Milla Silveira Pinto Brandão

Short-beaked common dolphins (*Delphinus delphis*) in São Miguel Island, Azores: photo-identification of HII (Highly Identifiable Individuals) and spatio-temporal distribution

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Mestrado em Biologia Marinha

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Declaração de autoria de trabalho

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Declaro ser a autora deste trabalho, que é original e inédito. Autores e trabalhos consultados estão devidamente citados no texto e constam da listagem de referências incluída.

I hereby declare to be the author of this work, which is original and unpublished. Authors and works consulted are properly cited in the text and included in the reference list.

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Abstract

Short-beaked common dolphin, *Delphinus delphis*, is a well distributed species worldwide and one of the most sighted species in the Azores archipelago. However, there are no studies focusing on their photo-identification or residency patterns in the region. The main objectives of this thesis are to assess the spatio-temporal distribution of common dolphins around São Miguel and identify the Highly Identifiable Individuals (HII) to analyze their residency patterns. To do so, we used opportunistic data, both sightings and photographs, collected by Futurismo Azores Adventures during whale watching trips between May 2008 and March 2020 in São Miguel (Azores). Common dolphins were encountered year-round with lower encounter rates in summer time and reflect on a possible displacement caused by Atlantic spotted-dolphins. They were mostly found in shallow waters (69% at < 450 m) and close to the shore (61% at < 5 km). Calves were present year-round, but mostly in summer likely due to higher water temperature and availability of food. A total of 5.698 photos were processed and visually compared to create a catalogue with the HII individuals, which contains 402 right dorsal fins, 472 left dorsal fins, and 72 individuals identified by both sides. About 87% of the individuals identified were sighted only once and considered transients. From the resighted 13%, 47% were residents or sighted in several seasons in several years; 10% seasonal residents or sighted only in one season in several years; and 43% transient or sighted within a year. Long-lasting potential associations between individuals are suggested based on the same dates of occurrence over the study period, with a maximum re-sighting interval of 4 years. These findings provide evidence of resident individuals of common dolphins in a busy coastal area of São Miguel. Therefore, further research would be of help to support appropriate management plans in the future.

Key-words: Short-beaked common dolphins, photo-identification, spatio-temporal distribution, São Miguel, Azores, residency.

Resumo

O golfinho-comum-de-bico-curto, *Delphinus delphis*, é uma espécie amplamente distribuída pelo globo. Em algumas áreas, a grande disponibilidade de presas, juntamente com as características ambientais que distinguem o local, resultam numa maior probabilidade de avistar o mesmo grupo de golfinhos repetidamente, caracterizando os indivíduos residentes. O arquipélago dos Açores é um lugar muito favorável para a presença de golfinhos-comuns devido à heterogeneidade oceanográfica que suporta uma grande quantidade de alimento, que é a principal influência para a distribuição de cetáceos. Em estudos anteriores de foto-identificação, golfinhos-comuns, considerados uma espécie pouco marcada, necessitam de características distintas que os permitam serem facilmente reconhecidos em futuras capturas. Os indivíduos que possuem características bastante distintas consideram-se Highly Identifiable Individuals (HII). Apesar de ser uma das espécies mais avistadas nos Açores, estudos sobre sua foto-identificação e residência ainda são escassos, o que evidencia a necessidade de aprofundar e procurar novas informações sobre esta espécie.

Os objetivos deste estudo foram 1) avaliar a distribuição temporal e espacial dos golfinhos comuns em São Miguel de 2008 a 2020, 2) identificar HII de golfinhos-comuns e atualizar o catálogo de foto-identificação com fotografias tiradas em viagens de observação de cetáceos entre 2008 e 2020, 4) analisar os padrões de residência com base em avistamentos oportunistas, 5) estimar o tempo mínimo de permanência na área para os indivíduos re-avistados e 6) reconhecer associações entre indivíduos, observando indivíduos avistados juntos ao longo do tempo.

Os dados e fotos foram coletados pela Futurismo Azores Adventures, de Maio de 2008 até Março de 2020 em São Miguel, Açores. A localização exata de cada avistamento foi utilizada para avaliar sua distribuição espacial e temporal, calculando sua taxa de avistamento (ER) e avaliando o mapa de densidade, profundidade e distância da costa de São Miguel. As fotos tiradas foram organizadas e comparadas com as que já estavam no catálogo iniciado anteriormente pela Futurismo, sendo atualizado e utilizando apenas indivíduos com características facilmente identificáveis. Os padrões de residência, o tempo mínimo de permanência e as associações entre indivíduos foram analisados de acordo com as datas em que os indivíduos foram vistos novamente. Classificamos os indivíduos em: transientes, como indivíduos vistos apenas dentro de um ano; residentes, vistos em mais de um ano e em

estações do ano diferentes; e residentes sazonais, vistos em mais de um ano, porém na mesma estação. A taxa de avistamento mensal foi calculada para todos os indivíduos.

O número de avistamentos de golfinhos comuns foi maior no verão e menor no inverno. Contudo, golfinhos-comuns apresentaram maior ER em Fevereiro (1,9) e menor ER em Maio (0,7). Crias de golfinhos-comuns foram vistos com maior ER no verão e outono, assim como o tamanho do grupo, sendo maior em Agosto (64,6 ± 31,4) e menores em Fevereiro (25,3 ± 15,7). Os golfinhos foram preferencialmente encontrados ao sul de São Miguel e em profundidades de até 450 m (69%; n=2660). A grande maioria dos avistamentos (61%; n=2267) ocorreu em até 5 km da costa, com 34% (n=1250) encontrados entre 1-3 km da costa de São Miguel. O catálogo é formado por fotos de indivíduos identificados pelo lado esquerdo (50%; n=472) e lado direito da barbatana dorsal (42%; n=402). Apenas 72 golfinhos foram identificados pelos dois lados. Quatro golfinhos com pigmentação anômala foram encontrados, com dois indivíduos melanísticos e dois leucísticos. Cerca de 13% (n=120) dos indivíduos do catálogo foram vistos novamente. Dentre eles, a diferença de tempo entre o primeiro e o último avistamento variou entre 1 e 11 anos. Foram encontradas 9 associações entre indivíduos, sendo quatro delas indivíduos vistos juntos novamente anos depois. O tempo de permanência dos indivíduos variou entre 1 e 10 semanas (3,1 ± 1,7), onde 25% (n=10 de 42) permaneceram por uma semana, enquanto 22% (n=9) permaneceram por três semanas. Cerca de 87% dos golfinhos-comuns do catálogo foram vistos apenas uma vez e por isso são considerados indivíduos transientes. Entre os 120 indivíduos que foram re-avistados, 47% (n=56) são considerados residentes, 43% (n=52) são transientes e 10% (n=12) são residentes sazonais. A taxa de avistamento mensal teve uma média de 0,008 ± 0,004 e um valor muito baixo (0,007) para a maioria dos indivíduos identificados (89%, n=843).

Apesar de reconhecermos que a coleta de dados oportunistas podem interferir em nossos resultados, muitos deles concordam com outros estudos já realizados com golfinhos-comuns. Um menor ER de golfinhos-comuns de Abril até Setembro sugere que esta espécie se movimenta de acordo com a distribuição de suas presas. A presença de crias durante todo o ano e principalmente no verão, devido à temperatura da água e disponibilidade de comida, sugere que São Miguel é lugar ideal para a sua nutrição e desenvolvimento. A distribuição de golfinhos-comuns perto da costa de São Miguel indica que estes tenham preferência por áreas mais de menor profundidade para se alimentarem. Indivíduos encontrados em pequenas associações refletem laços sociais estáveis ao longo do tempo, principalmente aqueles avistados juntos novamente após anos de diferença. Nossos resultados podem ainda não ser

suficientes para definir grupos específicos, mas servirão de base para futuros re-avistamentos destes indivíduos, atualizando os dados que temos. Os padrões de residência sugerem que os golfinhos transientes utilizem os habitats que rodeiam São Miguel por curtos períodos durante suas migrações. Residentes e residentes sazonais tendem a passar longos períodos de suas vidas na ilha, indicando um habitat favorável que esta apresenta habitats muito favoráveis para esta espécie. A criação de um catálogo com fotos de golfinhos-comuns como neste estudo incentiva a sua pesquisa, já que esta espécie não costuma ser o foco principal em estudos de foto-identificação. Adicionalmente, as informações fornecidas aqui servirão como referência para próximos estudos, incluindo padrões de residência e distribuição espacial e temporal, encorajando mais estudos a focar a sua investigação em golfinhos-comuns nos Açores e em outras regiões.

