important role on the distribution of bottlenose dolphin. This type of information permit to infer the relative importance of habitats on geographic distributions, which are essential information in development of species conservation plans (Phillips et al., 2006).

Conservation status:

Bottlenose dolphin is considered a keystone and a sentinel species, because of his role on the dynamics of the ecosystems and his sensitivity to the health status of the marine ecosystems, respectively. As a top predator, bottlenose dolphins, like other dolphin species, are important species for conservation due to their charismatic features, and to their impact in marine and coastal habitats which can contribute to the conservation of entire ecosystems (Wells et al., 2004).

Bottlenose dolphin is under protection by several international agreements, such as through Convention on International Trade in Endangered Species of Wild Fauna and Flora –CITES. According to the International Union for the Conservation of Nature, the specie *Tursiops truncatus* is considered as “least concern” since 2008. However, several populations are threatened and declining due to several environmental changes and human impacts.The major threats are by-catch in fishing gear, chemical and acoustic pollution, marine debris, hunting, habitat degradation and over-exploitation of prey resources (Harwood, 2001). The major threats are principle related with anthropogenic activities, where coastal populations are the most affected.

In Europe, the trend is the same with several coastal populations declining or even disappear (Jepson et al. 2016). Bottlenose dolphin is listed in Annex II and IV of the Habitats Directive (92/43/EEC). With this status, is require to all state-members of the European Union, the designation of Sites of Community Importance (here after named as SCIs) and Special Areas of Conservation (SAC’s) specific for the bottlenose dolphin (Hammond et al. 2012). It means that is crucial to identify key-habitats for bottlenose dolphin and establish monitoring programmes for this species (Hastie et al., 2003). The objective of these areas is to improve and/or maintain the good conservation status of this species in European waters, in a long-term way (Wilson et al. 1997). Some SAC’s have already been established, such as in Moray Firth (Bailey and Thompson, 2010).

In Portugal, the species is protected by law nº 263/81, which protect all the marine mammals’ species in the Portuguese ZEE, and by the law nº 9/2006 that regulates the whale and dolphin watching activities in Portugal mainland.

Bottlenose dolphin in Portugal

Portugal is composed of an extensive coast with complex oceanographic and topographic features, such as submarine canyons and seamounts, which are important for the occurrence of cetaceans. It is proved the presence of several cetaceans species in Portugal since the 19^{th} century (Brito et al., 2009; Correia et al., 2015; Dinis et al., 2016; Silva et al., 2008) but little is known about populations patterns, distribution and abundance of cetaceans, especially in mainland Portugal. Information of bottlenose dolphins is limited and sparse, being mainly focused on the small resident population, inhabiting in the Sado Estuary (dos Santos et al., 2005). The presence coastal bottlenose dolphins along mainland Portugal is known, but the information of these animals is mainly available in technical reports based on stranding data, (e.g MARPROLIFE, 2017). Only recently it was estimated, using aerial survey data, an abundance of 3000 individuals, approximately, along the continental coast, over a vast area of 74 870 km^2 (MARPROLIFE, 2017). However, in other study where they estimate the abundance of several cetaceans species in the European waters, it was estimated an abundance of 5061 individuals for the Atlantic East coast (Hammond et al., 2013).

In Sesimbra region, in 2009, started a systematic study of coastal population, in order to better understand the patterns of individuals with different levels of residence and site fidelity, in the region (Martinho et al., 2014). In Southern Portugal, one of the most popular touristic destination and where ecotourism activities are increasing, was, recently, evidenced the occurrence of bottlenose dolphins, along the coast (Castro, 2010) and in Sagres was observed individuals with some residency and others transients (Magalhães, 2016). This information gives some evidence that probably exist different coastal groups and they might have some connection between them.

This year, the "Instituto da Conservação da Natureza e das Florestas – ICNF" based on aerial transect data (ICNF, 2016) proposed three SCI's (here after named pSCI) for the bottlenose dolphin in mainland Portugal (see Fig. 2.1), the final decision is still waiting governmental approval for the effective implementation of these SCI's. Adding local information on habitat use, on distribution and movement patterns of bottlenose dolphins in each of the proposed areas, and analyse possible connections between the different areas, can bring new information about the dynamics of the coastal bottlenose dolphins and help the future management and conservation efforts in these protected areas.

Thesis aims

The knowledge of population patterns in relation to the environment it is essential to propose management and conservation strategies. The focus of the conservation of a species should be in a regional scale, however is important to have an insight into the local scale in order to understand the ecological dynamics of each population. The marine environment is heterogeneous, which influence the cetacean's populations, reflecting differences in the distribution, abundance and the habitat use of populations. The absence of physical barriers in the ocean permits that individuals move widely, adding challenges to the implementation of accurate management and conservation measures for marine populations.

This study pretend to analyse and compare the behavioural ecology of bottlenose dolphin in two regions, in central and south west of mainland Portugal. This study is the first study conducted in mainland Portugal, which emphasise the analysis of different coastal groups and understanding the movement patterns of individuals between regions.

The aim of this work is to understand the habitat use and the dynamics of coastal bottlenose dolphins, in two different regions of mainland Portugal, Sesimbra and Sagres. Five general goals were aimed:

1. Estimate the population size (relative abundance) in the two coastal areas, using mark-recapture methods;
2. Assess the site fidelity and residency patterns in each area;
3. Analyse the behaviour patterns, group characteristics and social structure of coastal bottlenose dolphin in the two areas;
4. Identify movements between areas of coastal bottlenose dolphin, through re-sightings of the individuals
5. Compare habitat preferences and predict suitable areas for the occurrence of bottlenose dolphins, in both study areas

The thesis is organized as follows: one introductory chapter, presenting an overall description of the bottlenose dolphin ecology, behaviour, conservation status and current knowledge. Follow by two chapters: The first chapter addresses the initial four objectives and the second chapter the last one. A final discussion chapter gives an overview of results with conservation implications and future research.

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Chapter 2: Bottlenose dolphins (*Tursiops truncatus*) in Portugal mainland: movements, abundance, habitat use and behavioural patterns in Sesimbra and Sagres regions

Chapter 2: Bottlenose dolphins (*Tursiops truncatus*) in Portugal mainland: movements, abundance, habitat use and behavioural patterns in Sesimbra and Sagres regions

Abstract:

Bottlenose dolphin populations can display a variety of distribution patterns, forming discrete populations or a combination of residence patterns and widely movements along a coastline. In Portuguese waters, information from these type of patterns of coastal individuals is scarce and limited. Recently, in Sesimbra and Sagres, two coastal areas, the regular presence of bottlenose dolphin has been described. The aim of this study was to estimate relative abundance, analysis of residence and site fidelity patterns, behavioural patterns, social structure in Sesimbra and Sagres regions and identify movements between these areas, using photo-identification methods. Between 2007 and 2014, boat-surveys were conducted in the two regions using different platforms (scientific and opportunistic surveys). Mark-recapture models performed by SOCPROG program resulting in a population size of 354 individuals (95% IC: 156.7 -797.8) for Sesimbra region and 350 individuals (IC: 184.69 – 662.4) for Sagres region; and by Mark program resulting in 167 individuals (95 % IC: 145,2 -192,7) for Sesimbra and 817 (95 % IC 459.6- 1458.7) for Sagres. Different levels of site fidelity were observed for both areas, existing a mixture of non-resident, transient and residents individuals, in both areas. Differences in terms of behavioural and group dynamics were found, being mainly observed travelling and feeding patterns. Overall, both areas, appeared to be important for feeding habits. Social structure was variable, but long term associations were observed in both regions. Mid-distance movements between the two areas were found, reflecting a direct connectivity between the individuals from the two areas. Individuals move on average 158 km and might be related with adult dispersal to other adjacent areas for reproductive mating and/or resource availability. This study was a first comparison of the distribution patterns of bottlenose dolphins, in different areas and pretended to contribute to a better understand of the habitat use of coastal bottlenose dolphin along the Portuguese coast.

Key words: Bottlenose dolphin; Photo-identification; Movements; Conservation

Introduction:

Bottlenose dolphin is a long-lived cosmopolitan specie that occurs in temperate to tropical waters (Leatherwood and Reeves, 1989; Wells and Scott, 2002). They display of an environmental plasticity leading to intra-specific variations, which populations can be resident year-round, seasonal resident with migratory patterns or a combination of periods of residence and mid or long-movements (Read et al., 2003). Social and behaviour variability is evident among populations and have an important role on spatial use of coastal populations (Díaz López and Methion, 2017; Whitehead and Rendell, 2004).

Coastal populations are inherently subject to human activities that can affect their distribution, abundance (Pleslić et al., 2015) and ranging patterns. Bottlenose dolphin is a species of Community interest under the Habitat Directive (92/43/EEC), which requires the implementation of Sites of Community Importance (SCIs) and Special Areas of Conservation (SAC's) to all European Union member-States. Rigorous and complete information of the patterns of coastal populations through the study of abundance, residence patterns and social structure provide basic data for management and conservation decisions on a long-term monitoring plan (Balmer et al., 2013; Parra et al., 2006)

A better understanding of the life history and dynamics of bottlenose dolphin population can be obtained by monitoring individuals over the years, during a long-term mark-recapture studies by using photo-identification. Photo-identification is a non-invasive method used to identify an individual, through distinctive and naturally marks, such as scars in dorsal fin, in photographs. This technique allows to estimate several populations parameters, such as population size, resident patterns (Hammond et al., 1990; Möller et al., 2002), social structure (Louis et al. 2015) or to monitoring movements (Baird et al., 2009; Lang et al., 2015; Piroddi et al., 2011; Tobeña et al., 2014). The identification of long movements of several bottlenose dolphins between UK and Ireland waters through the photo-identification catalogues, from several areas, have yielded a new sight on previously considered discrete populations (Robinson et al., 2012). This type of considerations have implications on the management of populations, especially in marine protect areas (Hastie et al., 2003). Bottlenose dolphin is present along the coast of mainland Portugal (Brito et al., 2009) with a recognised resident population in the Sado Estuary (dos Santos and Lacerda, 1987). The main research on this species has been focused on this small resident population and the information of coastal bottlenose dolphin is very limited. Recently, in Sesimbra, some studies have proved the presence of coastal bottlenose dolphin in the region, with some animals showing a certain degree of residence in the area (Martinho et al., 2014) and in Sagres area, it was documented the regular occurrence of this species (Magalhães, 2016).

Using photo-identification and mark-recapture methods, this study pretends, for the first time, to compare the patterns of coastal bottlenose dolphin in Sesimbra and Sagres regions through estimates of relative abundance, analysis of behaviour, social structure, residency, site fidelity patterns, and identify possible long movements between these two areas.

Methods:

Study Area:

The study-area comprise two locals of the west coast of Portugal mainland. One is located in the central west, in Sesimbra, between the Cape Espichel and Troia Peninsula, along the Arrabida coast and the other area is located in south west region, in Sagres, between São Vicente cape and close to Lagos region (Figure-2.1). The west coast of Portugal is influenced by the Atlantic north current. As Sesimbra and Sagres are facing south, this provides some protection from prevailing north-northwest winds and waves. Both regions, are located near of the northern limit of the main north-east Atlantic upwelling events, which are responsible for water temperature decrease and high productivity of coastal waters, during spring and summer (Horta e Costa et al., 2013; Loureiro et al., 2005).

In Sesimbra, the sea bottom is steep with depth ranging from 50 m to more than 100 m, and is constituted by the conversion of two submarine canyons from two main estuaries, Tejo (Lisbon) and Sado (Setubal). In 1998, a marine protected area the 'Marine Park Professor Luiz Saldanha' was created, covering 52 km^2, where different levels of management have been designated to restrict fisheries and other recreational activities.

In Sagres region, the sea bottom is rocky and steep with a sharp edge at 100-130 meters depth and then with a step to 700 m. In the proximity, the São Vicente submarine canyon is present (Relvas, 2002). Since 1995, a natural park ‘Parque Natural do Sudoeste Alentejano e Costa Vicentina’, exits in the region, which covers a Marine Protected Area, with 2 km wide along the coast, and within the park several restrictions for fisheries and recreational activities exist.

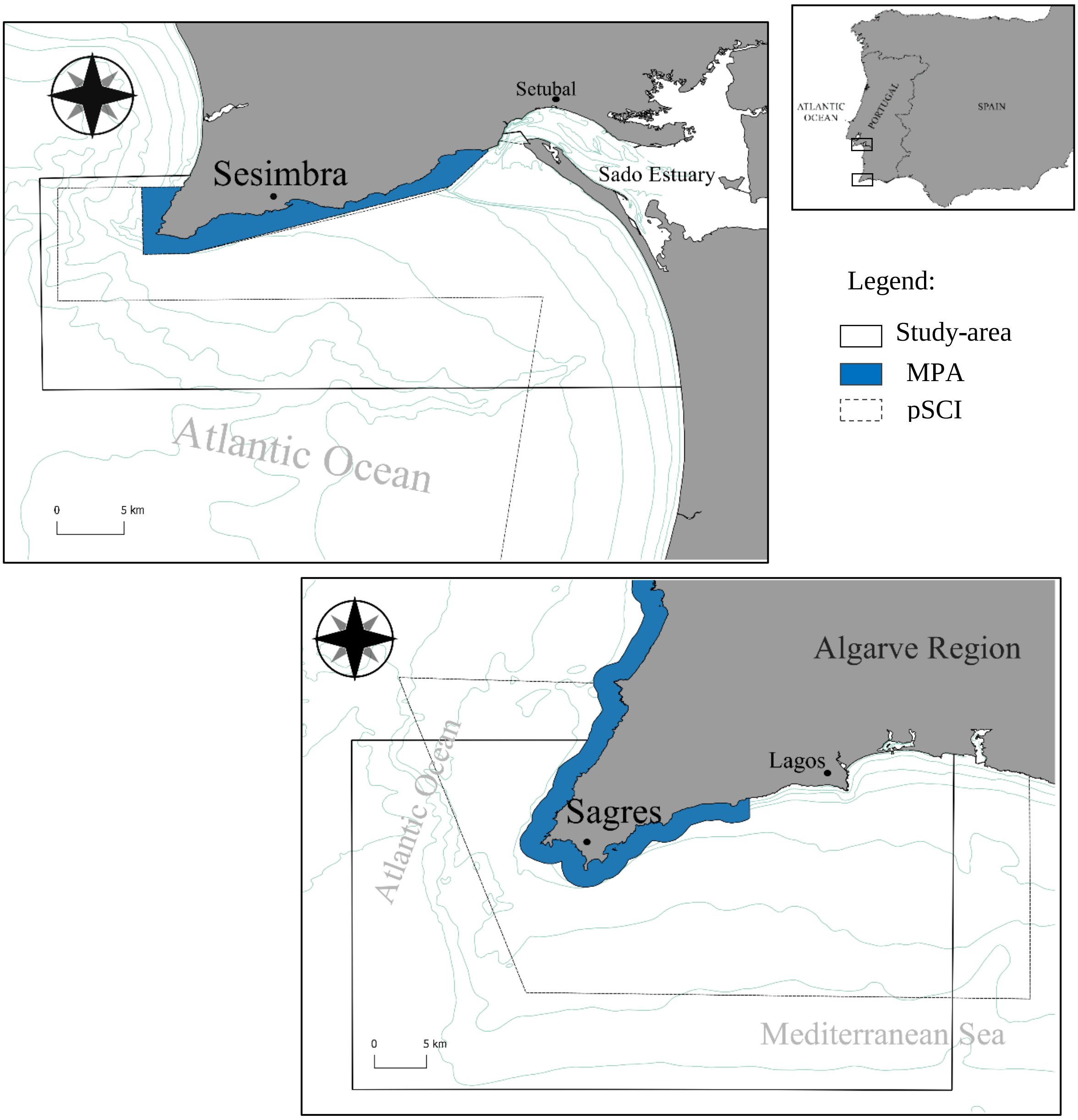


Figure 2.1-Geographical location of the two study-areas, in Portugal Mainland.

Data Collection:

In this study two datasets were used in the analysis. The datasets were collected between 2007 and 2014 by two different entities. In Sesimbra, the data were collected by a research organization, named 'Escola de Mar', an organization dedicated to cetacean research in Portugal, and in Sagres the data were collected by a dolphin-watching company, 'Mar Ilimitado'. Although the datasets were collected by different entities, the approach followed for data collection was similar, in both areas, therefore comparable.

In Sesimbra, non-systematic boat surveys were conducted between 2007 and 2014, along the coast between Espichel cape and Troia peninsula in order to increase the encounters with groups of bottlenose dolphins, since this was the target species of the research projects developed by Escola de Mar during that period. Several different boats were used for the surveys, ranging from 5.2 m to 7 meters long, but the most used was rigid-hulled inflatable boats with outboard motors. In each surveys, at least one observer was stationed at each side of the boat, scanning an area ahead the vessel to approximately 90º from his bow. Surveys were only conducted when Beaufort Sea state was inferior to 4. For every survey the date, time spent on effort and the route-track were recorded. In each dolphin sighting it was registered the species, geographic coordinates, size of the group, predominant behaviour activity (travelling, feeding, socializing, social-traveling, social-feeding) (Table 2.1), group composition, sea state, bathymetry and sea surface temperature. Digital photographs of dorsal fins were taken at the maximum of individuals possible for individual recognition and confirmation of group size and group composition, with reflex cameras with telephoto lens (70-300mm and 70-200mm).