Palavras-chave: Golfinho-comum-de-bico-curto, foto-identificação, distribuição espacial e temporal, São Miguel, Açores, residência.

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Chapter I: Introduction

1.1. Short-beaked common dolphin, *Delphinus delphis* Linnaeus, 1758

1.1.1. General description

Short-beaked common dolphin, *Delphinus delphis*, belongs to the family Delphinidae, suborder Odontoceti. In general, accounting to worldwide geographic variation, male adult common dolphins can reach 2-2,6 m, while females reach 1,93-2,3 m and calves are about 80-85 cm (Würsig *et al*., 2009; Jefferson *et al*., 1993; Neumann & Orams, 2005). Adults can weigh 200 kg on average (Jefferson *et al*., 1993; Murphy *et al*., 2009; Würsig *et al*., 2009).

Short-beaked common dolphin is distinguished from other species by its unique hourglass color pattern on the side, with a yellowish color at the front and greyish combination at the back (Figures 1.1; 1.2). This is considered as the species' main characteristic that allows an easier identification at sea than other delphinids (Jefferson *et al*., 1993; Amaha, 1994; Würsig *et al*., 2009). The high dorsal fin is moderately falcate or triangular. The colors of the flippers and dorsal fin may be all-dark to all-white or have white centers, which can only be seen in adults, not in newborns or juveniles (Amaha, 1994; Pawley *et al*., 2018; Carwardine, 2019). Common dolphins present a white abdominal field, dark patch around each eye and a dark stripe from the lower jaw to the flipper.

Anomalously pigmentations are based on alterations or mutations on tyrosinase gene, resulting in a defective enzyme which produces melanin (Fertl & Rosel, 2009). Leucistic animals are characterized by total or partial absence of pigmentation, as a hypo-pigment condition, but refers to dark-eyed anomalously white animals, different from albinism, which in turn refers to little or no pigment in the eyes, skin or hair (Fertl & Rosel, 2009; Alves *et al*., 2017). On the other hand, the overproduction of melanin pigment results in melanism, a hyper-pigmentation condition that leads to overly dark animals, which suppress the hourglass pattern of *D. delphis* (Visser *et al*., 2004). Both conditions prejudice visual or social group communication and tend to make them more susceptible to predators. Despite lower survival rates and decreased attractiveness that can affect mating success, records confirm that anomalously pigmented individuals do reach adult age and are able to breed (Fertl & Rosel, 2009; Alves *et al*. 2017; Gil *et al*. 2019).

Figure 1.1. Short-beaked common dolphin, with characteristic color pattern on the side. Illustration by Ida Eriksson - Futurismo Azores Adventures.

Figure 1.2. Short-beaked common dolphin with characteristic color patterns. Picture taken by Anxo Cao.

1.1.2. Global distribution and taxonomy

Short-beaked common dolphin is the most abundant dolphin species in offshore warm-temperature waters in the Atlantic and Pacific oceans (Figure 1.3), from the tropics to the cool temperate zones in both hemispheres (Lahaye *et al*., 2005; Würsig *et al*., 2009; Jefferson *et al*., 2011). Absolut limits of its distribution are about 60° N in the North Atlantic, 50° N in the North Pacific, and 50° S in the Southern Hemisphere (Jefferson *et al*., 1993). It is a cosmopolitan species and occurs in a range of habitat types, in both pelagic and neritic zones, being sighted from shallow to deep waters and well distributed with intermediate water depths, as in Azores (Amaha, 1994; Westgate & Read, 2007; Hammond *et al*., 2008; Silva *et al*., 2014; Braulik *et al*., 2021).

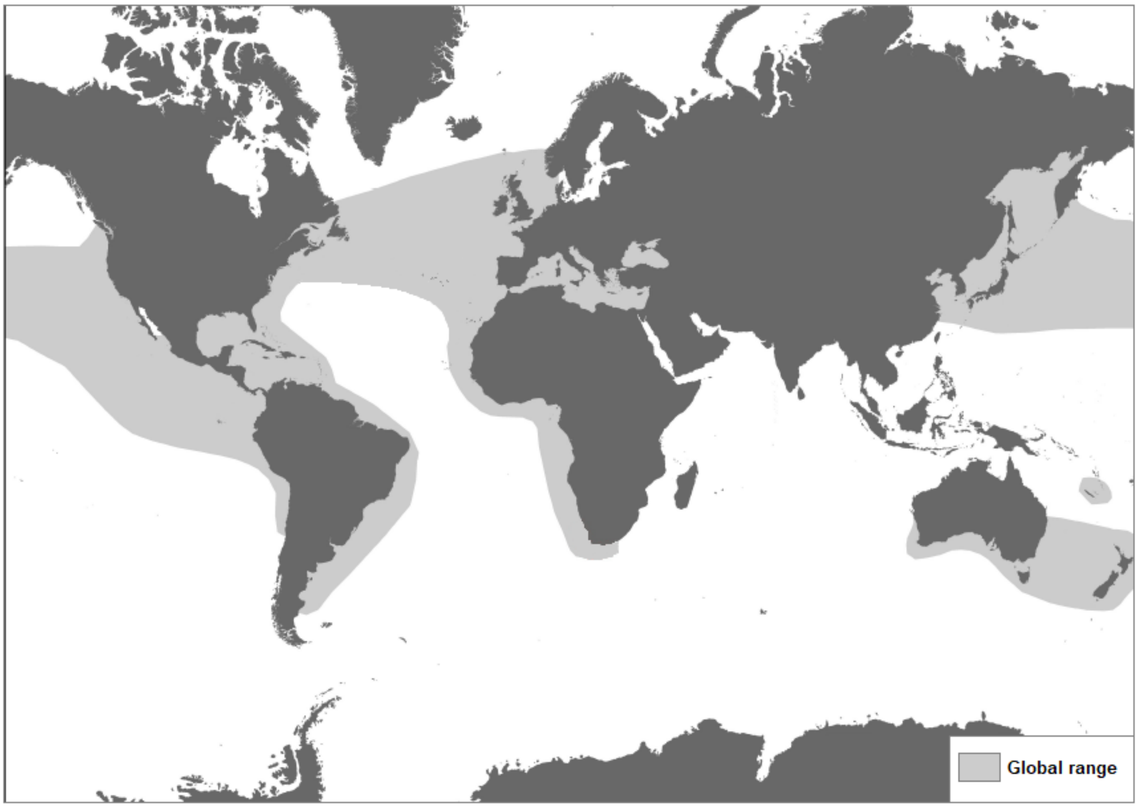

Figure 1.3. Global distribution of *Delphinus delphis*. Adapted from Plön & Cockroft (2016).

Because of its wide range distribution, geographic variation and differentiation, common dolphins worldwide can lead to speciation (Amaha, 1994; Bearzi *et al*., 2003; Murphy *et al*., 2006). Until the 90s, all common dolphins in nature seemed to belong to a single species, without having enough characteristics to distinguish or to consider as separate species (Jefferson *et al*., 2011). However, Heyning (1994) showed that two different species of common dolphins were represented by long and short-beaked variants in the eastern North Pacific (*Delphinus delphis* and *Delphinus capensis* respectively). The long-beaked common dolphin, *Delphinus capensis*, Gray, 1828, would have different color patterns than *Delphinus delphis*, Linnaeus 1758. The former presents a slightly larger body and adults rarely have white patches in dorsal fin and flippers, which are common in *D. delphis* (Ford, 2005; Jefferson *et al*., 2011; Pawley *et al*., 2018). Also, both common dolphin's species would have different habitat preferences, since *D. capensis* prefer more coastal/shallower and warmer waters than *D. delphis* (Jefferson *et al*., 1993; Ford, 2005). The long-beaked common dolphin was generally considered less seen in most regions and difficult to distinguish from its congender at sea (Bearzi *et al*., 2003; Neumann & Orams, 2005; Perrin *et al*., 2008).

Nevertheless, the Society for Marine Mammalogy (SMM) no longer considers *D. capensis* as a different species since 2016, as authors have found no genetic distinction between this species and *D. delphis*, after comparison of specimens of different regions (Cunha *et al.*, 2015; Committee on Taxonomy, 2020; Braulik *et al*., 2021). In fact, all common dolphins worldwide are considered by SMM to belong to a single species, *D. delphis*, and recognize four subspecies according to morphological distinctions in different areas: *D. d. delphis* (common dolphin), *D. d. bairdii* (Eastern North Pacific long-beaked common dolphin), *D. d. ponticus* (Black Sea common dolphin) and *D. d. tropicalis*, Indo-Pacific common dolphin (Amaha, 1994; Murphy *et al*., 2006; Committee on Taxonomy, 2020; Braulik *et al*., 2021).

1.1.3. Residency patterns

According to Bowen (1999), animal ecology explains the distribution and abundance patterns of an individual, reflecting the history of interactions between other individuals and/or with the environment. These patterns can be affected by the combination of factors such as water temperature, bathymetry, salinity, oxygen layer, predators, competitors, prey, species adaptations and even anthropogenic effects (Bearzi *et al.,* 2005; Brophy *et al*., 2009; Neumann & Orams, 2005). Still, prey availability is one of the main drivers that make groups of dolphins migrate, which makes them cover large distances in search of favorable places with food resources (Selzer & Payne, 1988; Mann, 1999; Doksæter *et al.*, 2008; Mason *et al.*, 2016).

In delphinids, residency is known to occur in ecological favorable areas where prey availability is regular and predictable and is related to site fidelity of an individual, reflecting the repeated return of a dolphin to an area (Gowans *et al.*, 2007; Stevens, 2014). Therefore, resident dolphins do not need to cover extended distances to forage because they supposedly have intimate knowledge of the area, and thus tend to spend less time and energy looking for food and can spend more energy in reproduction (Defran *et al.*, 1999; Parra *et al.*, 2006; Mason *et al.*, 2016). Moreover, according to Gowans *et al.* (2007), long-term residence of individuals familiarized to certain regions may be able to reduce the risk of predation, knowing where predators are most probably found and thus avoiding high risk areas. Dolphins' migration patterns accompany their prey movements and therefore, understanding prey distribution can provide information about predators' habitat preferences, since common dolphins are found in different geographic regions due to their varied diet (Young & Cockcroft, 1994; Lahaye *et al.*, 2005; Brophy *et al.*, 2009).

1.1.4. Diet and foraging behaviours

According to most studies, the short-beaked common dolphins' diet consists mostly of small shoaling fishes, crustaceans and cephalopods in pelagic and epipelagic water layers (Jefferson *et al.*, 1993; Hammond *et al.*, 2008; Spitz *et al.*, 2013; Cascão *et al.*, 2020). However, its diet varies taxonomically with region and season (Santos *et al.*, 2004; Pusineri *et al.*, 2007; Brophy *et al.*, 2009; Würsig *et al.*, 2009). Therefore, *D. delphis* is considered an opportunistic species and its diet can often reflect the abundance of prey species in an area (Clua & Grosvalet, 2001; Lahaye *et al.*, 2005; Brophy *et al.*, 2009).

Pusineri *et al.* (2007) affirms that *D. delphis* forages both in oceanic and neritic habitats. Common dolphins may forage in depths up to 260 m, although most dives are shallower than 100 m (Würsig *et al.*, 2009). Although they forage in groups and feeding on shoaling species seems to be the most profitable tactic, *D. delphis* can find foraging challenges depending on the region (Clua & Grosvalet, 2001; Neumann & Orams, 2005; Gowans *et al.*, 2007). For instance, in the Bay of Biscay most mesopelagic fishes and cephalopods species consumed by *D. delphis* migrate to the surface at night. The challenge for short-beaked common dolphins is to, during the day, dive repeatedly deeply enough to reach these species, while at night they could consume them at a shallower depth although groups of prey are less compacted, as they are looking for their own food (Jefferson *et al.,* 1993; Pusineri *et al*., 2007). In Condor and Gigante (two Azores seamounts), common dolphins have also shown preference in foraging at night, when their prey migrates towards the surface at sunset and returns to greater depths at sunrise (Cascão *et al*., 2020).

1.1.5. Life history

Gestation in common dolphins lasts ten to twelve months and calving intervals last 2-3 years (Neumann & Orams, 2005; Westgate & Read, 2007; Murphy *et al*., 2009). Maximum age registered was 33 years for a captivity female and over 30 for wild common dolphins (Würsig *et al*., 2009; Murphy *et al*., 2018).

Many delphinids show little sexual dimorphism; differences between rostrum and body lengths in both sexes are not highly noticeable at the sea (Amaha, 1994). Despite this, Neumann *et al*. (2002) have shown in New Zealand a secondary character to identify sexually matured male short-beaked common dolphins, since not all females in groups were followed by calves, and most females are identified by calves' presence in nature (Jefferson *et al*., 2011). Thus, authors have evidence of a postanal hump found only in males in New Zealand and Australia (Murphy *et al*., 2005; Neumann & Orams, 2005; Mason *et al*., 2016).

1.1.6. Social behaviour

Groups of dolphins are defined as individuals close to each other, showing similar behavior and moving in the same direction (Karczmarski *et al*. 2005; Rosel *et al*. 2011). *D. delphis* is an active, energetic, highly vocal species (specially while foraging) and can often be seen on the surface (Jefferson *et al*., 1993; Cascão *et al*., 2020). This species lives, travels and forages in groups of hundreds or even thousands of individuals, although they are mostly seen in groups of 20 or 30 individuals (Bearzi *et al.,* 2005; Gowans *et al.,* 2007; Mason *et al*., 2016; Castro *et al*., 2020).

Associations between other marine mammal species are common (Jefferson *et al.,* 1993; Perrin *et al*., 1995; Cecchetti *et al*., 2018; Hammond *et al.,* 2008). An example seen by Frantzis & Herzing (2002) was the mixed-species association between common dolphins, striped-dolphin (*Stenella coeruleoalba*) and Risso's dolphins (*Grampus griseus*) in Greece. Specific behaviors shown by authors go from swimming side-by-side to playful and/or harmful interactions. Also, there are records of "bow riding" on mysticeti whales, which possibly was the origin of bow riding on vessels (Würsig *et al*., 2009).

1.1.7. Main threats

Interactions between fishermen and *D. delphis* are common because of its diet (Kiszka *et al*., 2008; Brophy *et al*., 2009; Spitz *et al*., 2013). Common dolphins were, since the early times, considered as competitors by fishermen and thus killed to protect fishing stocks (Santos *et al*., 2004; Northridge, 2008; Brophy *et al*., 2009). In the Black Sea, until the 1960s (for former URSS, Romania and Bulgaria) and in the 1980s (Turkey), cetaceans including common dolphins were commonly killed in order to use their meat as bait or for food of fishermen and for different usages of oil, from lamp-oil to medicines by pharmaceutics (Birkun, 2002; 2008; Mintzer *et al*., 2018). Until 1964, more than 80% of the total number of cetaceans killed by the former Soviet Union was composed of common dolphins, followed by harbour porpoises (*Phocoena phocoena*) and bottlenose dolphins (*Tursiops truncatus*) (Birkun, 2002). Exploitation of *D. delphis* using nets or harpoon has still been occurring in different countries, such as in Peru and Venezuela (even if illegally) and in Japan (Romero *et al*., 1997; Kasuya, 2017; Mintzer *et al*., 2018; Braulik *et al*., 2021).

Fortunately, this species (and all other cetaceans) is protected by law in Portugal and many other countries, and only are caught by fishing nets incidentally (Silva & Sequeira, 2003; Santos *et al*., 2004, Cruz *et al.,* 2018). These "incidental catches", as bycatches, in fisheries operations are one of the main threat to common dolphins worldwide, which makes them one of the most common cetaceans killed by fishing nets in many regions (Neumann & Orams, 2005; Rogan & Mackey, 2007; Spitz *et al*., 2013; Cruz *et al.,* 2018; Braulik *et al*., 2021). The highest rates of mortality for common dolphins are caused mainly by gillnet fishery, as seen in most eastern North Atlantic countries (Santos *et al*., 2004; Westgate & Read, 2007; Northridge, 2008; Murphy *et al*., 2009).

Nowadays, common dolphins are considered as “Least Concerned” by IUCN at a global level (Braulik *et al*., 2021). However, this species is assessed as “Data Deficient” at a European regional level (Hammond *et al*., 2008) and since 2003 is “Endangered” in the Mediterranean Sea (Bearzi, 2003; 2012). Still, the competition for the same fish resource between common dolphins and fisheries negatively affects *D. delphis* not only directly, because of bycatches, but also indirectly, reducing the availability of food resources (Neumann & Orams, 2005; Brophy *et al*., 2009). The scarcity of prey can also be related to climate change, which affects dolphins’ distribution, leading them to often shift between regions and switch to other species, as an animal with an opportunistic diet (Simmonds & Isaac, 2007). Moreover, these effects on prey contributed to dolphin populations’ susceptibility to viral infection, due to their impaired health, as it happened in the Black Sea (Birkun, 2008). In addition, plastic pollution, known as a global concern, affects common dolphins as well by ingestion, e.g. microplastic found in the stomach of many specimens stranded in Galicia, Spain (Hernandez-Gonzalez *et al*., 2018).