In Sagres, were used two 7.5 m long rib boats with outboard motors as an opportunistic platform from a dolphin-watching company, 'Mar Ilimitado". In each boat was one skipper, one marine mammal guide, who had preview formation in marine biology, and a maximum of 12 passengers. Boat-surveys were dependent on weather conditions, Beaufort-sea-state level (less than 4) and tourist reservation. In each trip, the skipper and the marine guide were searching for cetaceans, information regarding with date, time spend on effort and route-track was recorded. During each cetacean sighting boat speed was decreased to 3 knots and boat was maintained on parallel course to the animals. In every sighting was recorded species, geographic coordinates, group size, group composition, cohesion of the group, predominant behaviour pattern, presence of other boats, bathymetry and sea surface temperature. Digital photographs of dorsal fins were, also, taken using reflex cameras with telephoto lens 70-300 mm.

A group was considered, as a number of animals in apparent association, moving in the same direction, with a spatial cohesion (Shane, 1990). The group composition was characterized as adults- individuals about 2-3 m long; juveniles- individuals approximately 2/3 the length of an adult swimming with association with an adult and sometimes swimming independently; calves: individuals ≤1/2 the length of an adult individual with light grey marks, in strong association with an adult.(Bearzi et al., 1999; Shane et al., 1986). Group size was estimated based on a minimum count of animals observed at surface at one time.

Table 2.1- Description of the behavioural category used in the present study.

Behaviour Category	Description
Travelling	Displacements of the whole group in a constant direction
Feeding	Long-dives and displacements with no direction; marine birds usually congregating in the area
Socializing	Some or all Individuals in physical contact with one another, oriented toward one another, and often displaying surface behaviours (leaps,jumps); no forward movement
Social-Travelling	Moving in one direction while socializing intermittently, with surface behaviour and/or individuals interaction
Social-Feeding	Presence of subgrups showing socializing and feeding activities

Data Analysis

Photo-identification analysis

Individuals were photo-identified according to the number of permanent marks (such as nicks and scars) in the dorsal fins, following: Wûrsig and Wûrsig (1977), Wells and Scott (1990) and Würsig and Jefferson, (1990). The digital photographs taken during boat-surveys were used to create a photo-id catalogue, for each area (Sesimbra and Sagres). The Sesimbra catalogue was constructed by Martinho et al. (2014) and Sagres catalogue, was initiated for Heil et al. (2014). To complete the Sagres catalogue, digital photographs, taken during boat-surveys conducted in Sagres, between August and November 2014, were analysed following the same criteria of Martinho et al. (2014). The photographs were classified in terms of photographic quality according 5 star categories: 1) bad photograph 2) poor photograph: slightly blurred with unmarked individuals 3) satisfactory photograph; 4) good photograph; 5) excellent photograph. Photographs were tagged according the number of permanent marks in each dorsal fin of each individual and a code-name was defined for each individual, in Windows Live Photo Gallery program. This approach permits a detailed and unique identification for each individual, which make it easier and faster for posterior photo-identification analysis. Calves were also tagged, but they were not considered for the analyses. Only photographs with satisfactory, good and excellent quality were used in the analyses in order to reduce mis-identification and have reliable data. In order to obtain two comparable photo-id catalogues, all photographs of both catalogues, were re-analysed to confirm whether they followed the same criteria mentioned above. Thus, 148 individuals were considered in the Sesimbra catalogue and 244 from de Sagres catalogue. Finally, the two catalogues were re-analysed by an independent observer.

Survey effort and Sighting rate analysis

Survey effort was defined as the amount of time spent searching for cetaceans, expressed in units of time (hours). A map of survey effort, divided into a 1km X 1km grid, was created using the software QGIS 2.18 (QGIS Development Team, 2017). In order to have a value of sightings relative to sampling effort, it was calculated the sighting rate as the number of sightings per unit of effort (SPUE), expressed per hour. For the analysis, it was considered just one sighting per day. Survey effort and SPUE were statistically tested in STATISTIC 10 (Statsoft, 2010) between areas, using T-test (t) or Mann-Whitney-U-test depending on the normality (significance level of p=0.05). The results were discussed taking in account the differences in survey effort between the two regions.

Population size estimates

A “population” was defined as the number of bottlenose dolphins that occur in each study-area, during the sample period (Krebs, 1994). Discovery curves (cumulative rate of identification of new individuals during sampling period) from each area were plotted to access the general population tendency and investigate if populations were considered closed or open (births, deaths, immigration, emigration). Population size (relative abundance) and trends were statistically analysed using the SOCPROG 2.7 (Whitehead, 2009) program with mark-recapture techniques, using all recognizable “marked” individuals. This program provides several open and closed models to estimate population size (Appendix 2.1). Also, it was performed the Jolly-Seber model with the POPAN parameterisation (Schwarz and Arnason, 1996) in MARK program (White and Burnham, 1999). This mark-recapture model, is commonly used in long-term studies, as provide estimates allowing entries (assume births and immigration) and losses (death, permanent emigration) in the population under study (Parra et al., 2006). This model estimate the existence of a super-population composed of all animals that would ever be born in the population during the sample period. The models parameters were developed with temporal variation (t) and no variation (.), resulting in several models, along the sampling period considered (Appendix 2.2). The best fitted model, from each program, was selected by the lowest Akaike’s Information Criterion (AIC) (Burnham and Anderson, 1998).

Several assumptions are made for the mark-recapture analyses (Amstrup et al., 2005): 1)Individuals marks are not lost or missed; 2) Sampling is instantaneous; 3) Survival probabilities are the same for all animals, marked and unmarked over sampling occasions; 4) Probability of Capture is the same for marked and unmarked animals, at each sampling occasion. Since, the temporal distribution of the survey effort, was not equal during each year, in both areas, was considered “a year” as a sampling occasion to estimate the population size. Only years with high survey effort and number of individuals identified were considered. So, population size, for each area, was estimate during 2009-2013. Due to the fact that only well-marked individuals were used for the analyses, it was calculated a mark rate to include the unidentified individuals, identified individuals which were excluded, juveniles and calves. This mark rate is the proportion between identified individuals and the total number of animals observed, in each sighting. The mark rate was applied to the population size estimate from the best fitted model, resulting in the total population size.

Site Fidelity and Residence patterns

Site fidelity could be defined as the tendency for individuals to return to a particular area repeatedly or remain in an area during a period of time (McSweeney et al., 2007). To assess the side fidelity, in each areas, all individuals were classified according to their sightings histories into three categories: Resident- seen in consecutive years; Transient-seen in non-consecutive years or re-sighted only within a year; Non-resident- only seen in one occasion.

In this study, residence was interpreted as the amount of time, which individuals spent in any particular area (Parra et al., 2006; Wells and Scott, 1990). The time of residence was analysed using the movement analyses in the program SOCPROG 2.7 (Whitehead, 2009) by calculating the Lagged Identification Rate (LIR) of re-sighted individuals in both areas. This parameter estimates the probability that an individual at any time is the same as a randomly chosen individual from the study area t time units later (Whitehead, 2001). Posterior, The LIR was compared with different models (Appendix 2.3). The selection for the best model fitted was based on the lowest quasi-Akaike Information Criterion (QAIC) value.

Behavioural analysis

Five behavioural categories were used: Travelling, Feeding, Social-Feeding, Socializing, Socializing-Travelling (Bearzi et al., 1999; Shane, 1990) and were analysed according to group characteristics. Chi-square tests (χ^2, p=0.05) were used to infer if behaviour patterns were independent of group size and group composition. Group size was defined in 4 classes: 1-10; 11-20; 21-50; 51-150. Group composition was defined as: Adults; Adults and juveniles; Adults and calves; Adults, juveniles and calves. Also, was statistically tested if group size was independent of group composition.

Social structure

For the social analyses, only re-sighted individuals seen at least in two occasions were taken into account in the SOCPROG 2.7 program (Whitehead, 2009). Association index is an estimate of the proportion of time that two individuals spend together (Whitehead, 2009) and it was measured using the half-weight index (HWI). This index is the most commonly used in the analysis of social structure in cetaceans, because it is a less biased index since it takes in consideration occasions when not all associates are identified (Cairns and Schwager, 1987). The index values range from 0 (two individuals never seen together) to 1 (individuals always seen together) and were divided in categories: low (0,01-0,20), medium-low (0,21-0,40), medium (0,41-0,60), medium-high (0,61-0,80) and high (0,81-1) (Quintana-Rizzo and Wells, 2001).

A permutation test was conducted to determine the existence of preferred/avoided associations among individuals, through the comparison between associations observed and a random distribution permuted 10000 times of the associations observed (Bejder et al., 1998).

A network diagram of the association's index was performed in order to understand the social relation between individuals. A Principal Coordinates Arrangement was obtained, where nodes (represent the individuals) are arranged in two-dimensions and the thickness of links between pairs of nodes indicate the strength of their relationship. It was selected HWI higher than 0.4, in order to observed easily the social relationship between individuals.

To analyse the temporal variation of social structure was calculated the Lagged association rate (LAR), which is an estimate of the probability that two individuals associated in a particular time are still associated in the future (Whitehead, 2009). The LAR was standardized (SLAR) in order to consider the sampling effort. SLAR was compared with other theoretical models and was applied the quasi-AKaike's information criterion (QAIC) to select the best model fitted (Appendix 2.4).

Mid-long Distance Movements:

The possible existence of mid-long distance movement of individuals, between Sesimbra and Sagres, were analysed through the matching of photo-identified individuals from both catalogues. In order to reduce mis-identification and maximize the certainty of matching, it was followed a rigorous and conservative approach, using only photographs with good and excellent quality. For the matching analysis, the catalogues were re-analysed by two independent observers. It was calculated the distance travelled by each individual matched, between Sesimbra and Sagres, through the GPS sightings positions in each area using the QGIS 2.8 (QGIS Development Team, 2017).

Results:

Survey effort and Sighting rate

In Sesimbra, between 2007 and 2014, were conducted 136 surveys, which corresponded a 425 hours of survey effort, and 29 bottlenose dolphins' sightings were recorded. The mean sighting rate, was 0.072 per hour (approximately 14h for one sighting). In Sagres region, were conducted 2160 surveys with 3856 hours of survey effort and 227 bottlenose dolphins' sightings were recorded. The mean sighting rate was 0.04 per hour (25 hours for one sighting) (Table 2.2). The distribution of the survey effort was concentred near the coast and sightings of the individuals were mainly distributed within the pSCI, in both areas (Figure 2.1; Figure 2.2). The survey effort (hours) between the two areas was statistically different during all sampling period (z=-17.79; p=0,00). However, the SPUE between the two areas was not statistically different, during sampling period (T= 1.65 p=0,12).

Table 2.2- Sample period, in both study areas, Sesimbra (SB) and Sagres (SG), number of surveys and sightings, survey effort (in hours) and number of sightings for photo-identification analyses. * Mean SPUE over the years.

Year	Number of Surveys		Number of Sightings		Survey effort (h)		SPUE (sightings h^{-1})	
	SB	SG	SB	SG	SB	SG	SB	SG
2007	8	75	1	1	18	126	0.05	0.01
2008	38	107	7	5	84	~179	0.08	0.03
2009	12	153	4	13	41	~275	0.10	0.05
2010	14	265	3	14	38	503	0.08	0.03
2011	28	293	7	27	121	~521	0.06	0.05
2012	17	398	1	70	59	~741	0.01	0.09
2013	16	418	5	38	53	702	0.09	0.05
2014	3	451	1	59	11	~809	0.09	0.07
Total	136	2160	29	227	425	3856	0.07*	0.04*

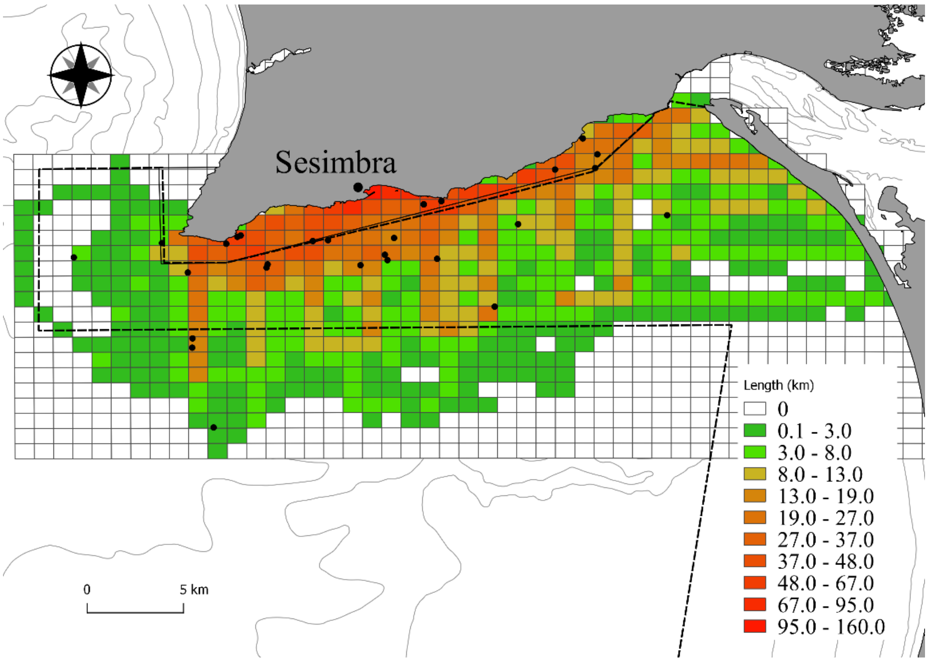


Figure 2.2- Survey effort (Km) between 2007-2014 and bottlenose dolphin sightings (black dots) in Sesimbra region. Marine Protected Area (MPA) represented as a continuous line. Proposed SCI (pSCI) represented as a dashed line.

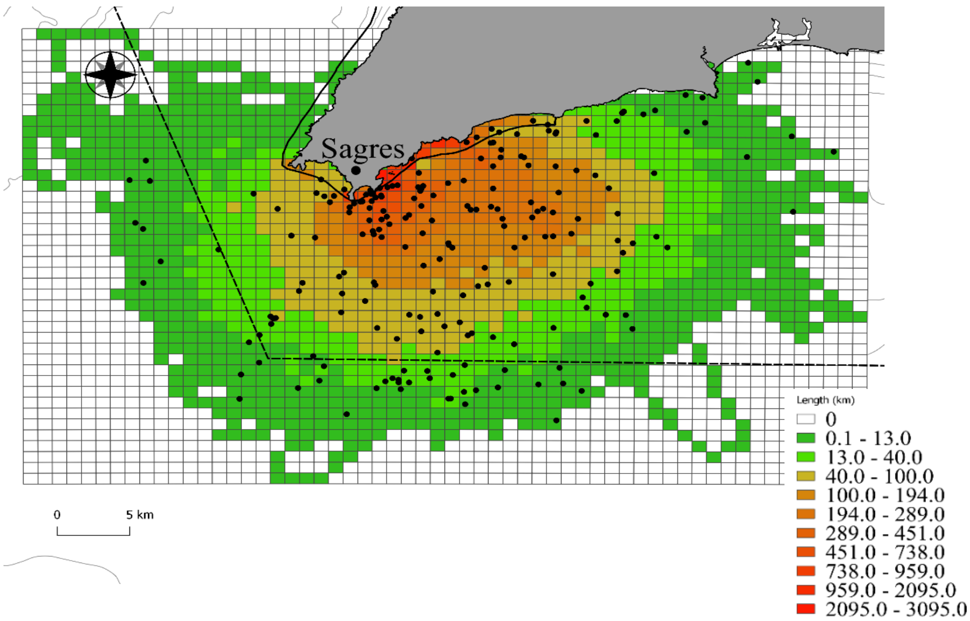


Figure 2.3- Survey effort (Km), between 2007-2014, and bottlenose dolphin sighitngs (black dots) in Sagres region. Marine Protected Area (MPA) represented as a continuous line. Proposed SCI (pSCI) represented as a dashed line

Photo-ID analysis

In Sagres, of a total of 1874 digital photographs, taken between August and November of 2014, 633 digital photographs were considered for photo-identification analyses, resulted in 59 new individuals identified that were added to the photo-identification catalogue (already with n=244). In the end, the Sagres catalogue was composed by 303 individuals.

The Sesimbra catalogue was composed of 148 individuals, of which 82% (n=121) were only seen once, and the remaining 18% (n=27) were individuals seen between 2 and 5 times, (Figure 2.4 -A).The Sagres catalogue was composed by 303 individuals, of which 65% (n= 197) were seen only once and 35% (n= 106) of the individuals were seen between 2 and 8 times, (Figure 2.4-B). The mean sighting of the individuals from Sesimbra was 1.32 (SD ± 0.77) and the mean re-sighting was 2.52 (SD=1.13) with a mean temporal variation of re-sighintg of the 413 days (SD ± 301). The mean sighting of the individuals from Sagres was 2 (SD ± 1.27) and the mean re-sighting was 3 (SD ±1.29) with a mean temporal variation of re-sightings of 147 days (SD ± 173.66). The mean mark rate for Sesimbra catalogue correspond a 73% and for Sagres catalogue was 28%.