1.2. Photo-identification

1.2.1. Mark-recapture technique

Understanding population biology and behavior of cetaceans often requires identifying animals individually contributing to improve their conservation and management (Markowitz *et al*., 2003; Hammond, 2009; Wells, 2009).

Studies in mark-recapture are used to provide information on movement patterns and social structure by marking the animals (Wells, 2009). This technique was initially represented by the physical capturing of animals, application of tags or mutilation, release, and then recapturing or resighting it without capture (Hammond, 2009). This capture method, however, has not shown much success in cetaceans once it is difficult to capture them and they may be vulnerable to handle them. Therefore, it led to the necessity of developing new, additional and less invasive ways of carrying out mark-recapture studies (Hammond, 2009; Pawley *et al*., 2018). Although the tagging and marking techniques were considered almost mandatory for animal behavior work from the 1950s to 1970s, the increasing number of long-term wild animal studies have shown that most vertebrates usually can be identified by their natural markings using non-invasive techniques (Würsig & Jefferson, 1990; Wells, 2009; Pawley *et al.,* 2018).

Therefore, nowadays, mark-recapture is usually associated with photo-identification (photo-id), an important technique which allows the identification of specific individuals by their natural body markings (Neumann *et al*., 2002; Markowitz *et al*., 2003; Wells, 2009; Pawley *et al*., 2018). With this method, researchers can link sightings separated by years and thousands of kilometers worldwide (Mann, 1999). The enhancement of quality of images for photo-id has been evolving by digital photography, with high resolution digital cameras, high-speed and auto-focusing. These provide high-color images in real-time, eliminating delays and challenges that old cameras had and gives a much more affordable way of collecting useful information (Adams *et al*., 2006; Wells, 2009). Photo-id methods can supply information on animal movements, ranging patterns, site fidelity, group composition, life story/history and even to evaluate cetacean-fisheries interactions (Neumann *et al*., 2002; Balmer *et al*., 2008; Tyne *et al*., 2016; Pawley *et al*., 2018).

1.2.2. Distinctive natural marks

Cetacean species show a variety of distinctive natural features, used to better identify an individual. The most used features are the ones that appear above the water surface when the animal gets to breath, such as heads, fins, flukes and backs (Wells, 2009). Each species has a body part frequently used to be easily recognized. For short-beaked common dolphins, the dorsal fin is used, as it is a useful identification feature easily visible during surfacing (Wells, 2009; Pawley *et al.,* 2018).

Depending on the aims of the study, the selection of fins for creating a catalogue may be appropriate only if individuals are sufficiently well marked (Bearzi *et al*., 2005; 2008; Hammond, 2009; Pawley *et al*., 2018). This fact excludes calves, juveniles, and adults with temporary or no visible marks from many photo-id studies, even though recording their presence is important to analyze the group structure.

Although being considered a poorly marked species, photo-id in common dolphins has been successfully employed in some behavioral ecology studies, aiming to identify and quantify the dolphins' movements, assess residency patterns and stability of group composition (Neumann, 2001; Neumann *et al*., 2002; Hupman, 2016; Hupman *et al*., 2018;

Pawley *et al*., 2018). Number, shape and size of natural markings can change over time, showing the importance of keeping up with them throughout their lifetime.

1.3. Short-beaked common dolphins in Azores

In the Azores archipelago, short-beaked common dolphins are usually the most sighted species in many studies and are seen year-round (Silva *et al*., 2003; 2014; González García, 2019). Even if found on a large range of water depths, they are mostly seen in waters shallower than 400 m deep, with low slopes and through the entire sea temperature range of the Azores (Silva *et al*., 2014; González García, 2019). Common dolphins occur year-round, but encounter rates are higher in autumn and lower in summer (González García, 2019). They have been observed foraging on small schools of tuna, which is usually also a target species for fisheries in the Azores, such as the blue jack mackerel (*Trachurus picturatus*) (Quéruoil *et al*., 2008; Cruz *et al.,* 2016).

Feeding-related associations between different species are common in the Azores (Clua & Grosvalet, 2001). Associations of short-beaked common dolphins and the large yellowfin tuna (*Thunnus albacares*) feeding on the same school fish have been reported (Clua & Grosvalet, 2001; Cruz *et al.,* 2016). Also, during feeding strategies, associations with other cetacean species, such as bottlenose dolphins *(Tursiops truncatus)*, Atlantic spotted-dolphins *(Stenella frontalis)* and striped-dolphins *(Stenella coeruleoalba)*; or seabirds such as the Cory's shearwater *(Calonectris diomedea borealis)* are common (Clua & Grosvalet, 2001; Quérouil *et al*., 2008).

In fact, bycatch of this species has been reported in the archipelago, since common dolphins are more likely to interact with fisheries during early morning and in the afternoon according to Cruz *et al.* (2016), when it happens to be the periods with more intense fishing efforts, even if interactions with pole-and-line tuna fisheries are low. Common dolphins are often targeted by whale watching or swimming with dolphins activities, and it has been changing their behaviour from foraging to socializing on the surface, when in the presence of boats as observed by Ceccheti *et al.* (2018). Oceanic dolphins have changed their foraging period to dawn and dusk, when usually whale watching activities do not occur, but in the Azores common dolphins seem to still feed during daytime, as seen by whale watch operators (Ceccheti *et al*., 2018).

Despite the fact that short-beaked common dolphin is one of the most sighted species in the Azores islands, their behavior, group composition and migration patterns are still poorly understood (Silva *et al*., 2014; Cecchetti *et al*., 2018; González García, 2019). Furthermore, there are no studies focusing on their photo-identification in the region so far or assessing its residency patterns in Azores, which benefit from the use of photo-identification.

1.4. Objectives

The main objectives of this study are to:

1) Assess the temporal distribution of common dolphins around São Miguel from 2008 to 2020.

2) Examine spatial distribution of the registered sightings of common dolphins according to water depth and distance to the coast where they are mostly found.

3) Identify Highly Identifiable Individuals of common dolphins by their dorsal fins' marks and pigmentation and update the previous photo-identification catalogue of common dolphins off São Miguel island with photographs taken on whale watching trips between 2008 and 2020.

4) Analyze residency patterns based on photo-id resightings. We expect to recognize individuals sighted on different days of the same month, months of the same year and in different years within the study period according to previous data.

As secondary objectives, we aim to:

5) Estimate minimum time of permanence in the area for the resighted individuals.

6) Recognize possible associations between individual common dolphins, looking at individuals sighted together over time, and likely belonging to the same group or at least likely to have lasting social bonds.

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Chapter II

Short-beaked common dolphins (*Delphinus delphis*) in São Miguel Island, Azores: photo-identification of HII (Highly Identifiable Individuals) and spatio-temporal distribution

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1. Introduction

Short-beaked common dolphin (*Delphinus delphis* Linnaeus, 1758) is distinguished from other species by a yellowish color and greyish combination, forming an hourglass color pattern on the side of its body (Würsig *et al*., 2009). This pattern is suppressed when the individual presents an anomalous pigmentation condition, characterized by hyper-pigmentation (melanistic or all-black individuals) or hypo-pigmentation (leucistic or all-white individuals) (Visser *et al*., 2004; Fertl & Rosel, 2009; Alves *et al*., 2017). These conditions are considered rare in nature and infrequently reported (Stockin & Visser, 2005; Fertl & Rosel, 2009).

Common dolphin is a widely distributed species, from the tropics to the cool temperate zones in both hemispheres (Lahaye *et al*., 2005; Jefferson *et al*., 2011). It occurs in a range of habitat types, in both pelagic and neritic zones, being sighted from shallow to deep waters and well distributed with intermediate water depths (Hammond *et al*., 2008; Braulik *et al.*, 2021). In some areas, the large availability of prey with few competition with other species leads to better chances of resighting the same group of dolphins on repeated occasions (Parra *et al*., 2006; Gowans *et al.*, 2007). Residency is related to site fidelity, i.e. the tendency of an animal to return to a previously occupied place, and can be defined for individuals, groups or species that spend great part of their lifetime in a certain area (Greenwood, 1980; Rosel *et al*., 2011; Giacomo & Ott, 2016).