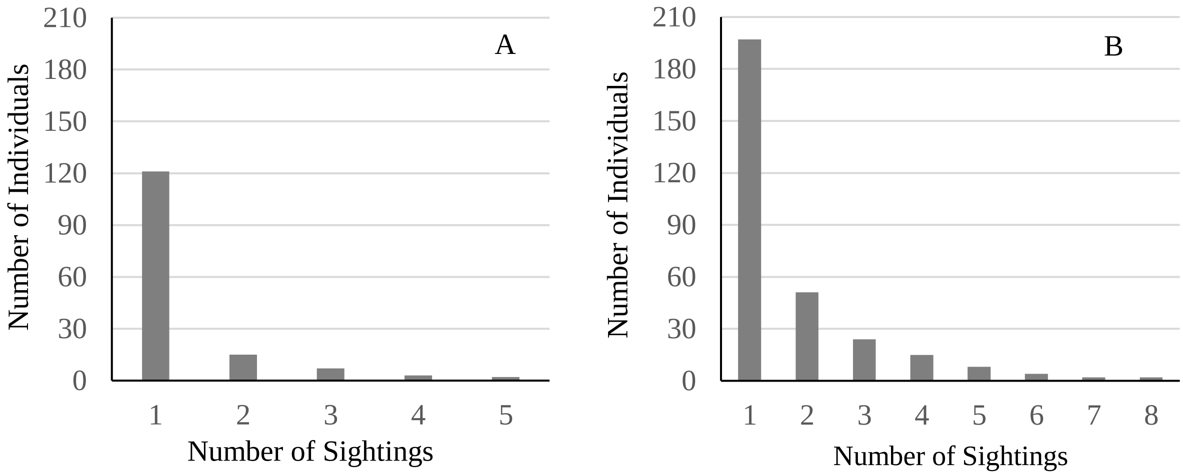


Figure 2.4- Sightings histories of the identified individuals, from Sesimbra (A) and from Sagres (B) dataset, during the sample period (2007-2014).

Population Size estimates:

According to the discovery curves (Figure 2.5), an increasing of new individuals identified occurred throughout the sampling period and the number of re-sighting individuals was always inferior to the number of new individuals, in both areas. The increasing of new individuals per sighting was more pronounced in Sesimbra than in Sagres, where it was more gradual. In both areas the cumulative curve of new individuals never reach the plateau.

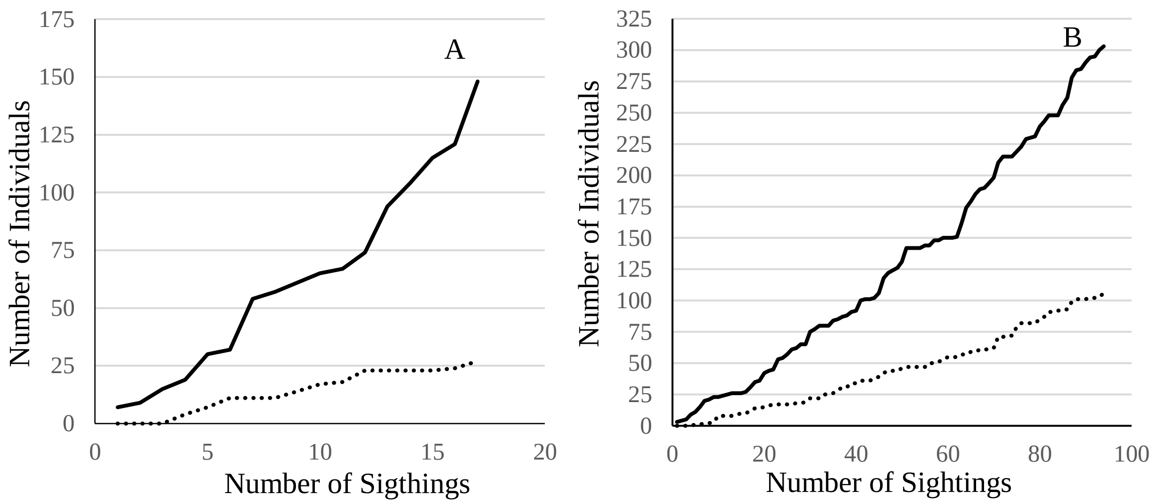


Figure 2.5-Cumulative curve of new individuals (solid line) and re-sighting curve (dotted line) in Sesimbra (A) and Sagres (B) during the sample period.

Regarding the AIC values, the best fitted model for population size estimative, given by SOCPROG program, was the open model “Mortality + trend”, in both areas. The estimated population size for Sesimbra was 258 individuals and for Sagres was 98 individuals (Table 2.3). When adjusting the mark rate (Sesimbra: 73%; Sagres: 28%), the total population size estimative was 354 individuals (95% IC: 156.7 -797.8), for Sesimbra region and 350 individuals (95% IC: 184.69 – 662.4) for Sagres region. The estimates calculated by Mark program revealed that the best fitted model was the time dependence for all parameters, for both areas. According to this model the estimated population size for Sesimbra was 122 individuals and for Sagres was 229 (Table 2.4). The application for mark rate was also considered to this model, resulting of a total population size of 167 (95 % IC: 145,2 -192,7) individuals for Sesimbra region and 817 (95 % IC 459.6- 1458.7) for Sagres.

Table 2.3- Population size estimates (N) giving by SOCPROG program. The model a bolt represent the model selected for both areas, Sesimbra (SB) and Sagres (SG).

	N̂		SE		95%IC		Log-likelihood		AIC	
Model	SB	SG	SB	SG	SB	SG	SB	SG	SB	SG
Schnabel (Closed)	263.06	276.62	68.5	32.9	173.9 425.1	231.4 340.9	-51.02	-92.12	104.03	186.25
Mortality	82.00	135.31	43.9	33.4	60.0 235.1	92.3 234.9	-48.47	-89.05	100.95	182.10
Mortality + Trend	**258.14**	**97.94**	**111**	**30.2**	**63.7 488.1**	**78.0 213.7**	**-29.24**	**-86.36**	**64.48**	**178.72**

Table 2.4- Population size estimates (N) giving by Mark program. The model a bolt represent the model selected for both areas, sesimbra (SB) and Sagres (SG). Years as sampling occasions. ρ =probability of capture an individual; ϕ = apparental survival probability of an individual; b =probability of entrance of an individual in the population; The (t) under each parameter symbol indicate that time dependent effect was considered and (.) indicate constant effect was considered.

Model	$\hat{N}$		SE		95%IC		AIC		Number of parameters	
	SB	SG	SB	SG	SB	SG	SB	SG	SB	SG
$\{\rho_t, \phi_t, b_t\}$	**122.12**	**229.26**	**5.51**	**62.27**	**117.35** **143.74**	**170.3** **458.25**	**82.54**	**211.45**	**7**	**11**
$\{\rho_., \phi_., b_t\}$	314.50	252.61	97.17	29.17	196.02 608.38	209.4 327.21	159.21	213.04	7	6
$\{\rho_., \phi_t, b_t\}$	190.24	233.66	28.11	39.94	152.23 268.15	177.2 349.24	84.29	211.46	6	10

Site fidelity and residence patterns:

According to the definition of site fidelity and re-sighting histories of each individual identified, in Sesimbra region, 82% (n=121) of the individuals identified were considered non-resident (only seen once), 11% (n=16) were considered transients and 7% (n=11) were considered resident. From these residents, 7 individuals were seen between 2 consecutive years and 4 individuals, between 3 consecutive years. In Sagres region, 65% (n=197) of the individuals identified were considered non-resident and the maining 35% of the individuals were considered transients (24%; n=75) and Residents (11%; n=31). Of the resident individuals, 26 individuals were seen consecutively during 2 years and 5 individuals were seen between 3 consecutive years.

The Lagged Identification rate (LIR) is the probability of re-sighed an individual previously identified. In Sesimbra, the probability of re-sighting an individual is approximately constant within 100 days (Figure 2.6-A), which mean that bottlenose dolphins might remain this period of time, in the study-area, before living. As the LIR decrease over time to very low values, this suggest that individuals tend to emigrate from this area permanently or during a period longer than the sample period and/or simply die. The model which best adjust to data is the Emigration/ mortality model. (Figure 2.6-A).

For the Sagres region, the high values of LIR in the first days reveals that, it is more likely to re-sight an individual, previously identified, approximately in ten days than later (Figure 2.6-B). This suggest that bottlenose dolphins might spend a few days inside the study-area before living. The decrease of the LIR with time, show that emigration or mortality, might occur. The slight increase of LIR after 100 days indicates that some individuals might re-immigrate into the study-area. The selected model for the population of Sagres is the model Emigration + Reimmigration + mortality (Figure 2.6-B).

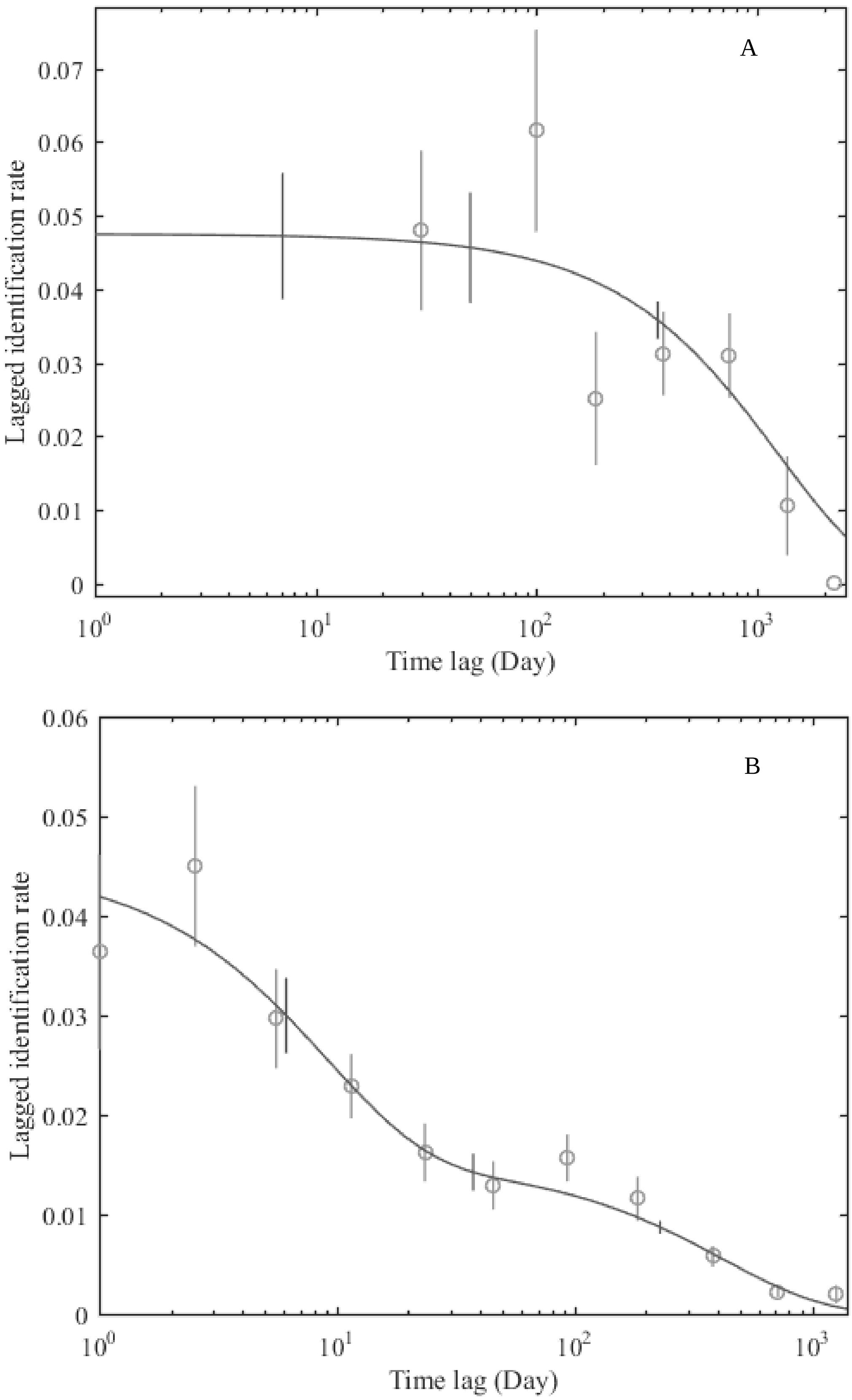


Figure 2.6- Lagged Identification rate for bottlenose dolphins seen at least 2 times, in Sesimbra (A) and in Sagres (B). Data points are represented as circles and the best fitted model was (Emigration/Mortality) for Sesimbra (A) and (Emigration + Reimmigration + mortality) for Sagres (B). The best fitted models are represented with a line. Error bars were estimated with 100 bootstrap replications.

Behavioural Analysis

According to the behavioural patterns stabelished, all categories were observed in Sesimbra and Sagres. The most observed behaviour pattern in Sesimbra was Travelling (57%) and in Sagres was Feeding (50%).The qui-chare tests reveal that behaviour is independent of group size (SB: χ^2= 15,22 df = 19 p=0,708; SG χ^2= 25,43 df = 19 p=0,147) and group composition (SG: χ^2= 21,165 df =19 p=0,327; SG: χ^2= 16,057 df =19 p=0,653), for both areas (Figure 2.7; Figure 2.8).

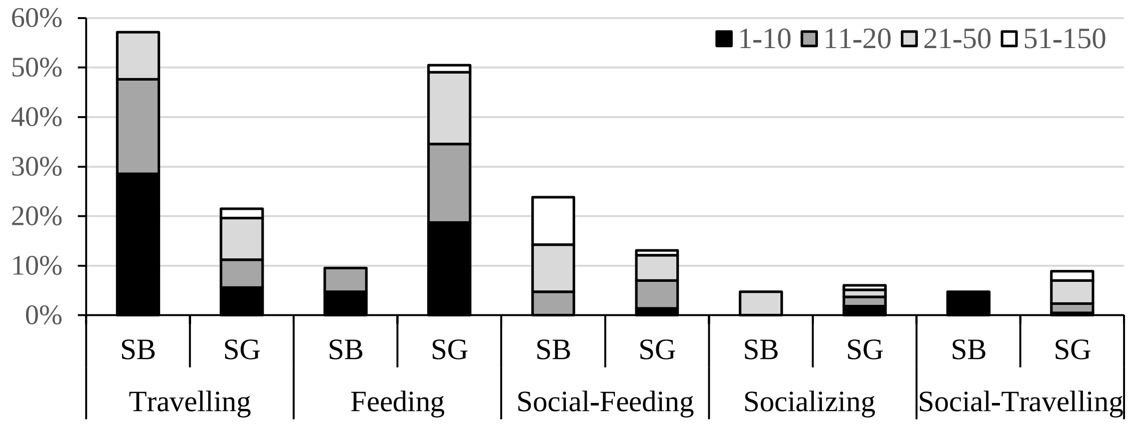


Figure 2.7- Behavioural pattern frequency according group size in SB-Sesimbra (n=21) and SG-Sagres (n=214)

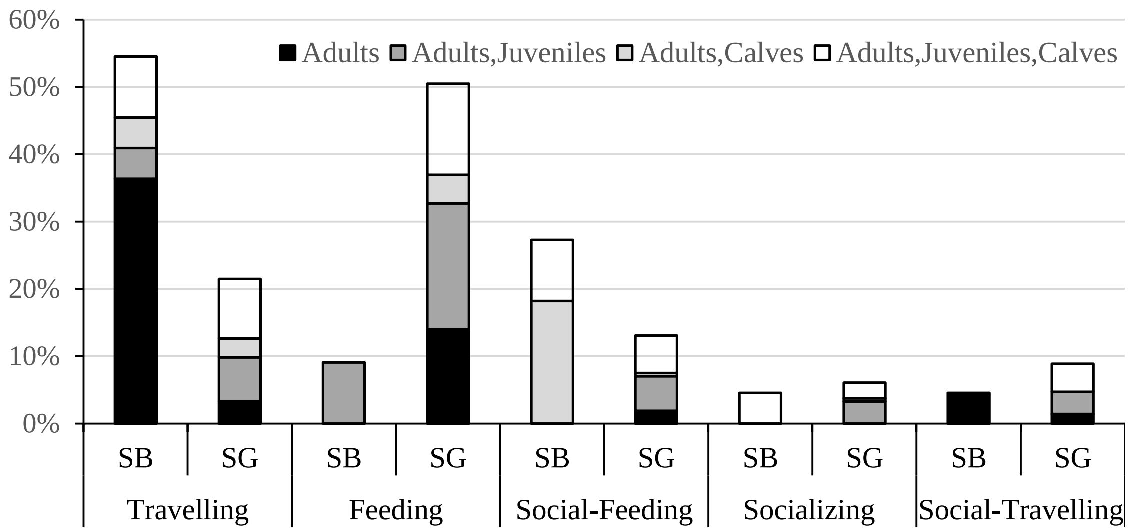


Figure 2.8- Behavioural pattern frequency according group composition (Adults; Adults, Juveniles; Adults, Calves; Adults, Juveniles, Calves), in SB-Sesimbra (n=22) and SG-Sagres (n=214).