Different studies have classified residency in some categories according to the dolphin's number and timing of the resightings such as: year-round residents, seasonal residents and transients. Dolphins considered as "year-round residents" were defined by Giacomo & Ott (2016), in a year of data, as the ones resighted in more than five months during a year, which indicates potential presence on most of the year. "Seasonal residents" are animals observed in one same season over several years, as documented in New Zealand (Constantine & Baker, 1997; Balmer *et al*., 2008). This seems to be usual and likely related to favorable environmental factors, for feeding or reproduction (Bowen, 1999; Mann, 1999; Neumann & Orams, 2005). On the other hand, dolphins that rarely visit the area, i.e. seen or resighted only once, can be defined as "transients", also called "occasional transients" or "temporary migratory" (Neumann & Orams, 2005; Rosel *et al*., 2011).

Common dolphins are also widely distributed in the Azores archipelago, Portugal, occurring in inshore and offshore waters over a large range of water depths year-round (Silva *et al*., 2014; Cecchetti *et al*., 2018; González García, 2019; Gannier *et al*., 2020). In different studies, assessing the occurrence of various cetaceans species, short-beaked common dolphins were the most sighted species and considered a resident species of the archipelago (Silva *et al*., 2014; González García, 2019). According to Doksæter *et al*. (2008), the Azores is a favorable place for common dolphins because of the water temperature (12-22°C), an important factor that determines dolphin's prey distribution. However, these would be secondary factors, compared to the large prey abundance and distribution that seem to be the real influential drivers (Doksæter *et al*., 2008). Thermoregulatory needs and the need of consuming large amounts of food influence the distribution of common dolphins (Doksæter *et al*., 2008; Toth *et al*., 2010). Mainly, prey movement patterns and availability are confirmed to be the main drivers of common dolphins' distribution by several studies (Caputo *et al*., 2020). This species is an opportunistic feeder, and thus seems to follow prey patches and tend to exploit high primary productivity (PP) areas with predictable prey availability (Lahaye *et al*., 2005; Stevens, 2014; Castro *et al*., 2020).

The Azores archipelago has high concentrations of nutrients than surrounding areas due to a combination of oceanographic heterogeneity of physical factors, supporting upwelling, the input of different water masses and currents which turns this region into a complex habitat (Santos *et al*., 1995; Silva, 2007; Silva *et al*., 2008; Stevens, 2014). This contributes to a great diversity of species in the archipelago and tends to offer enough food resources to support resident populations (Silva, 2007).

Whaling started in the Azores archipelago in the eighteenth century and lasted until 1986 when Portugal banned all invasive and destructive interactions with all cetacean species following the Moratorium established by the International Whaling Commission (IWC) (Ellis, 2008). Soon after whaling stopped, whale watching started to develop in the Azores (early 1990's) inheriting expertise, knowledge and even the methodology used to find whales from land, which was adapted to whale watching and is still used today. Since then, it has grown rapidly, becoming a relevant tourism activity in the Azores (González García, 2019). Nowadays, the Azores is considered one of the best regions for cetacean observation in the world, with 28 cetacean species already seen in the archipelago (Silva *et al*., 2014; Afonso *et al*., 2020).

Whale watching in São Miguel started in 1994, and has been providing not only tourism for the region, but also taking advantage of whale watching trips which do not have the study of cetaceans as a main objective, to collect as much information about them as possible (Viding *et al*., 2015; González García, 2019). Studying cetaceans may be challenging because they are very mobile and wide ranging animals (Hauser *et al*., 2006). Therefore, the use of opportunistic data has shown several advantages as an affordable way of providing useful information about cetacean distribution and seasonal patterns (Hauser *et al*., 2006; González García, 2019). This type of data is collected in the Azores by whale watching companies such as Futurismo Azores Adventures, whose main base port is located in São Miguel island.

Photo-identification (photo-id) is a non-invasive technique used to identify individuals by their natural markings, providing information about group composition, life story and residency patterns in long-term studies (Wells, 2009; Pawley *et al.,* 2018). Some specific features, on backs or dorsal fins, used on photo-id studies are nicks, notches, scratches, scars and wound marks, gained usually through intraspecific or interspecific interactions, including fishing gear and lines (Würsig & Jefferson, 1990; Neumann *et al*., 2002; Kiszka *et al*., 2008).

Common dolphins are considered a poorly marked species compared to other ones and this led to the necessity of finding new unique characteristics to identify them (Hupman *et al*., 2018; Pawley *et al*., 2018). Therefore, the pigmentation pattern in *D. delphis*' dorsal fins was shown as an additional feature used to easier identify and recognize an individual, since short-beaked common dolphins show great variability in fin coloration patches, i.e. in the intensity/shape of a white patch in the middle of the dorsal fin (Amaha, 1994; Neumann *et al*., 2002; Mason *et al*., 2016; Pawley *et al*., 2018).

This poor marking of common dolphins, together with the big number of individuals per sighting, makes its photo-identification even more challenging and can affect data collection. Considering this, Hupman *et al*. (2018) have created a catalogue on New Zealand with only highly distinctive marked individuals, which they considered the presence or absence of fin pigmentation, number and sizes of nicks or notches and quality of pictures. Therefore, based on Hupman *et al*. (2018), we consider in this study only Highly Identifiable Individuals (HII), defined as common dolphins with very distinctive natural marks, used to easily identify and recognize each individual. Focusing only on HII helps to facilitate data collection management and to avoid possible mistakes.

The aims of this study were, mainly, to 1) assess the temporal distribution of common dolphins around São Miguel from 2008 to 2020, 2) examine spatial distribution of the registered sightings of common dolphins, 3) identify HII of common dolphins and update the previous photo-identification catalogue with photographs taken on whale watching trips between 2008 and 2020 off São Miguel island and 4) analyze residency patterns based on photo-id resightings. We expect to recognize individuals sighted on different days of the same month, months of the same year and in different years within the study period according to previous data. Secondly, we aimed to: 5) estimate minimum time of permanence in the area for the resighted individuals and 6) Recognize possible associations between individual common dolphins, looking at individuals sighted together over time, and likely belonging to the same group or at least likely to have lasting social bonds.

2. Methods

2.1. Study area

The Azores consists of nine volcanic islands and several islets. The islands are divided into three main groups (western, central and eastern), which extend over 600 km and are located in the middle of the Atlantic Ocean, on the Mid-Atlantic Ridge (MAR), between 40-37°N and 32-25°W. This archipelago is under the influence of several oceanographic factors which contribute to heterogeneity of different habitat types, supporting a great number of resident and transient species (Afonso *et al*., 2020; Gannier *et al*., 2020).

This study was carried out in São Miguel, the largest and most populated island in the Azores, located in the eastern region together with Santa Maria island and Formigas islets (Figure 2.1; Afonso *et al*., 2020). São Miguel island has a wide range of marine habitats, with depths up to 2000 m close to the coast; higher temperatures occur in summer, with sea surface temperature (SST) varying from 15ºC to 25ºC in winter and summer, respectively, and it presents a seasonal cycle, with higher chlorophyll-α (Chl-α) concentration in spring (González García *et al*., 2018).

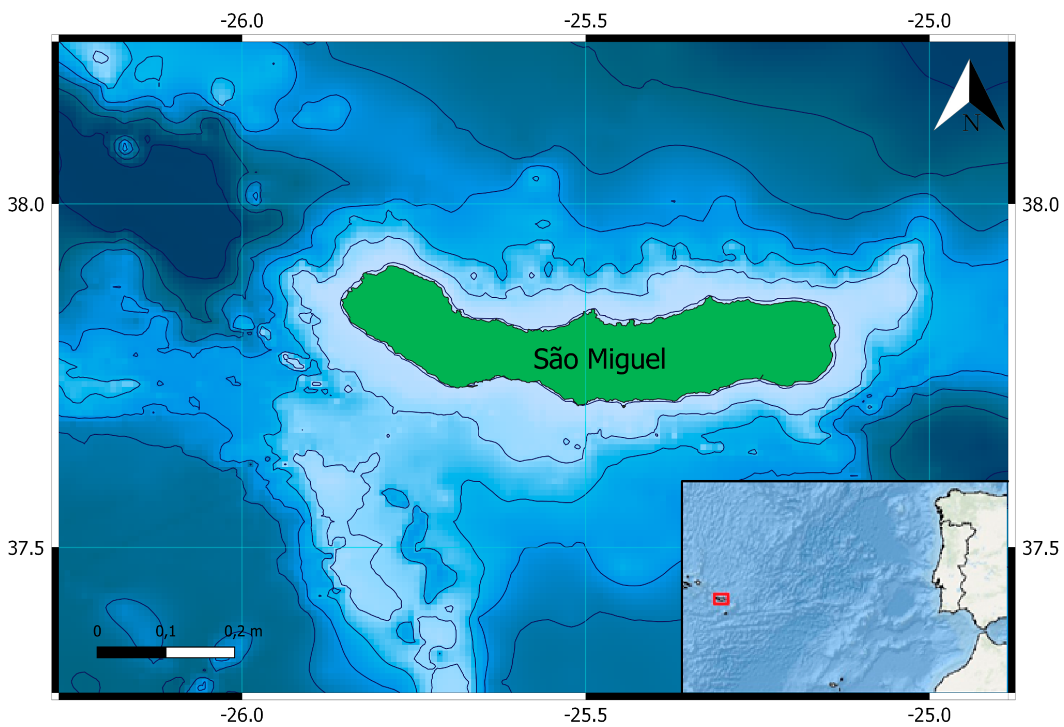

Figure 2.1. Island of São Miguel, study area, located in the Azores archipelago.