In both areas, groups sighted had approximately the same average size [SB:20 (± 14); SG=21(±13)], but in relation to group composition there was differences, between study-areas. The percentage of observed groups constituted only by adults was higher in Sesimbra (43%) than in Sagres (22%). The percentage of observed groups composed with "Adults and juveniles" and "Adults, Juveniles and calves" was higher in Sagres region than in Sesimbra (Figure 2.9). In Sagres, the group composition and group size are dependent (SG: χ^2= 52,747 df = 15 p=0,000). In Sesimbra, the influence of group composition on group size was not statistically significant (SB: χ^2= 12,29 df = 15 p=0,656).

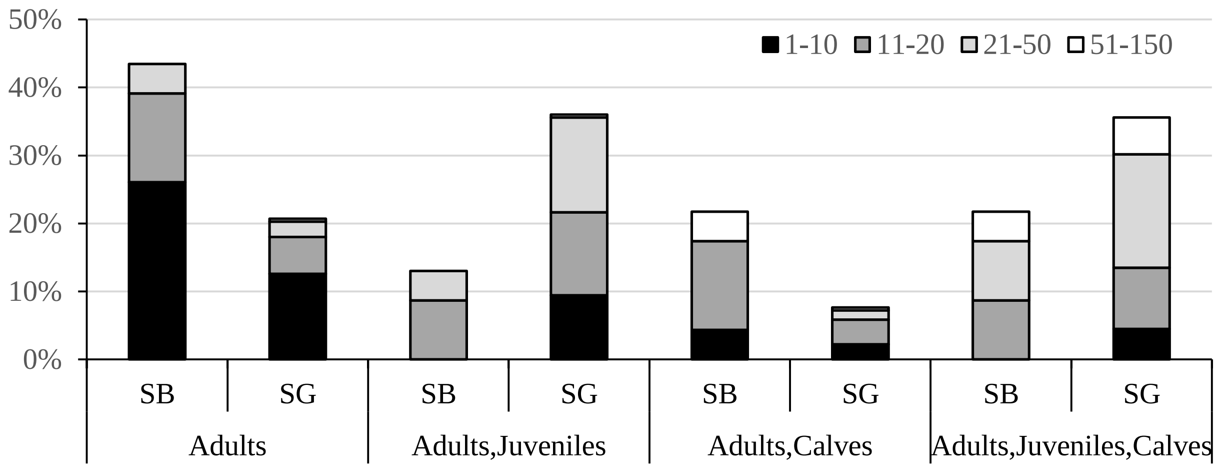


Figure 2.9- Group composition (Adults; Adults, Juveniles; Adults, Calves; Adults, Juveniles, Calves) according to group size (1-10; 11-20; 21-50; 51-150) in SB-Sesimbra (n=23) and SG-Sagres (n=222).

Social Structure:

Only the re-sighted individuals were considered for social structure analysis, resulting in 27 individuals from Sesimbra and 106 individuals from Sagres. The association index values between the individuals were mostly low, in both study-areas. In Sesimbra, the mean association index of the all individuals was medium-low 0.21 (SD±0,09) and in Sagres was low 0.05 (SD±0.03). However, there is some medium to high associations of individuals in each area (Figure 2.10).

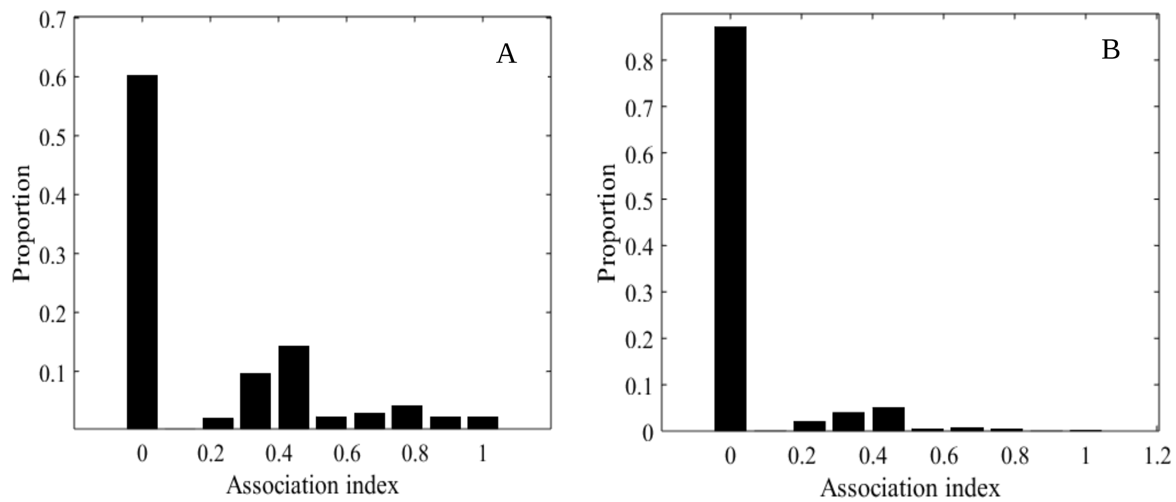


Figure 2.10-Histograms of the association index of re-sighted bottlenose dolphins from Sesimbra (A) and Sagres (B), during 2007-2014, given by the SOCPROG program.

Through the network diagram was possible to observe the social relationship between the individuals (Figure 2.11). In both areas, there was an evident social aggregation, which some individuals are more social related than with others, given by the variable distances observed between nodes (individuals). In Sesimbra region, a principal social group was observed, which high social cohesion, as given by the thickness of the links between some nodes. The two individuals separated from the principal group (SBTT_233; SBTT_152) display a weak social relationship (HWI less than 0.4) with this principal social group (Figure 2.10-A). In Sagres region, there is a principal core social group, given by the proximity of several nodes. This core group display weak social relationships with others social groups, as the link between noodles is thin (Figure 2.10- B).

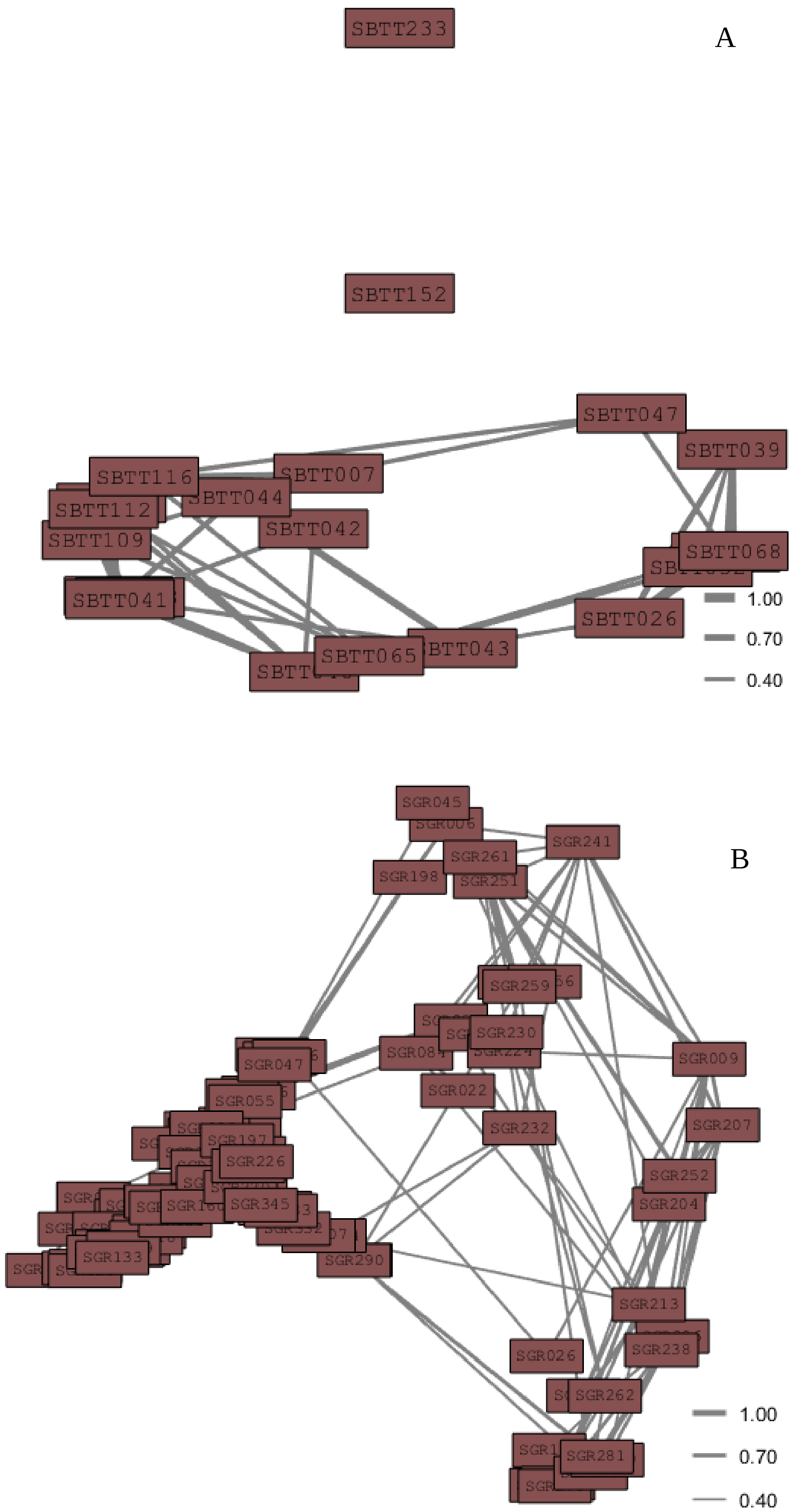


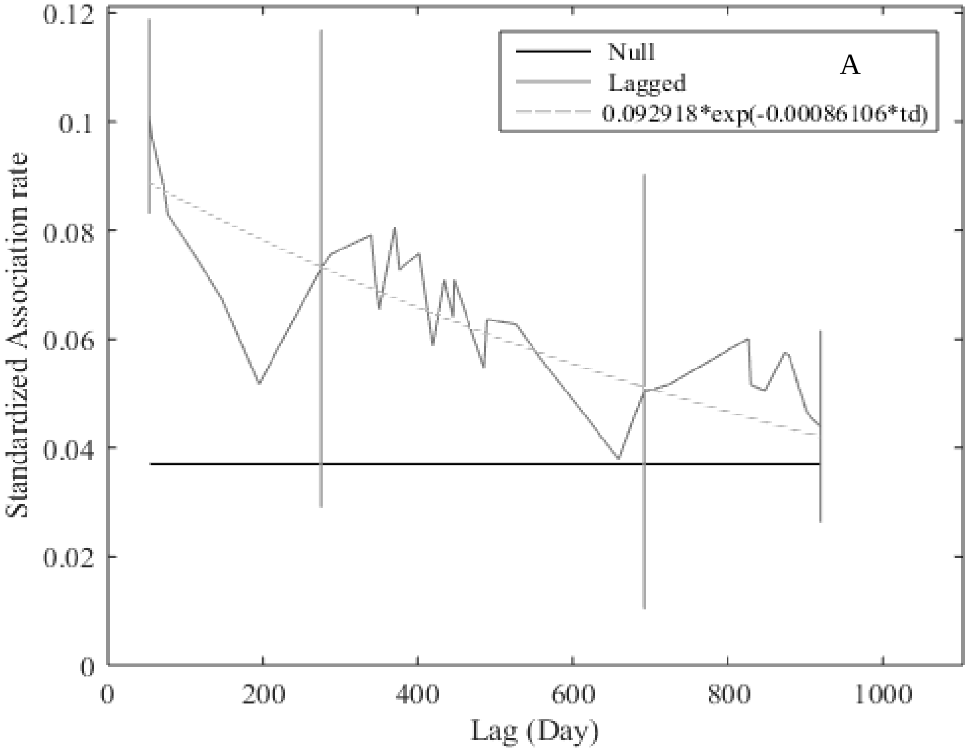
Figure 2.11- Principal component arrangement of the association index (HWI) between individuals, in Sesimbra (A), and in Sagres (B). Nodes represent the individuals. Lines represent association index between individuals. Only assocation index higher than 0.4 were represented.

The results of preferred/avoided associations test revealed a higher value of standard deviation and coefficient of variation of the real data comparing with the permuted data, between individuals in each area, indicating the existence of long and preferred associations and not random associations among individuals (Table 2.5).

Table 2.5 -The results of the preferred/avoided associations test of the re-sighted bottlenose dolphins, for Sesimbra (SB) and Sagres (SG), given by the SOCPROG program. Permuted data were calculated based in 10.000 random permutations.

	Real		Random		p-value	
	SB	SG	SB	SG	SB	SG
Mean association index	0.20822	0.05095	0.00002	0.00001	0.0000	0.0000
Standard deviation	0.29005	0.14201	0.00003	0.00001	0.0000	0.0001
Coefficient of variation	1.39303	2.78749	0.00014	0.00028	0.0000	0.0001

The temporal analysis of the social relationships among individuals was given by the Standardized Lagged Association Rate (SLAR). The values of SLAR of Sesimbra and Sagres were inconsistent over sample period, although it was more evident on Sagres data. The SLAR values of the individuals from Sesimbra were slightly higher than the SLAR values of individuals from Sagres, and never reached the null rate. The best fitted model for each area was the “Casual Acquaintances model”, which associations of the individuals last from a few days to a few years (Figure 2.12).



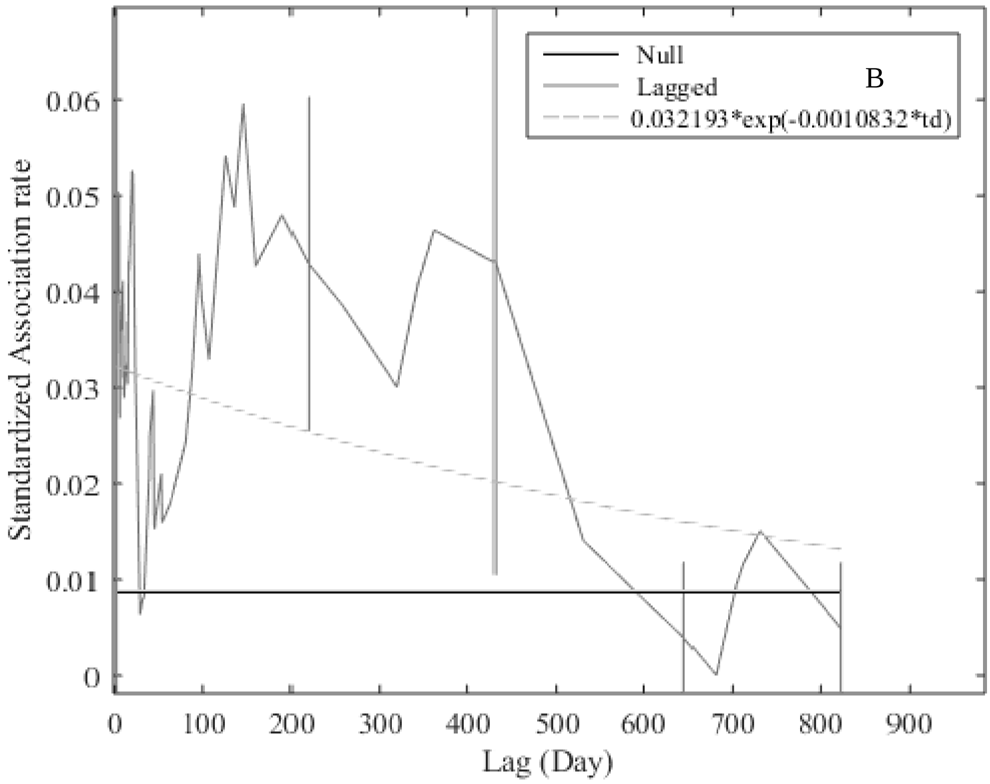


Figure 2.12- Standardized Lagged Association rate of the re-sighted bottlenose dolphins in Sesimbra (A) and in Sagres (B), during the period of 2007 and 2014. The null association represents the expected SLAR values if there is no preferred associations. The best fitted model for both areas is Casual Acquaintances Model. Erro bars were given by the jackniffe procedure.

Mid-long Distance Movements:

From the total of 274 individuals considered (Sesimbra - 118 individuals; Sagres -156 individuals) it resulted in 28 matches. The 28 individuals had different temporal patterns, between the two areas, and different site fidelity in each area. The majority of the individuals were considered transient or non-resident individuals, in each study-areas (Table 2.6).Some individuals were seen in several years, in Sesimbra and Sagres. Only two individuals (T_ 05; T_06) were seen in 3 different years, but only the individual 'T_05' was seen in 3 consecutive years (Sagres: 2012-2013; Sesimbra: 2014). The mean temporal variation of sightings, between the two areas, was 267 days (SD± 355), with a minimum variation of only 11 days (T_19) and a maximum temporal variation of 1465 days (T_18). The mean distance travelled between the two areas, was 158 km (SD± 3.5), with a minimal distance of 152 km (T_07; T_18) and a maximum distance of 164 km (T_08; T_09; T_14; T_20). Individual T_14 is a possible female, since it was observed in association with a calf.

From the 28 individuals matched, 18 individuals were firstly sighted, in Sesimbra, and then re-sighted in Sagres, after a variable period of time (North to South movements) and 5 individuals were seen firstly in Sagres and re-sighted in Sesimbra (South to North movements), with no evidence if these individuals return to the area, where they were firstly sighted. The remaining 5 individuals, were sighted in Sagres in different days, re-sighted in Sesimbra, and posterior re-sighted again in Sagres (back-and-forth movements) (Table 2.6; Figure 2.13). This last movement pattern was observed only in summer months of 2014.

Interestingly, some individuals were seen together (in the same sighting), both in Sesimbra and Sagres. For example, the individual 'T_08' was seen with 'T_09' with a temporal variation between sightings of 2 years. Some of the individuals, which have made back-and-forth movements, were seen together in Sagres, and then all were seen together in Sesimbra. (Figure 2.14).

Table 2.6- The 28 bottlenose dolphins sighted in Sesimbra and in Sagres, during the sample period 2007-2014. Light gray box represent sighted in Sesimbra and dark gray box represent sighted in Sagres.

ID	2010		2011		2012					2013					2014			
	M	J	A	J	M	J	A	S	O	J	J	A	S	J	J	A	S	O
T_01																		
T_02																		
T_03																		
T_04																		
T_05																		
T_06																		
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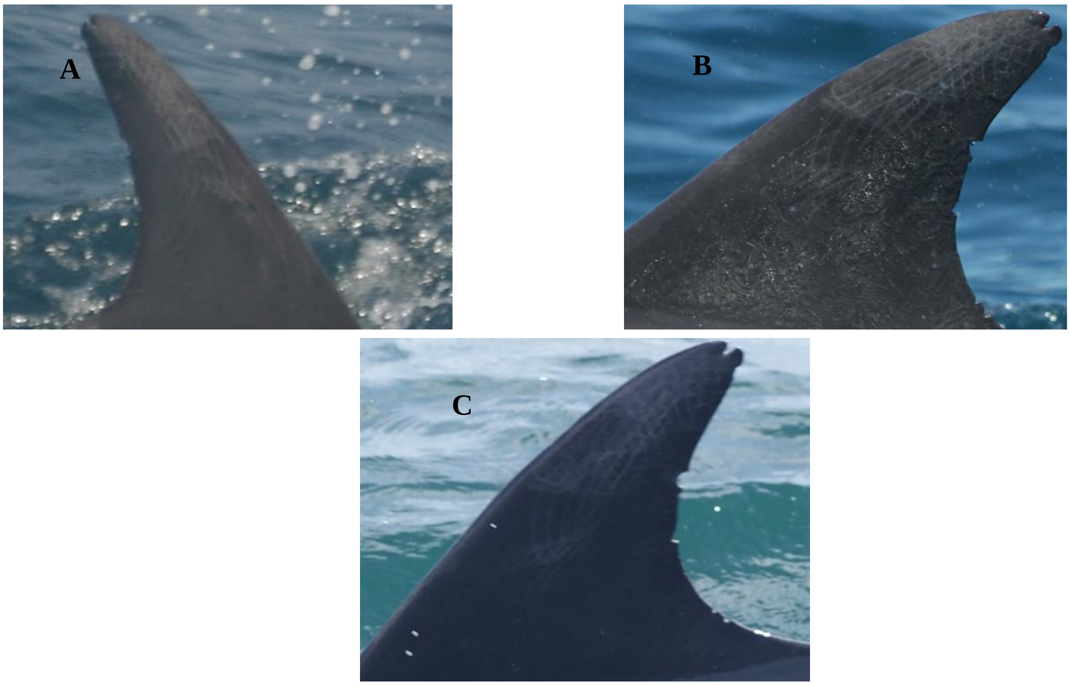

Figure 2.13 - Dorsal fin profile of bottlenose dolphin designated as T_16; photo-identified in (A) Sagres, in July 2014; (B) Sesimbra, in August 2014; (C) Sagres, in September 2014.

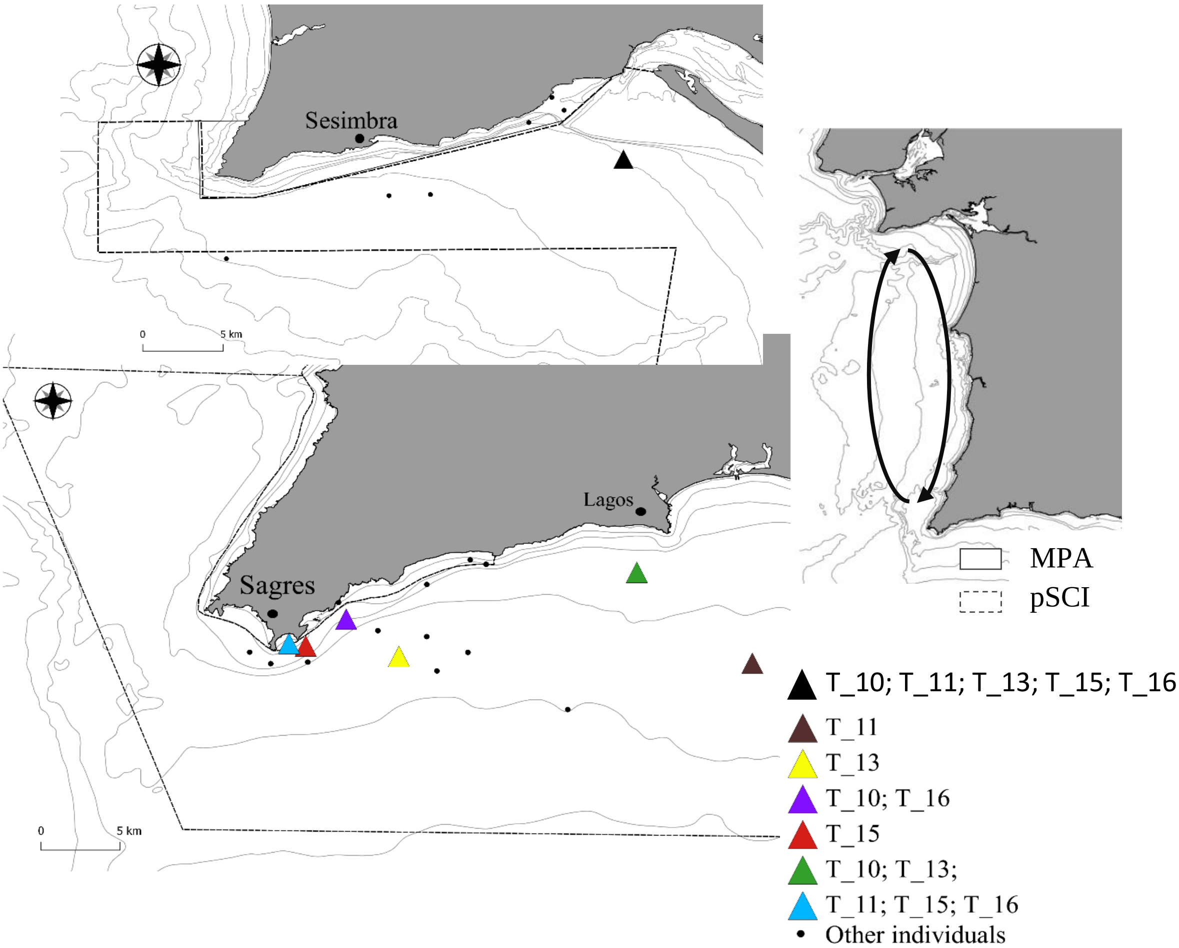

Figure 2.14- Sightings of the 28 individuals matches, between Sesimbra and Sagres. The Triangle represent the sightings of the individuals which made “back and Forth movements”. Black dot represent sightings of other individuals matched.

Discussion:

This study was the first ecological comparison of coastal bottlenose dolphin in two different regions of Portugal mainland. Through this multi-site study, it was possible to infer differences and similarities between bottlenose dolphins of Sesimbra and Sagres areas and to identify connections between the two regions with direct movements of identified individuals.

Using data from different platforms is quite challenging and has some limitations. The uneven survey effort among the study-areas could have influenced the results, but this limitation has been considered in all the analyses and results interpretation. Even though this, when calculating the SPUE of each area, there were no statistical differences which means that higher survey effort doesn't mean, necessarily, more sightings. The similarities of sampling methods, in the two regions, enable the comparison of the distribution patterns of the two regions studied. In fact, several studies have been conduct using cetacean data collected from different platforms (scientific surveys versus opportunistic surveys) (e.g. Azzellino et al., 2008; Silva et al., 2012).

Population size estimate:

Discoveries curves revealed an increase of individuals identified, during sampling period, which suggest that populations, in both areas, were considered open, occurring changes in the number of individuals, due to births/deaths events and/or migrations events. Also these results could indicate that data collected was not sufficient to identify all the individuals that occur in each areas and probably the two study-areas correspond to a small part of the home-range of bottlenose dolphins occurring in southwest coast.

The results given by the models performed were different in both areas. This could be due to differences in survey effort and differences in models performance. Mark-recapture adjusted estimates to the model given from SOCPROG program showed that the results were similar in both areas, whereas from Mark program there were differences. However, due to differences on survey effort and sightings numbers between each region and the fact that the discovery rates never reached the plateau, it might be difficult to have precise estimates (Brown et al., 2015). In this way, it could be accurate to performed several models and compare the intervals confidence estimate for each population. Comparing, each study-area separately, there was an overlap of the intervals of confidence from adjusted models of total population size given by both programs [SB: SOCPROG-354 individuals (IC: 156.7- 797.8) MARK= 167 (95% IC: 145.2-192.7)) (SG: SOCPROG: 350 individuals (95% IC: 184.69 – 662.4) MARK: 817 (95 % IC 459.6- 1458.72)]. In Sesimbra it was between 158-193 individuals and in Sagres was 460-662 individuals. This suggest that at least these individuals occurred in study-areas, during the period of 2009-2013. The results from Sesimbra region were a little higher comparing with previous population size estimates from the same area (Martinho et al., 2014). In Sagres region, there was no previous information about population size, so the results from this study serves as baseline information to compare with future mark-recapture estimates.

The low mean mark rate obtained from Sagres dataset (28 %) could be due to several reasons. Firstly, since this dataset was collected from an opportunistic platform with the main goal of searching for cetaceans (independent of the species), with a limited time with the animals in each sighting before continuing to search for other animals, so the effectiveness of photo-identification could be lower when comparing with a research survey. In addition, 80% of the sightings, were groups composed with juveniles, since these individuals are not well-marked, they are difficult to identify and re-sight, so normally they are not incorporated in the photo-identification analysis (e.g Hammond et al., 1990; Stephanie Levesque et al., 2016; Würsig and Würsig, 1977).

Site fidelity and residence patterns:

In both areas, the bottlenose dolphins have shown similarities in terms of site fidelity. Both show low site fidelity, due to higher percentage of non-residents (SB: 82%; n=121; SG: 65%; n=197) and a low percentage of transients (SB: 11%; n=16; SG: 24% n= 75) and residents (SB: 7%; n=11; SG: 11%; n=31). The transient individuals had revealed different levels of transience. Some of these individuals were seen during a short period of time, for example less than one month and others were seen regularly during a year. This tendency was more evident in Sagres, as it could be related with survey effort, which was much higher when compared with Sesimbra region. Although these differences, these results are consisted with other studies of coastal bottlenose dolphin. Coastal populations are known to have low site fidelity, as this could be an evidence that the home-range of the individuals extends outside the study area (Bearzi et al., 2009; Defran et al., 1999; Papale et al., 2017). Then, the two study areas might correspond to a small part of the home-range.

The results given from SOCPROG program have demonstrated some differences, in terms of residence patterns in Sesimbra and Sagres regions, but are in agreement with site fidelity patterns found, even though Sagres population have shown less residency. This could be explained if the individuals used the study-area as a transition area to others adjacent areas, for example due to feeding strategies.

Behavioural analysis:

Differences in behavioural patterns and group dynamics differences between Sesimbra and Sagres were found. The most frequent behaviour in Sesimbra was travelling, while in Sagres was feeding. It seems that Sagres region might be an important feeding area for bottlenose dolphins, possibly due to an abundance of prey species, also indicated by the an intense fisheries activities (Fonseca et al 2008; Henriques et al. 2014). The predominant behavioural pattern observed in Sagres region, could explain the low levels of residence found in the region, individuals are likely to feed and forage in a much larger area than the study-area, which they move inwards and out constantly, influencing the short time spent within the study area.

In Sesimbra region, the most common groups were constituted only by adults and in Sagres were constituted by "adults and juveniles" and "adults, juveniles, calves". In Sagres, group size is influence by group composition, which smaller groups were composed by adults and larger groups were composed by juveniles and calves. This evidence also were seen in other studies and could be related with calf assistance and increase protection from predators (Bearzi et al., 1997; Sarabia et al., 2017). In Sagres, it is known an occasional occurrence of orcas (*Orcinus orca*) and several species of sharks, which could predate juveniles and calves (Shane et al., 1986).

Social Structure:

The social analysis have shown that, in both areas, individual associations are very dynamic and social bound can be very flexible. This result is consistent with other studies, as bottlenose dolphins living in fission-fusion society, the associations among individuals are temporally variable, during several hours to a few months (Connor et al., 2000) or even years (Louis et al., 2015). Social structure is influenced by ecological factors, such as prey availability or oceanographic conditions, and intrinsic factors, such as shared knowledge and behavioural strategies (Lusseau et al., 2003; Mann et al., 2012).

When comparing the HWI with other coastal populations, the bottlenose dolphins occurring in Sesimbra have higher association values, which is more related with populations living in more enclosed areas, such as bays. Even though the mean HWI in Sesimbra population is higher than in Sagres population, it was also evidence of the strong associations in both study-areas. Associations tend to be influence by sex and age, for example, associations might be strong between adult males and between adult females with similar reproductive state (Papale et al., 2017; Smith et al., 2016). Long-term associations might increase the reproductive fitness in different ways, for example, for juvenile male survival, adult male mating success or calving success (Frère et al., 2010; Smith et al., 2016). Then, this type of associations might occur in Sesimbra and Sagres.

Preferred and long-associations between the individuals were observed in both areas and also was reported in other studies of bottlenose dolphin (Blasi and Boitani, 2014; Connor et al., 2001). It was documented that females particularly during the first year of post-parturition, have stronger associations with one another than with other individuals (Möller and Harcourt, 2008) and this could be important in reducing the risk of infanticide (Dunn et al., 2002), predation risk (Gowans et al., 2007) and the costs of competition in feeding (Papale et al., 2017). Also, males form alliances to pursuit females in reproductive condition (Blasi and Boitani, 2014).

Mid-long Distance Movements:

For the first time, it was possible to confirm mid/long-movements of bottlenose dolphin, along the Portugal coast. Matching photo-identification catalogues in order to investigate bottlenose dolphin movements patterns is simple, less expensive and non-invasive than others methods, such as radio and satellite telemetry (Mate et al., 1995). The 28 individuals matched represent 10% of the total individuals used for the matching of photo-identification catalogues. This percentage is superior when comparing with other similar studies, in coastal areas, like in Greece waters (Bearzi et al., 2011), Black sea (Gladilina et al., 2016), Brazilian coast (Lodi et al., 2008), and is more similar with results found in Iris coast (O'Brien et al., 2010). This result suggest that Sesimbra and Sagres populations show a certain level of direct connectivity and probably individuals occurring in both study-areas belong to a larger coastal population.

The majority of individuals matched were considered non-resident in each study-area, but some were considered transients (sighted several times), which may evidence that although bottlenose dolphins display different site fidelity patterns in each study-area, they can also travel hundreds of kilometres, in short period of time (Gnone et al., 2011; Robinson et al., 2012). However, in a regional perspective, some individuals were seen in several years within a range of 4 years, which suggest that animals may have a certain level of fidelity, in Southwest coast, among study-areas. Thus, this region might be important for the ecology of bottlenose dolphin.

The distances travelled by individuals, between Sesimbra and Sagres, were also reported in other coastal bottlenose dolphin (Bearzi et al., 2011; Gladilina et al., 2016; Hwang et al., 2014; Lodi et al., 2008). The distance travelled in shortest period, found in this study was 14km/day (T_19: Travelled 159 km in 11 days). From tagging studies done in Florida (USA) it was identified one dolphin who travelled at least 581 km in 25 days (23 km/day) (Mate et al., 1995) and two offshore bottlenose dolphins travel more than 2000 km in one month, which is the most extensive movement reported so far (Wells et al., 1999), highlight that this species is highly mobile.