2.2. Data collection of *Delphinus delphis*

Opportunistic data of short-beaked common dolphins (hereafter referred to as only "common dolphins") were collected from 2008 to 2020 during whale watching trips made by Futurismo Azores Adventures, mostly run from Ponta Delgada (São Miguel island, Azores). Trips were run year-round, with higher frequency in summer due to better weather conditions and presence of more whale watching customers to go out. On average, they last approximately 3 hours and are carried out morning and afternoon every day. Cetaceans, and therefore common dolphins, were usually found by watchmen, spread in strategic coastal locations along the island. These lookouts search for the animals with powerful binoculars and inform their position to the whale watching vessels by radio. Sighting GPS location, weather conditions, group size, general behavior and other interesting notes are recorded for each sighting. Good quality photos are taken whenever it is possible, increasing its number and quality over the years due to the improvement and affordability of digital cameras and more experienced and qualified staff onboard. Photos used for this study cover the period between May 2008 and March 2020.

2.3. Spatio-temporal distribution

Exact location and date of common dolphin' sightings were used to assess its spatial and temporal distribution between May 2008 and March 2020 (when data collection stopped due to COVID-19 pandemic and lockdown situation).

As cetaceans are found from land, and boats are directly piloted towards the animals, sea-effort cannot be properly calculated, as it depends on land observations. Therefore, calculating an absolute effort is not possible due to the opportunistic nature of the dataset. However, the number of whale watching trips can be considered a proxy of effort, which allows us to compare sighting rates within our study period. For example, there are months when there are fewer whale watching trips, i.e. winter months, due to weather conditions. Thus, encounter rates (ER) were calculated by dividing the number of sightings of common dolphins by the number of trips per month or per year, i.e. monthly ER or yearly ER respectively. Monthly and yearly ER was also calculated for presence of groups with calves over the study period.

GPS locations of common dolphin sightings were plotted on a map using QGis (Geographic Information System 3.14.1, 2021) with bathymetry extracted from General Bathymetric Chart of the Oceans (GEBCO, 2012) with 1 km resolution, in order to better visualize their spatial distribution, and identify areas with higher number of sightings. The associations found between individuals were also plotted in a map to check possible distribution differences among potential different groups around the island, using the location of the dates which each association was sighted. The depth and distance from the coast were extracted from each sighting using QGis. The heatmap was created using Kernel Density Estimation (with radius 0.05° and pixel size 0.01) based on the number of sighting points, in order to identify "hotspots" with higher density of common dolphins. The bathymetry product was obtained from European Marine Observation and Data Network (EMODNet) with grid resolution of 1/16 * 1/16 arc minutes (circa 115 * 115 meters). The high resolution coastline of São Miguel was extracted from *Instituto Hidrográfico de Portugal* to check the distance to the coast of each sighting. Distribution of sightings was analyzed according to different depth intervals and distance to the coast to check where dolphins were mostly seen.

2.4. Photo-identification of common dolphins

The existing catalogue of common dolphins made by Futurismo was created in 2019 only with pictures from 2017 to 2019. It was created based on Highly Identifiable Individuals (HII), i.e. those dolphins with easily identifiable characteristics such as nicks, notches and/or pigmentation patterns (Hupman *et al*., 2018). In this study the catalogue was updated, covering a 12-year period of data, following an improved version of the protocol created by Futurismo in 2019, but keeping the same approach of identifying only HII. The previous protocol included the identification only of the left side of the fin, while here we consider both sides.

The photos were taken by Futurismo's staff during the daily whale watching trips. Once on land, they were daily stored in folders and separated by species. Valid photos for common dolphin photo-identification should be high quality, likely in perpendicular angles to the right and left dorsal fin of the animal. Only these good quality pictures were used to identify individuals and create the catalogue. For instance, unfocused photos, too distant pictures and photos with considerable water splashes (covering important parts of the fin) were rejected. Copies of the original pictures were cropped with Ninja Photo-ID (software developed by Massey University, 2021), which crops all the fins present in one photo automatically. Then, cropped fins were organized in folders by date (year, month and day). Original pictures were stored conveniently as back-up.

Once the new pictures are organized in folders, the identification process based on mark-recapture of photos of the individuals starts. This process consists in looking for resightings, i.e. to compare every new individual with the ones already identified and try to find a “match”, defined in this study as different photographs considered as the same dolphin according to its nicks, marks and coloration patterns.

An Excel file is created in order to control all information of each dolphin, such as photo identification number/picture code, side of the fin (left or right), dates of first sighting and resightings and number of recaptures, which is the number of times this individual was photographed again, also considered as matches. The individuals from new pictures are compared to the ones already in the catalogue, and if they are matched, a new recapture, i.e. the number of resightings, is assigned to the already identified (and known) dolphin over time. Every time a new match is found, the recapture number is raised by 1. New pictures that did not have any match in the catalogue, but were still considered a HII, are added to the catalogue. New photographs are systematically checked with the existing individuals in the catalogue to look for matches.

Highly identifiable individuals (HII), based on Hupman *et al*. (2018), are defined in the present study as individuals with distinctive marks which makes them easily identifiable or recognizable. These marks can include the combination of nicks/notches, different shape, scratches, wound marks and pigmentation patterns. However, a well-marked individual who does not present all features, but some or even one of them, can still be considered as an HII. In addition, dolphins that do not present a fin or have anomalous pigmentation conditions, such as melanism or leucism, are also considered an HII. Dolphins which do not have enough distinctive marks are not considered in the catalogue, i.e. dolphins with a barely seen single small nick and absence of other features.

2.5. Insights about residency patterns

Checking the dates, number of months, seasons and years of the resightings of each dolphin using long-term data series, allows analysis of the residency patterns of each individual, its time of permanence around a defined area, or even potential insights into its life story. Residency patterns of common dolphins were assessed with an adapted methodology based on authors who have already defined residency of other cetacean species in the Azores and in El Hierro, Canary Islands (Silva, 2007; Reyes Suárez, 2018). Silva (2007) defined residents as dolphins re-sighted in at least four years in the main area and transients as individuals seen once. Reyes Suárez (2018) defined residents as dolphins resighted two or more years during the study period (12 years) and transients seen in one year.

In our study, residency categories of common dolphins around São Miguel were defined based on the frequency of sightings counted between months, seasons and years of each individual. We define the common dolphins' residency in São Miguel as: Residents (R), as individuals seen in more than one year and in different seasons; Seasonal Residents (SR), as individuals sighted in more than one year, but in the same season; and Transients (T), as individuals found within a year only, with or without recaptures.

For seasonal comparisons of encounter rates and residency patterns seasons, based on similar oceanographic conditions as suggested by González García *et al*. (2018) we defined: winter, as December, January and February; spring as March, April and May; summer as June, July and August; and autumn as September, October and November.

The time of permanence is considered here as the number of days on which a certain dolphin or group is resighted around the island. The number of days considered can be consecutive days or closer (i.e. days or few weeks later) to provide more reliable information. In this study, we provided the time of permanence of individuals by week for better understanding of time spent around the island. If one individual was found one day and then again one year or six months later, his time of permanence in São Miguel would not be considered. Common dolphins are very mobile and have shown that they can migrate from a place to another in a short period (430 km in 10 days as shown by radio-tagged survey by Evans (1982); Neumann *et al*., 2002) and thus only dolphins seen in a two-month range (with more pictures between first and last time they were seen in this period) were considered for this type of analysis. To bear in mind, the time of permanence does not necessarily mean the exact number of days or weeks that the dolphin stayed around, but at least the minimum in which it was sighted around the area.