The direction of the movements observed in this study was variable and some individuals have shown evidence of “back and forth movements”. Cetaceans can travel long distances for feeding and reproductive purposes (Balance, 1992; Piroddi et al., 2011). For example, male adults may disperse to mate with unrelated conspecifics, hence reducing the risk of inbreeding (Bearzi et al., 2011). The observed movements in the summer months, between Sesimbra and Sagres areas might be related with resource availability. In Portuguese coast the occurrence of upwelling events occur mainly during spring and summer months, increasing the productivity of waters and the concentration of prey species in some regions.

Final Considerations:

Understand the ecology of populations is important to infer conservation strategies of target species, such as bottlenose dolphin. Through an integrative approach was possible to have an overall perspective of how bottlenose dolphin use different areas, in a local and regional scale. They display a variety of patterns, which reflect differences in site fidelity, residence patterns, behaviour patterns and social structure. Sesimbra and Sagres regions might be important feeding areas and Sagres also could be important for calves/juveniles development. The movements observed between these areas might be related with resource availability and adult dispersal.

This study corroborates that photo-identification is an accurate method to study bottlenose dolphin and better understand their habitat use. Using photo-identification data from the two study areas permit to show mid-distance movements and infer the connectivity between the two populations studied. It is worthwhile to continue making this type of comparisons to better understand the patterns of coastal populations and inferring about the connectivity among them.

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Chapter 3: Identify habitat preferences of bottlenose dolphin (*Tursiops truncatus*) in Central and South west region of mainland Portugal, using Species Distribution Modelling

Chapter 3: Identify habitat preferences of bottlenose dolphin (*Tursiops truncatus*) in Central and South west region of mainland Portugal, using Species Distribution Modelling

Abstract:

Understanding the distribution of wild populations and the relationship between environmental factors and species' requirements is essential to implement conservation measures. This information provides a better understanding on the habitat use and distribution of populations. Species Distribution Modelling (SDM) is becoming commonly used to address these issues and to study cetacean populations. In Portugal, the habitat preferences of coastal bottlenose dolphins are still not well understood. The aims of this study were to identify and compare the habitat preferences of bottlenose dolphin through species distribution modelling, and predict key areas for their occurrence in Sesimbra and Sagres regions. Maximum entropy modelling of species distribution was done using seven environmental explanatory variables: distance to coast, habitat type, chlorophyll-a, seabed aspect, seabed slope sea surface temperature and water depth. In the 2007-2014 period a total of 29 bottlenose dolphin sightings were recorded in Sesimbra, and 227 in Sagres. Maximum entropy had a performance of AUC 0.77 in Sesimbra and AUC 0.628 in Sagres. Distance to coast, habitat type, Chlorophyll-a and seabed aspect were the environmental variables with highest contribution to explain the distribution of bottlenose dolphin, but with different percentage contribution in each study-area. The areas near shore in both study-areas present suitable condition to the occurrence of bottlenose dolphin, but in Sagres some areas far from shore were also suitable. Habitat preferences seem to be related with resource availability and predator avoidance. Most of the suitable habitats predicted by these models are within marine protect areas, in each region, and within existing or proposed Sites of Community Importance (SCI).

Key words: Maximum entropy models; Bottlenose dolphin; Distribution; Marine Protected area;

Introduction

Understanding the relationship between species and the environment can provide insights on the habitat use and distribution of wild populations (Cañadas and Hammond, 2006). Therefore, it is likely that certain areas that present best conditions will be more used than others and consequently have a greater importance for species. This type of information is essential to develop conservation measures and planning management on target species (Thorne et al., 2012). Top-predators, such as dolphins, are one of these species, and they have a high influence on equilibrium and structure of marine ecosystems. Identify key areas where these animals occur, might have an increased interest under a conservation perspective, and is a first step for the implementation of protect areas (Cañadas et al., 2005). The establishment of marine protect areas (MPA) is an effective and important conservation measure for the preservation of marine ecosystems (Agardy, 1994; Boersma and Parrish, 1999; Hooker and Gerber, 2004). However their effectiveness could be limited for highly mobile species, such as cetaceans, so it is important to collect appropriate spatial information of populations (Game et al., 2009; Hooker et al., 2011). Spatial modelling is becoming a useful tool to enhance management and conservation of species, as they can assess the influence of environmental variables on species distributions (Phillips et al., 2006).

This type of information is extremely important to identify critical habitats for marine mammals, especially in coastal areas, where animals are under higher anthropogenic pressure.

Several different approaches have been used to study species distribution, but presence-only modelling methods such as Maximum Entropy Model (Maxent) have been widely used in the recent years. This is mainly due to the excellent performance compared with other modelling methods (Hernandez et al., 2006), since this is a presence-only model, it works well with relatively small sample sizes and can deal with missing absence data and spatial sampling bias (Phillips et al., 2009). Therefore, it, is particularly useful for ecological studies of species, with large range and low sightings, like cetaceans species. Also, this modelling method could give good results from different types of information such as systematic or opportunistic surveys (e.g Moura et al., 2012; Thorne et al., 2012; Tobeña et al., 2014).

Several studies have demonstrated that distribution of cetaceans populations are related with habitat features, such as underwater topography and distance to shore (Baumgartner, 1997; Blasi and Boitani, 2012; Carlucci et al., 2016; Ferguson et al., 2006; Pitchford et al., 2016). As the contribution of environmental factors can vary among regions, it is difficult to make general and broad generalizations, so it is important to study the requirements of each population in a fine-scale (Blasi and Boitani, 2012; Hastie et al., 2005).

Coastal bottlenose dolphin has a regular occurrence in the Portugal mainland (Brito et al., 2009) and the presence of a resident population, in the Sado Estuary, is well known (dos Santos and Lacerda, 1987). Other populations of coastal bottlenose dolphin are known to exist in north and south regions, but the occurrence of these animals and their habitat preferences are not well understood. The Portuguese coastline has a complex topography and oceanographic features, such as submarine canyons, eddies, steep topography and upwelling events, which might be important to prey species and for predators, such as bottlenose dolphins.

The aim of this study is to identify habitat preferences of bottlenose dolphin, through distribution modelling in two areas of Central and South west coast of Portugal mainland, Sesimbra and Sagres, where marine protect areas have been implement, and identify important areas for this species.

Methods:

Study-area:

The study-area is located in the west Portuguese coast and is composed of two study-sites, Sesimbra and Sagres regions (Figure 3.1). Both areas are facing-south, and thus sheltered from north-northwest winds and swells (and are influenced by Atlantic upwelling events, during spring and summer months) (Horta e Costa et al., 2013; Loureiro et al., 2005).

In Sesimbra, the sea bottom is steep with a depth between 50 and more than 100 m and is characterized principally by sandy subtract. Near this area, it occurs the convergence of two submarine canyons from two estuaries, Tejo (Lisbon) and Sado (Setubal), which influence the water currents in Sesimbra region.

In Sagres region, the continental platform is narrow and the sea bottom is rocky. Sandy bottoms are found beyond the rocky substratum at a depth of 20 meters (Gil Fernández et al., 2016). Between

100 a 130 meters, the topography is very steep reaching 700 meters abruptly. The presence of the São Vicente submarine canyon (Relvas, 2002), also, influences the oceanography of the region.

The annual mean sea surface temperature in the two study-areas is somewhat different, being warmer in Sagres than in Sesimbra.

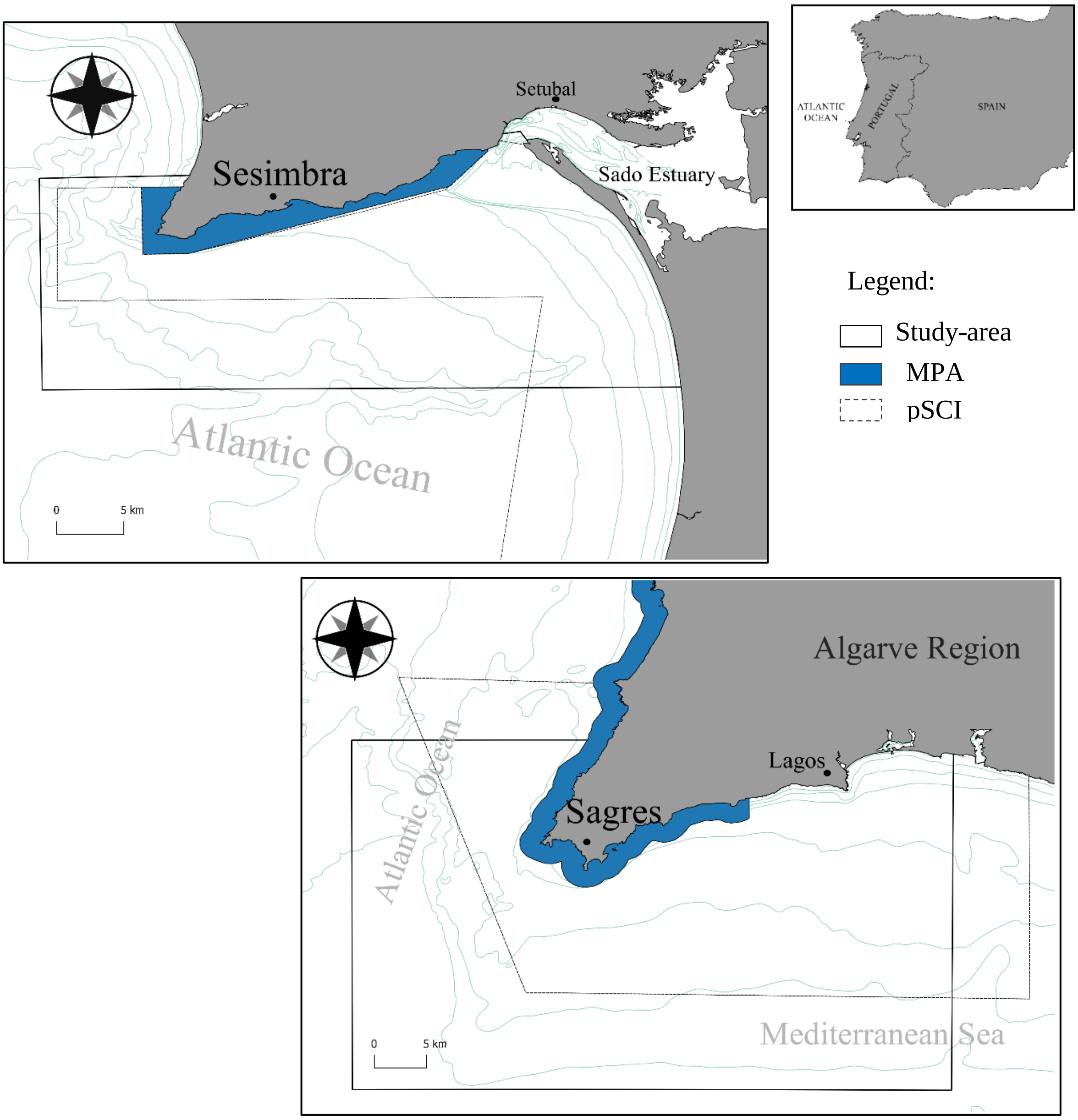

Figure 3.1-Geographical location of the two study-areas, Portugal Mainland.

Data Collection and Environmental data:

Surveys in Sesimbra and Sagres regions were conducted between 2007 and 2014, following scientific and opportunistic surveys, respectively. In Sesimbra, dedicated surveys were conducted by "Escola de Mar", an organization dedicated to marine research. In Sagres, surveys were conducted by a dolphin-watching company "Mar Ilimitado", as an opportunistic platform. In both areas, surveys were done depending on weather and sea conditions, and in Sagres, also was depending on the availability of tourists. When a cetacean was sighted, time, location, group size and composition, digital photographs for photo-identification purpose and behavioural patterns were recorded.

According to the literature, seven environmental variables were selected as potential explanatory variables of the distribution of bottlenose dolphin: depth, seabed slope, seabed aspect, distance to coast, sea surface temperature (SST), Clorophyll-a (as proxy for primary productivity) and Habitat type. Depth (in meters) was generated using two different layers: depth until the 200 m was extracted from the bathymetric Grid of the Portuguese Hydrographic Institute (http://www.hidrografico.pt/), and from 200 m bathymetric were extracted from a global bathymetric Grid with a 0.125 arc-minutes resolution, from European Marine Observation and Data Network (http:// www.emodnet.eu). Seabed slope and seabed aspect were derived from bathymetric Grid using the DEM (Terrain Models) Analyst Tool, in QGIS 2.18 program (QGIS Development Team, 2017). Slope was calculated as the gradient of maximum change in depth for each grid cell, ranging from 0º to 90º. Seabed aspect is the geographical orientation of bottom slopes, measured in degrees, and values for this variable were classified in 10 categories: 1=Flat (-1), 2=North (0-22.5), 3=Northeast (22.5-67.5), 4=East (67.5-112.5), 5=Southeast (112.5-157.5), 6=South (157.5-202.5), 7=Southwest (202.5-247.5), 8=West (247.5-292.5), 9=Northwest (292.5-337.5), 10=North (337,5-360). Distance to coast was derived using distance matrix 'Nearest neighbour' Analyst Tool, which calculates the distance between the midpoint of each grid cell and the closest point to the source (land). The land source was extracted from Portuguese Hydrographic Institute (http://www.hidrografico.pt/). SST (ºC) and Clorophyll-a (log10 $mg.m^{-3}$) were extracted from a global dataset of monthly average values with a resolution of 4km X 4km from the Marine Geoportal EMIS (Environmental Marine Information system).(http://mcc.jrc.ec.europa.eu/emis/index.py). Habitat Type was created from the layer EMODnet broad-scale seabed habitat map for Europe 2016 (EUSea Map 2016) extracted from (http:// www.emodnet.eu), where each habitat type is classified trough European Nature Information System (EUNIS) (Bellan-Santini et al., 2002).

There is an uneven distribution of sampling effort, in the two areas, and therefore sample spatial bias may affect habitat modelling. In order to reduce a possible sample bias, it was introduced a background bias layer (Phillips et al., 2009), to discriminate among environmentally unsuitable and under-sampled areas (Clements et al., 2012). For Sesimbra and Sagres data, this sampling bias layer was created through the calculation of the number of survey-tracks, in each grid cell (100 m X 100 m) using the Join attributes by location tool (Spatial Joins tool).

All environmental grids and Sampling bias file were re-sampled to a cell size of 100 m X 100 m.

Statistical Tests:

All environmental variables were tested for multicollinearity, using a Pearson correlation (r) in STATISTICA 10 (StatSoft, 2010).

Maximum entropy modelling

The maximum entropy algorithm available in MAXENT 3.4.1 (Phillips, 2008) was used to model the distribution of bottlenose dolphin, in Sesimbra and Sagres regions. With this algorithm, is possible to estimate the species' distribution, under a set of conditions, that represent incomplete information of the actual distribution of a species (Phillips et al., 2006). The model algorithm attributes a probability of occurrence, which is the relationship between presence-only information (sample points) and environmental variables (features), to each-point (pixel) in the study-area (Phillips et al., 2006).

We used a logistic output to evaluate the suitability of each grid square, assigning a value ranging from 0 (unsuitable habitat) to 1 (optimal habitat) (Phillips and Dudík, 2008). Models were run in replicate using the cross-validation method with default settings, except the number of replicates, which was set to 10. This method separates the occurrence data randomly into a specified number (in this case, 10) of equal-sized groups (called "folds"), and runs the model leaving out each fold in turn. The retained fold is used for evaluation of the model (Phillips et al., 2006). Each final model, results from the average of the 10 replicates. We used hinge features to improve the performance of the models without increasing the complexity (Phillips and Dudík, 2008).

Model Evaluation and Analysis:

The Area Under the Receiver Operating Characteristic Curve (AUC) (Pearson et al., 2007) was used to assess the performance of the models, from Sesimbra an Sagres regions. It defined the sensitivity (proportion of observed occurrences that are correctly predicted by the model) and "1-specificity" (the proportion of observed absences that are correctly absences (or pseudo-absences) that are correctly predicted by the model, and has been commonly used as a tool for model evaluation (Elith et al., 2006; Phillips et al., 2009; Thuiller et al., 2004). The AUC values range from 0 (under 0.5 for models have no predictive ability) to 1 (models with perfect predictive ability) (Phillips et al., 2009).

Results:

Between 2007 and 2014, 136 surveys were conducted, from which 29 bottlenose dolphin sightings were recorded, in Sesimbra region, and 2160 surveys were conducted in Sagres region, resulting a total of 227 bottlenose dolphin sightings. Correlations between environmental variables were observed. (Appendix 3.2; Appendix 3.3).

Performance of model

Spatial distribution models for both areas were generated. The performance was fairly good with a mean AUC value of 0.771 for Sesimbra region and 0.628 for Sagres region (Figure 3.2).