To assess the degree of residency of each dolphin, we calculated the monthly sighting rate per individual, based on Silva (2007) and here referred as "monthly SR", is the number of months each dolphin was sighted in São Miguel divided by the total number of months of this study (n=145). The monthly SR reflects the degree of fidelity of an individual during the study period, which shows the individuals' tendency of time spent in São Miguel, by using the number of months, and is independent of the number of years they were seen (Silva, 2007).

As a secondary objective, association between individuals was assessed considering two or more dolphins to be associated when they are sighted together on repeated occasions. The higher the number of sightings together, the larger the probability of estable associations. However, due to the opportunistic nature of the data, together with the high number of dolphins per group and the lack of photos of all individuals present, this approach should be only considered as a first step, as it likely underestimates the existence of associations between individuals.

3. Results

3.1. Spatio-temporal distribution

3.1.1. Temporal distribution

From May 2008 to March 2020, Futurismo registered 4.599 trips in total. The year with most trips (n=452) was 2017; 2020 and 2008 were the years with less trips (n=47 and n=227, respectively), even though 2008 has only six months of data (May to October) and 2020 presents data from January to March due to COVID-19 pandemic situation (Figure 1A in Appendix). The graph on Fig. 3.1 shows a higher tendency of trips from April to September. July and August were the months with more trips (total of n=684 and n=646 respectively, in summer), while December and January presented less trips (total of n=140 and n=112 respectively, in winter).

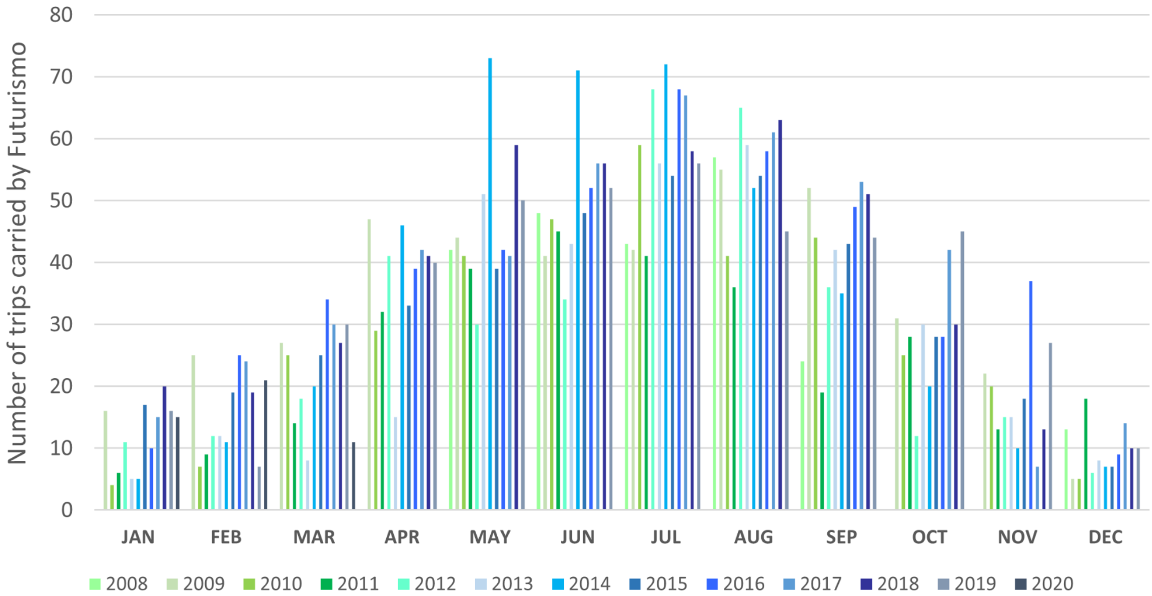

Figure 3.1. Number of trips carried by Futurismo in São Miguel from 2008 to 2020, showing monthly trends and higher tendency of trips from April to September.

Common dolphins were seen every year and year-round, with a total of 4.002 sightings from May 2008 to March 2020. Number of sightings was higher in 2019 (519 sightings in total) and lower in 2020 (117 sightings). Also, influenced by the different number of trips per season, the number of common dolphin sightings was higher in warmer months, from June to August (Figure 3.2 A), with July presenting the highest (483 sightings, 12% of all *D. delphis* sightings along the study period), and less seen in colder months, from November to January, with December being the lowest (151 sightings).

Data of 2008 and 2020, although present on Fig. 3.2 A, will not be considered in this encounter rate section for interfering in results, since in these years data collection was not possible in many months for both years. Yearly ER of common dolphins were higher in 2013 (1,16; 400 sightings in 344 trips). They had the lowest ER in São Miguel in 2018 (0,55; 249 in 447 trips). In addition, monthly ER was higher in winter months (season average = 1,51; sd = ± 0,33), sharply decreasing from April towards summer time (Figure 3.2 B). February presented the highest ER of common dolphins (1,9; 324 sightings of 191 trips), while May showed the lowest (0,7; 389 of 551 trips).

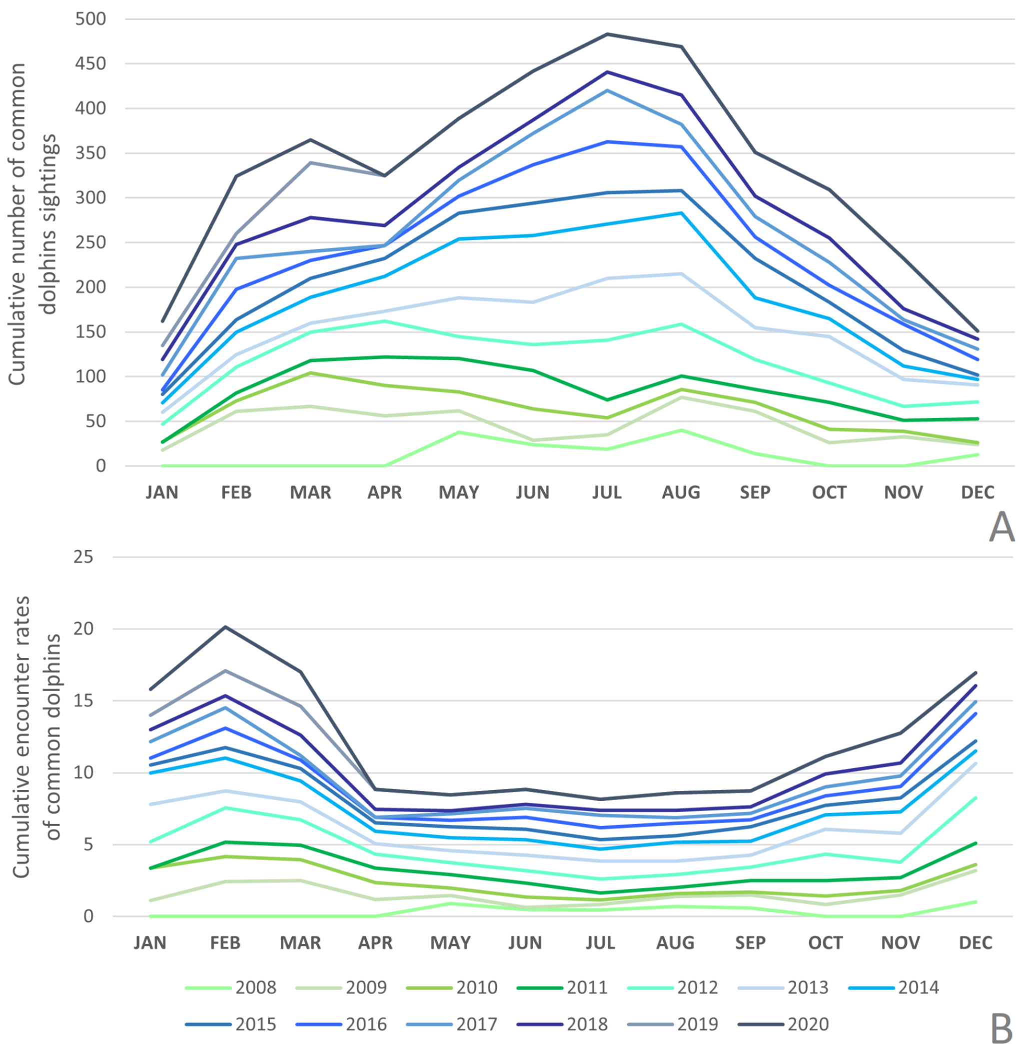

Figure 3.2. (A) Cumulative sightings and **(B)** Cumulative Encounter Rate of common dolphins per month and per year reported in São Miguel.