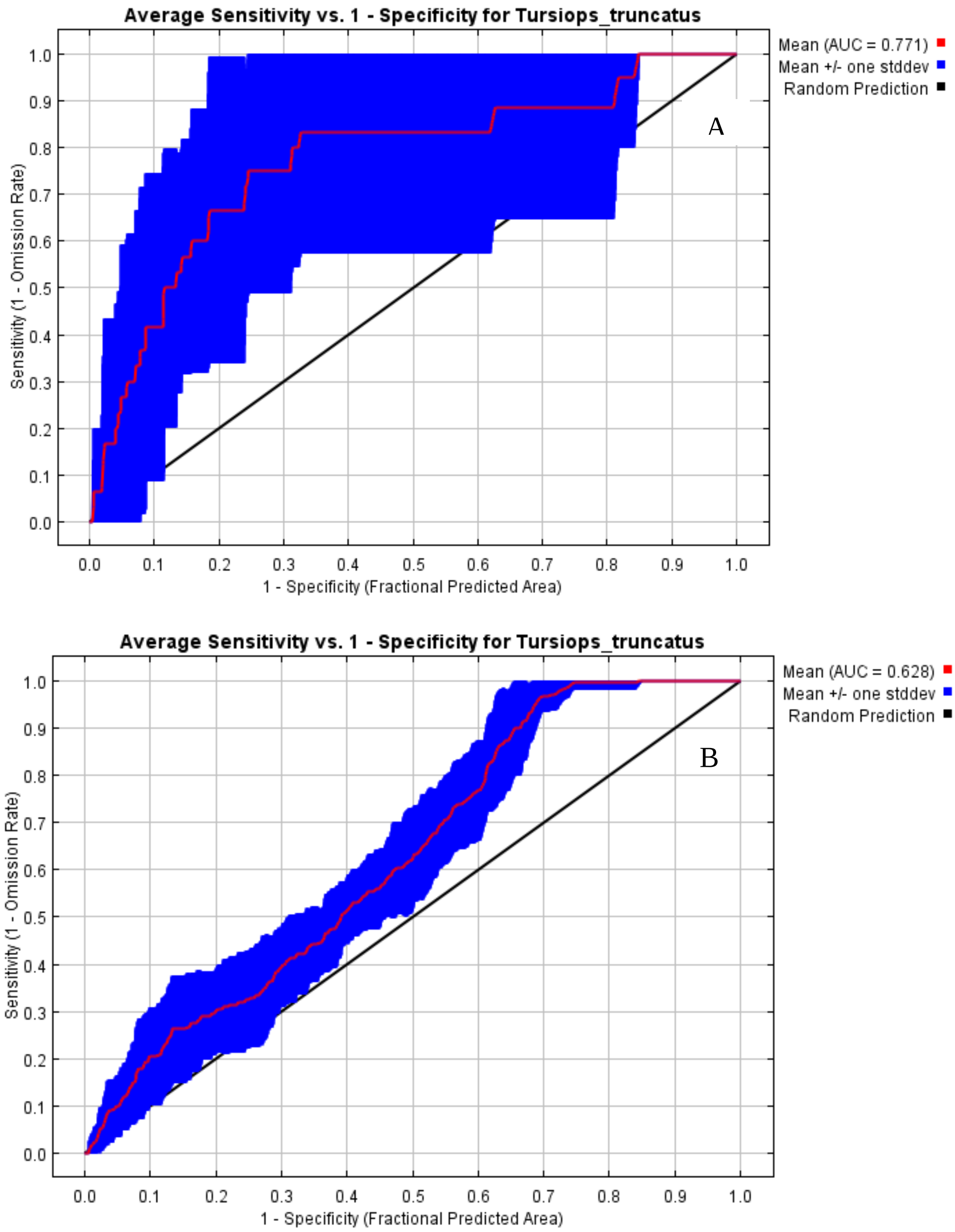

Figure 3.2- Maxent receiver operating characteristic (ROC) curve for bottlenose dolphin, from Sesimbra region (A) and from Sagres region (B).

Environmental variables contributions

The environmental variables with highest importance for Sesimbra region were distance to coast, habitat type and seabed aspect. Whereas, in Sagres were habitat type, distance to coast and chlorophyll-a (Table 3.1).

Table 3.1- Estimates of relative contributions of the environmental variables to the Maxent models of bottlenose dolphin in Sesimbra (SB) and Sagres (SG).

Variable	Percent contribution (%)		Permutation importance (%)	
	SB	SG	SB	SG
Habitat_Type	23.6	58.9	9.6	23.5
Distance to coast	44.7	14.4	70.6	48.9
Chlorophyll-a	4.6	12.5	2	3.3
Seabed_Aspect	14.3	1.1	6.4	4.3
Sea Surface temperature	10.1	3.9	10.6	15.8
Seabed_Slope	2.6	2.2	0.6	4.2
Depth	0.1	7.1	0.1	0

The figure 3.3 represent the most important response curves for bottlenose dolphin from Sesimbra region, showing the probability of species occurrence. A high occurrence probabilty occurred , in waters closer to the shore and with south orientation of seabed (category 6). The environmental variable “habitat type” seems to influence the occurrence of bottlenose dolphin and it seems that there is a preference for habitats types 5 and 11(Circalittoral rock Infralittoral sandy mud, respectivelly) .

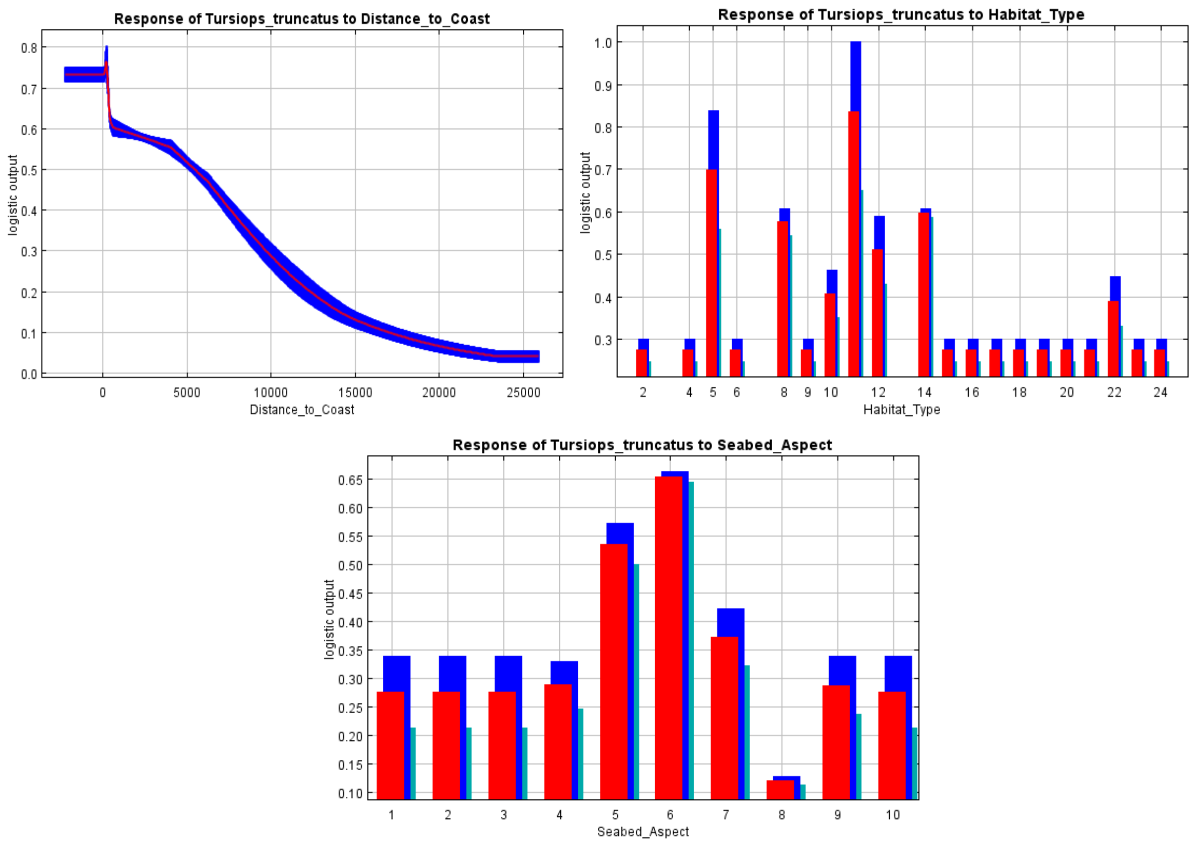

Figure 3.3-Response curves of Maxent prediction relating to environmental varibles for bottlenose dolphin, from Sesimbra region.

The figure 3.4 represents the most important response curves for bottlenose dolphin from Sagres region, showing the probability of species occurrence. The graphic from environmental variable habitat type, shows a high probabilty of occurrence in habitat type 2 (Infralitoral rock), habitat 11 (Infralittoral sandy mud and habitat 22 (Deep-sea muddy sand subtract). There was a high probabilty of occurrence in waters closer to shore and to a distance of 20000 meters from coast.

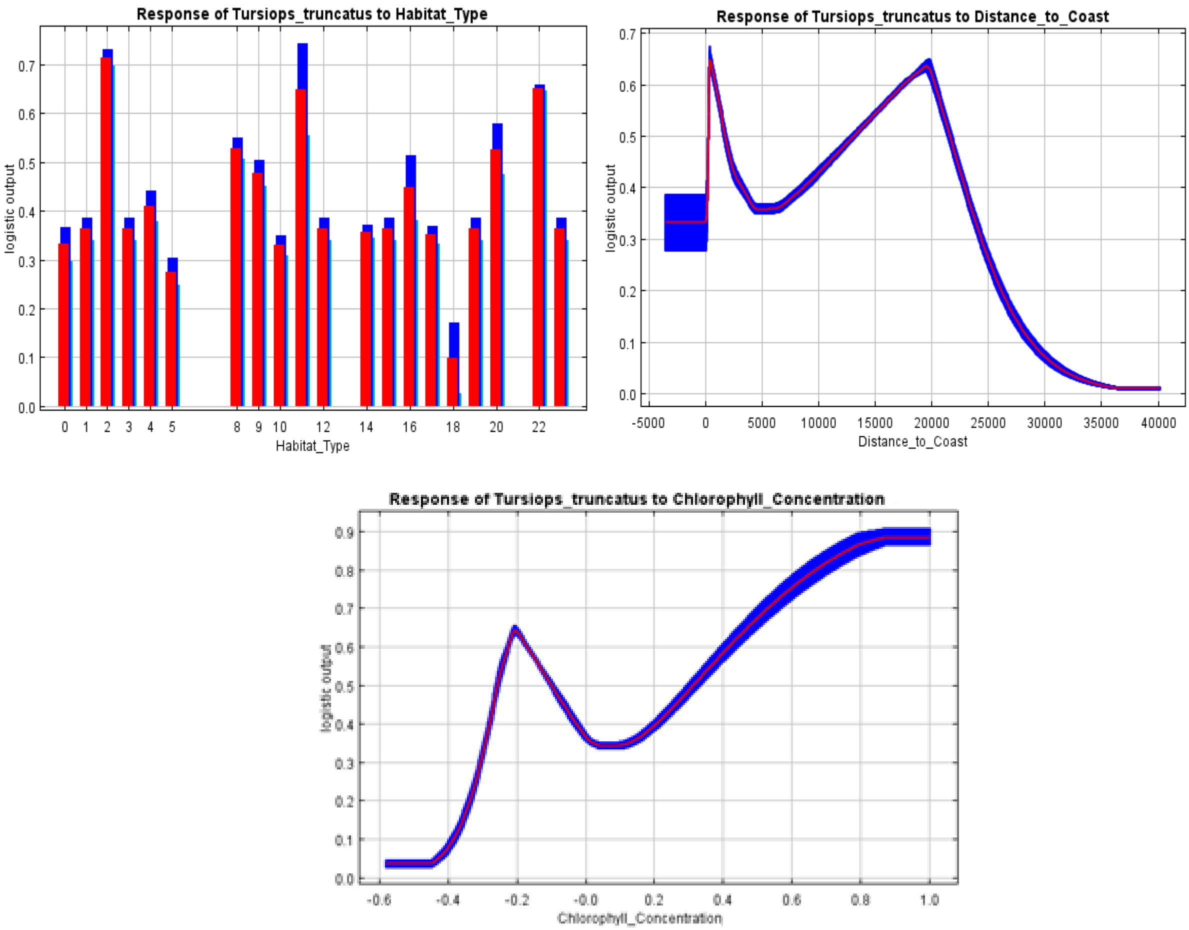

Figure 3.4- Response curves of Maxent prediction relating to environmental variables for bottlenose dolphin, in Sagres region.

Distribution map of the model:

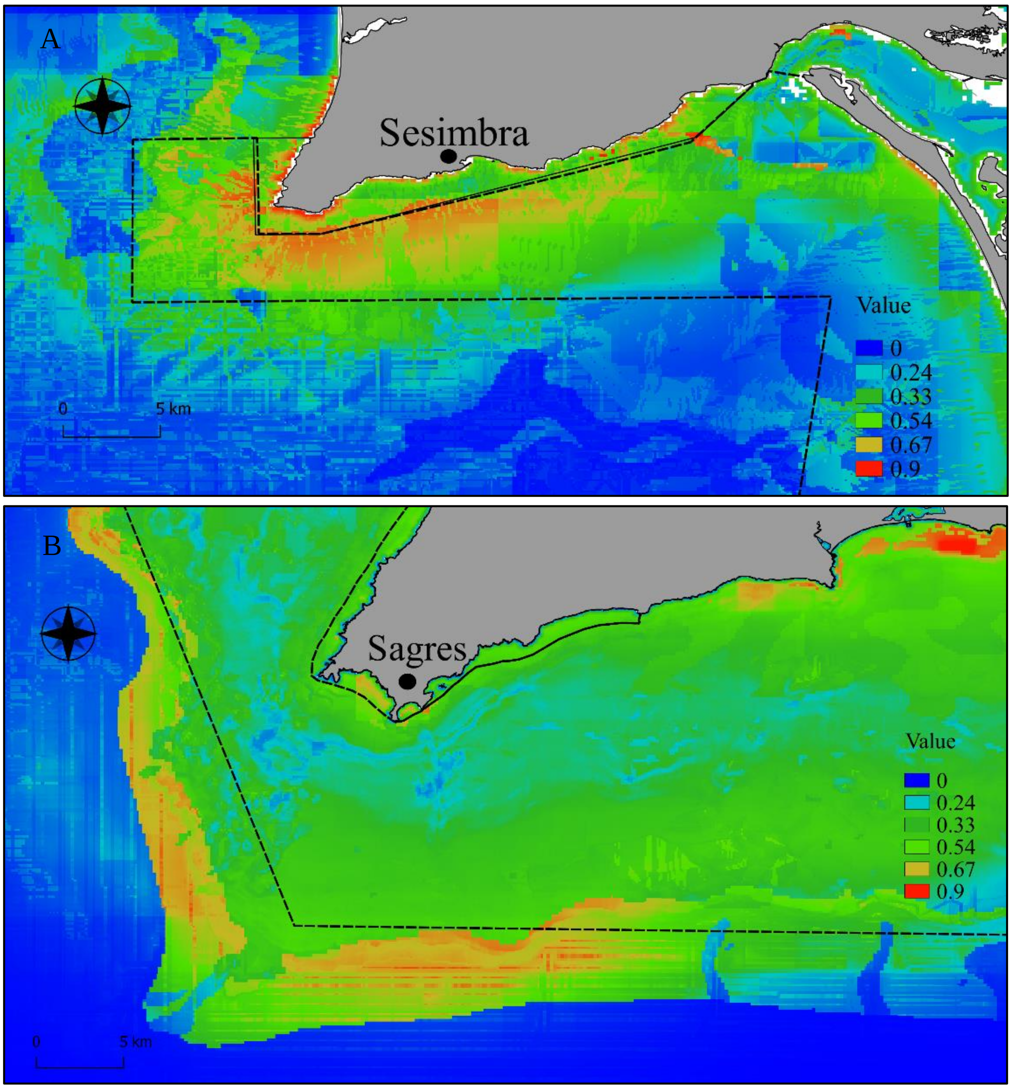

Figure 3.5- Maxent average model for bottlenose dolphin in Sesimbra region (A) and in Sagres region (B). Most suitable habitats are indicated by warm colours (red) and lighter shades of blue have low predicted probability of suitable conditions. MPA represented as a continuous line; pSCI's represented as a dashed line.

Discussion:

The results from this study represents an effort to identify habitat preferences of bottlenose dolphin in Sesimbra and Sagres regions, through species distribution modelling and identify suitable areas for his occurrence. Maximum entropy models have shown that distribution of bottlenose dolphin is different among areas. In Sesimbra region, Maxent models have shown that the probability of occurrence was mostly influenced by distance to coast, habitat type and seabed aspect. In Sagres region, the most important factors were habitat_type, distance to the coast and chlorophyll-a. The differences observed in the contribution of each environmental variables explains the distribution of bottlenose dolphin in these two areas and are in agreement with the ecology of the species. As bottlenose dolphin inhabits a variety of habitats, they show different habitat preferences, which might contribute to differences in habitat use. For example, the distribution of bottlenose dolphins from Northeast Atlantic waters was mainly predicted by water depth and sea-bottom slope, as animals prefer deep waters with steep topography (Breen et al., 2016), whereas in Lampedusa waters, the distribution of bottlenose dolphin was mainly explained by distance to coast and depth variables, as they prefer shallow waters between 700 and 1370 meters distance to shore (La Manna et al., 2016). In both studies, the habitat preferences for these areas were mainly related with availability of prey species, which is the main factor responsible for changes on the movements and use of habitat by bottlenose dolphin (Ballance, 1992; Hastie et al., 2004) and might explain the differences observed between Sesimbra and Sagres.

In this study, the suitable habitat for bottlenose dolphin from Sesimbra region was near shore, south-facing seabed and habitat type "Infralitoral sandy mud". The South orientation, in this area, gives protection from north and northwest winds from North Atlantic, and might reduce the energy cost on travelling or foraging, for example. The high importance of seabed aspect was also reported in other small cetaceans species, such as in Risso's dolphin and harbour porpoise (De Boer et al., 2014). In Sagres region, the most suitable habitat was in areas with three habitat types ("Infralitoral rock"; "Deep-sea muddy sand", "Infralitoral sandy mud"), near shore and offshore areas (~20000 meters) and with high levels of chlorophyll-a. Even tough bottlenose dolphin demonstrated some differences in the habitat preferences, the areas near shore seem to be important for these animals, as they show high probability of occurrence in areas close to the coast, both in Sesimbra and Sagres regions. The importance of distance to coast, as predictive variable of the distribution of bottlenose dolphins, was also seen in other studies (Carlucci et al., 2016; Pierpoint et al., 2009) and might be related with prey availability and predator avoidance (Blasi and Boitani, 2012; Wells and Scott, 2002). However in the case of Sagres region, a somewhat unexpected result occurred with a high probability of occurrence at a distance of about 20000 m from the coast. At this distance in this area it is very common to observe bottlenose dolphins feeding near trawlers boats (Sara Magalhães, Personal communication). In this case, we may be in the presence of an offshore population rather than a coastal population, or an interaction of these two types of populations, and this issue might be investigated, in the future.

The habitat type had a considerable contribution to explain the occurrence of bottlenose dolphin, in both areas (especially in Sagres region), indicating a preference for habitats types composed by sandy/muddy sand substrate. The substrate type was already reported to have influence on the distribution of cetaceans, such as in the cases of the spinner dolphin or Indo-Pacific bottlenose dolphin (e.g Cribb et al., 2013; Naud et al., 2003; Thorne et al., 2012). The preference for deep-sea areas, observed in Sagres, could be related with particular schooling prey species, such as European hake, which is known to be a bottlenose dolphin prey species (Giménez et al., 2017). Also, these areas are near São Vicente canyon, which might contribute to the occurrence of prey species.

The variable clorophyll-a, commonly used as proxy variable for local primary production in open-seawaters and close to coastal areas (La Manna et al., 2016) was an important predictor to the probability of bottlenose dolphin occurrence, in Sagres region. This variable is not able to directly influence dolphin distribution, but it might be interpreted as a good proxy for other bioecological factors related to feeding preferences, such as the distribution of schooling fish (Moura et al., 2012).

The results from this study highlight the importance of spatial modelling as a useful tool to understand the habitat preferences of species. Sesimbra and Sagres areas appear to be important areas for feeding activities of bottlenose dolphins. Part of the most suitable habitats predicted in this study, are within marine protect areas in each region and within the proposed SCI's. This highlights the importance of management measures in order to preserve these habitats within these areas, thus, contributing to a favourable conservation status of bottlenose dolphin in Portuguese waters. Nevertheless, the suitable habitat observed far from shore, in Sagres region, is not included in the presently proposed SCI, suggesting a need to research that particular interaction between bottlenose dolphins and the trawlers boats in the offshore waters.

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[1]According to the Journal Biological Conservation

Chapter 4: General discussion

General Discussion:

Marine habitats have a complex structure depending on oceanic and topography factors, which may change temporally and spatially. This heterogeneity leads to differences on the distribution and the habitat use of marine species (Ballance, 1992; Hastie et al., 2003), such as marine mammals or fish species. Marine mammals have an important role in the marine ecosystems as they are top predators several species are conditioned by their activities, influencing the entire ecosystem. Through the study of habitat use of these top predators it is possible to identify important areas to their ecology mainly related to reproductive and feeding habits (Bejder et al., 2006; Whitehead and Rendell, 2004) and to take appropriate management and conservation measures, in these areas (Agardy, 1994; Hooker and Gerber, 2004; Smith et al., 2016). These patterns could be better understood through the study of residence patterns, site fidelity, behaviour and movements patterns of the populations, for example (e.g Parra et al., 2006; Wilson et al., 1997; Zanardo et al., 2016). This study is a contribution to understand the ecology of coastal bottlenose dolphins and provide new baseline information to further conservation and monitoring purposes. Using a seven-year dataset from bottlenose dolphins from two different regions it was possible to compare the habitat use of coastal groups from Sesimbra and Sagres, identify movements along coast, and habitat preferences in each region.

This study suffered from some limitations. Firstly, two different platforms (scientific and opportunistic) were used for collecting data, which resulted in differences in spatial effort and survey effort between Sesimbra and Sagres. This complicates the comparison of habitat use between bottlenose dolphin occurring in both study-areas and it may be difficult to understand if differences observed were due to natural causes or due to differences in survey effort and type. Secondly, sampling effort, in each area, was temporally heterogeneous, occurring mostly during spring and summer months. This may have not allowed a total understanding of habitat use in each study-area.

Data collection in Sagres was done using an opportunistic platform, which has some advantages. Whale-watching activities are increasing and their popularity has been growing globally. As southern Portugal is a common touristic destination, this type of eco-tourism activities are expanding rapidly. The information from these opportunistic platforms enables the collection of valid data on cetacean populations, especially in areas where it may be difficult to conduct scientific investigations, due to logistic or cost reasons. Therefore, opportunistic platforms can bring benefits to the scientific communities. In this study, the survey effort observed in Sagres study-area was easily explained due to the popularity of dolphin-watching activity in this region and permitted to gather information during seven years. However, this type of activities may also cause some changes in animal's behaviour and distribution. Therefore, it may be relevant to develop in the future studies to understand the impact of whale-watching activities on dolphin populations' patterns in Algarve region. Overall, whale-watching activities can make an important contribution to the understanding of ecology of cetacean communities.

Bottlenose dolphin occurring in the two study areas consisted of a mixture of residents, transients and non-residents animals. Although individuals were seen several times in the same area, some of them ranged between Sesimbra and Sagres, moving on average 159 kilometres, for each side. The movements of bottlenose dolphins are a challenge to researchers because animals have mainly a transitory pattern and only rarely do we know how far and wide they can go. This multi-site study gave some clues to fill this gap of knowledge in Portuguese Southwest coast, and has shown at regional scale that this area is used by bottlenose dolphin, due to the dynamic of movements observed, with some individuals moving between the two study areas, in a short period of time. The occurrence of emigration and re-emigration movements between the two study-areas, might be an evidence that bottlenose dolphins present in Sesimbra and Sagres could be part of a super-population, where individuals display a combination of occasional mid-range movements and residency patterns. Coastal populations are known to have large home-ranges, displaying this type of patterns (Defran et al., 1999; Gladilina et al., 2016). Further research in order to understand the range of these animals might be relevant in Portuguese coast, for example through comparing photo-identification catalogues from other coastal areas of mainland Portugal, such as Nazaré, Lisbon or other Algarve regions. Moreover, it would be interesting to compare them with catalogues of other areas of the Iberian Peninsula like Galiza and Gibraltar/Cádiz (Spain) in order to understand habitat use and distribution in a broader scale.

At a fine-scale, bottlenose dolphin displays a variety of patterns. According to behaviour analysis and group dynamics, bottlenose dolphins were mostly observed on travelling and feeding activities in Sesimbra and Sagres, but groups in Sesimbra were mainly composed by adults whereas in Sagres, groups were mostly observed with juveniles. Overall, both areas might be important for feeding. Sesimbra could also be an area where adults are in dispersal movements to adjacent areas and Sagres might be important for calving and juveniles development. In further studies it could be relevant to understand the sex composition of groups in Sesimbra and Sagres.

Multi-site studies allow a general perspective on how animals use different areas and permit to understand the distribution of populations at wider-scale (Gnone et al., 2011). Therefore, these cooperative studies might be important to understand the relationship between different coastal populations or even with resident groups. The coastal bottlenose dolphin from Sesimbra occur in areas close to those occupied by the resident population of Sado estuary. In fact, in some areas individuals from both groups overlap (Duarte, 2014) and have already been observed together on a few occasions. The entry of new individuals from coastal populations to resident populations is important to increase genetic diversity, and reduce possible inbreeding. This might be particularly relevant for the resident population of Sado Estuary since it is a small population with a tendency for demographic decline (Augusto et al., 2012). Therefore, it might be important to monitor adjacent waters and understand how the resident population is relating with other coastal groups.

Implications for Conservation:

Sesimbra and Sagres appear to be important areas for the ecology of bottlenose dolphins, where individuals are repeatedly seen and observed in activities related to feeding. In fact, some individuals were seen several times over a period of 4 years between Sesimbra and Sagres. According to the species distribution modelling analysis, waters near shore represent a suitable habitat for the occurrence of bottlenose dolphins, where anthropogenic activities might be more intense. Potential anthropogenic impact may include leisure activities, overfishing and chemical pollution (Pace et al., 2015). Monteiro et al. (2016) observed high mercury levels on bottlenose dolphins from Portuguese waters, which may cause health problems to the animals. Marine protected areas can play an important role in the conservation of species, where specific protection actions should be taken in order to preserve the habitats where animals occur. Nevertheless, protected areas might be inefficient, when the initial size and design are not adapted to the ecological requirements and to the distribution of the populations (La Manna et al., 2016). Although Sesimbra and Sagres study-areas have marine protected areas, the majority of sightings and important areas for the occurrence of bottlenose dolphins are outside of these areas. In fact, with the new proposed of SCI's for Sesimbra and Sagres, the majority of the area most suited for this species become included in the boundaries of the future SCIs. This highlight the importance of these areas for the conservation of bottlenose dolphins. With the identification of movements between Sesimbra and Sagres, it might be relevant to assess the importance of the region along the southwest coast. Moreover, these movements should be monitored in order to infer possible changes in the distribution and habitat use of the populations. This type of changes have already been observed in populations in Moray Firth, Scotland (Wilson et al., 2004) and in New Zealand (Hartel et al., 2015), requiring an adjustment of the local marine protect areas. Having a monitoring network program in Sesimbra and Sagres SCI's, controlling emigration and immigration events, might serve to validate the long-term adequacy of the boundaries of these SCI. This study highlights the importance of having a multi-scale conservation and monitoring approach, which might be important to maintain populations of wide ranging animals, such as cetaceans.

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[1]According to the Journal Biological Conservation

Appendices

Appendix 2.1- Theoretical models to estimate population size in Sesimbra and Sagres given by the SOCPROG program.

Model Type	Model	Description
Closed	Schnabel	Closed population (no immigration, emigration, birth, death).
Open	Mortality	Assumes a constant size population, which mortality is balanced by birth
	Mortality +Trend	Assumes population growing or declining at a constant rate

Appendix 2.2- Theoretical models to estimate population size in Sesimbra and Sagres given by the MARK program.

Model Type	Description
$\{\rho_t, \phi_t, b_t\}$	Open model . Where ρ_t = probability of capture of an individual is temporally variable; ϕ_t = apparent survival of an individual is temporally variable; b_t = probability that an animal from the super-population enters the subpopulation (considered as the number of animals in the study area) is temporally variable
$\{\rho_., \phi., b_t\}$	Open model . Where ρ = probability of capture of an individual is time-constant ; $\phi.$= apparent survival of an individual is time-constant ; b_t = probability that an animal from the super-population enters the subpopulation (considered as the number of animals in the study area) is temporally variable
$\{\rho_., \phi_t, b_t\}$	Open model . Where ρ = probability of capture of an individual is time-constant; ϕ_t = apparent survival of an is temporally variable; b_t = probability that an animal from the super-population enters the subpopulation (considered as the number of animals in the study area) is temporally variable

Appendix 2.3- SOCPROG fit of theoretical population model results of lagged identification rates for bottlenose dolphins in Sesimbra (SB) and Sagres (SG).

Model Type	QAUC	
	SB	SG
Closed population	177.817	2919.84
Emigration/Mortality	177.814	2737.64
Emigration + Remigration	181.00	2725.17
Emigration + Remigration + Mortality	180.49	2722.39

Appendix 2.4- SOCPROG fit of theoretical social models to the standardized lagged association rate for bottlenose dolphins in Sesimbra(SB) and in Sagres (SG)

Model Type	QAUC	
	SB	SG
Constant companions (CC)	670.08	864.14
Casual acquaintances (AC)	665.89	862.82
CC + AC	674.08	868.11
Two levels of CA	669.89	866.69

Appendix 3.1- Description of the principal habitat types to the occurrence of bottlenose dolphins in Sesimbra and Sagres

Habitat_type	Name	Description
2	Infralittoral rock	Infralittoral rock in wave and tide-sheltered conditions,
5	Circalittoral rock	Occurs on wave-sheltered circalittoral bedrock and boulders subject to mainly weak/very weak tidal streams
11	Infralittoral sandy mud	Infralittoral, cohesive sandy mud, typically with over 20% silt/clay, in depths of less than 15-20 m. This habitat is generally found in sheltered bays or marine inlets and along sheltered areas of open coast.
20	Deep sea mixed substrata	Deep-sea benthic habitats with substrates predominantly of mixed particle size or gravel. Includes habitats with mobile substrates of biogenic origin but no longer living.
22	Deep-sea muddy sand	Deep-sea benthic habitats with substrates predominantly of muddy sand.

Appendix 3.2- Correlation matrix for all environmental variables for bottlenose dolphin from Sesimbra region. Red correlations are significant at $p < 0.05$; r, first row, p, second row.

	Seabed_Asp	SST_NEw	ChlA	Seabed_Slo	Habitat_Ty	Water_Dept	Distance_t
Seabed_Aspect	1,0000	,0453	,0453	,1456	,1888	,0170	,1143
	p= ---	p=,837	p=,837	p=,507	p=,388	p=,939	p=,603
SST	,0453	1,0000	-,6451	,1132	,6666	,7824	,7055
	p=,837	p= ---	p=,001	p=,607	p=,001	p=,000	p=,000
ChlA	,0453	-,6451	1,0000	-,2226	-,3205	-,4550	-,2374
	p=,837	p=,001	p= ---	p=,307	p=,136	p=,029	p=,275
Seabed Slope	,1456	,1132	-,2226	1,0000	,2432	-,0264	-,1423
	p=,507	p=,607	p=,307	p= ---	p=,264	p=,905	p=,517
Habitat Type	,1888	,6666	-,3205	,2432	1,0000	,8136	,7777
	p=,388	p=,001	p=,136	p=,264	p= ---	p=,000	p=,000
Water Dept	,0170	,7824	-,4550	-,0264	,8136	1,0000	,9198
	p=,939	p=,000	p=,029	p=,905	p=,000	p= ---	p=,000
Distance to	,1143	,7055	-,2374	-,1423	,7777	,9198	1,0000
coast	p=,603	p=,000	p=,275	p=,517	p=,000	p=,000	p= ---

Appendix 3.3- Correlation matrix for all environmental variables for bottlenose dolphin from Sagres region. Red correlations are significant at $p < 0.05$; r, first row, p, second row.

	A	B	C	D	E	F	G	H
1		Seabed_Asp	Seabed_Slo	SST	Habitat_Ty	Water_Dept	Distance_t	ChlA
2	Seabed_Asp	1,0000	-,4119	,1087	,1550	,1617	,2149	-,1540
3		p= ---	p=,000	p=,139	p=,034	p=,027	p=,003	p=,035
4	Seabed_Slo	-,4119	1,0000	,0814	,0125	,1109	,0684	-,1088
5		p=,000	p= ---	p=,268	p=,865	p=,131	p=,352	p=,138
6	SST	,1087	,0814	1,0000	,6200	,7768	,8475	-,7117
7		p=,139	p=,268	p= ---	p=0,00	p=0,00	p=0,00	p=0,00
8	Habitat_Ty	,1550	,0125	,6200	1,0000	,7718	,6667	-,6548
9		p=,034	p=,865	p=0,00	p= ---	p=0,00	p=0,00	p=0,00
10	Water_Dept	,1617	,1109	,7768	,7718	1,0000	,8951	-,8213
11		p=,027	p=,131	p=0,00	p=0,00	p= ---	p=0,00	p=0,00
12	Distance_t	,2149	,0684	,8475	,6667	,8951	1,0000	-,7865
13		p=,003	p=,352	p=0,00	p=0,00	p=0,00	p= ---	p=0,00
14	ChlA	-,1540	-,1088	-,7117	-,6548	-,8213	-,7865	1,0000
15		p=,035	p=,138	p=0,00	p=0,00	p=0,00	p=0,00	p= ---