Calves were seen in all years (Figure 3.3), being registered in 1.697 encounters from 2008 to 2020, with the highest yearly ER of calves in 2020 (0,65; 31 sightings of common dolphins with calves in 47 trips) and in 2019 (0,61; 260 sightings in 422 trips). The year with the lowest ER was 2016 (0,2; 93 sightings with calves in 451 trips). Calves were most found in summer and autumn months, mainly in June (with ER of 0,6; 294 sightings in 483 trips) and less in February (ER of 0,13; 45 sightings in 324 trips). Photos of calves were detected in 20% (n=61) of the 309 days in which common dolphins were photographed along the study period, according to original pictures.

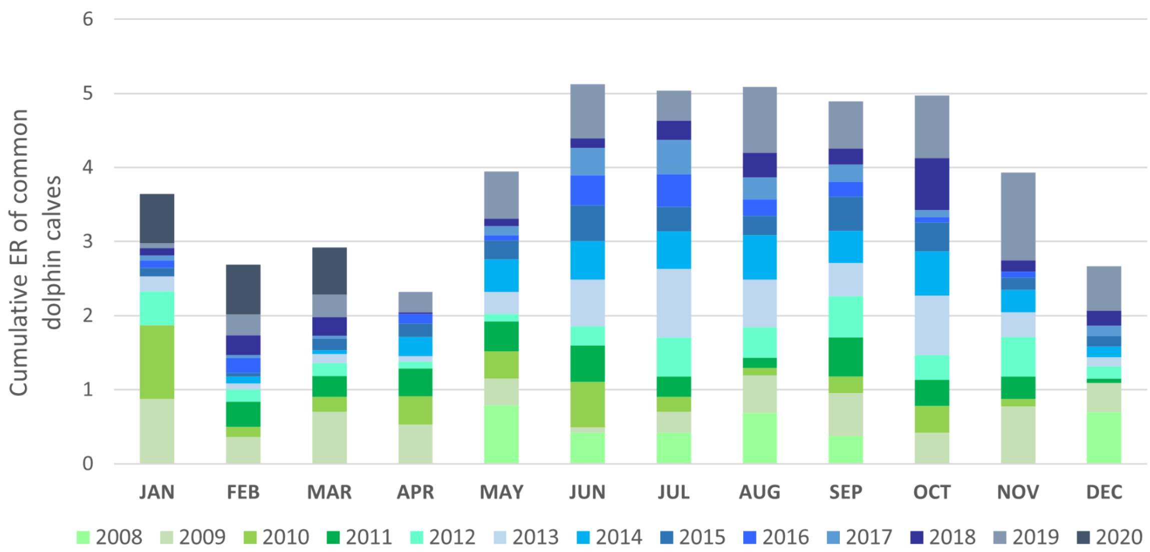

Figure 3.3. Cumulative ER (encounter rates) of common dolphin calves found in São Miguel per month and per year.

Common dolphins were seen in groups of 1 to 750 individuals (average = 47,1 individuals; sd = ± 64,9) over the years. Differences of group size between months and years can be seen in Fig. 3.4. Groups are larger during summer months, mainly in August (monthly average = 64,6 individuals; sd = ± 31,4), while February presents smaller groups (monthly average = 25,3 individuals; sd = ± 15,7).

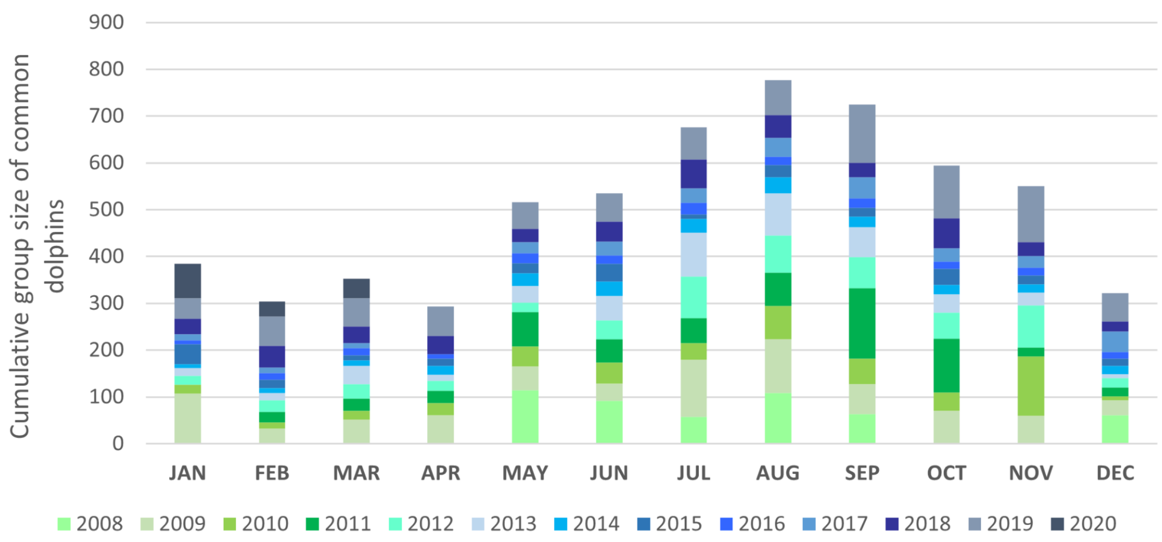

Figure 3.4. Monthly average group size of common dolphins per year.

3.1.2. Spatial distribution

Common dolphins' sightings spatial distribution in the study area can be seen in Fig. 3.5. Higher density of common dolphin sightings is present in the south of São Miguel, mostly in Ponta Delgada, with more sightings in the central-west side of the island.

Most common dolphins (69%; n=2660) recorded were found in waters depth up to 450 m, with 25% (n=952) found within 50 to 150 m depth (Figure 3.6). Most common dolphins (61%; n=2267) were mainly found within 5 km from the coast, with most of the sightings in this range between 1-3 km to the coast (34%; n=1250) (Figure 3.7).

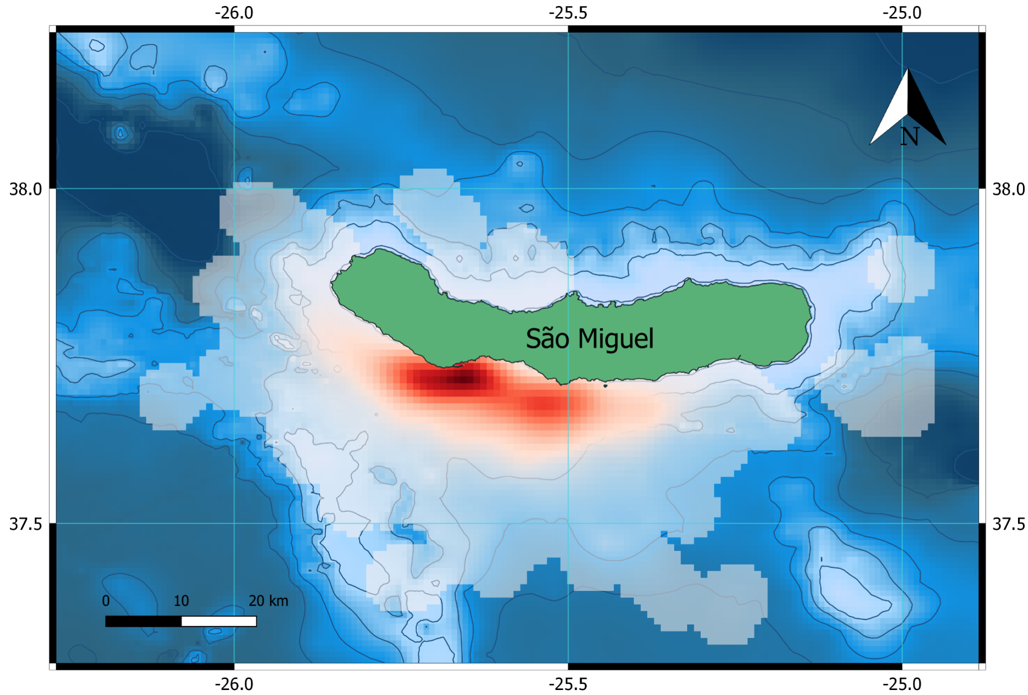

Figure 3.5. Density map with all common dolphins' sightings in São Miguel over the study period (May 2008 - March 2020). Areas with darker red have higher density of sightings and lighter red and light grey with less sightings. Bathymetry isolines are shown every 100 m deep change.

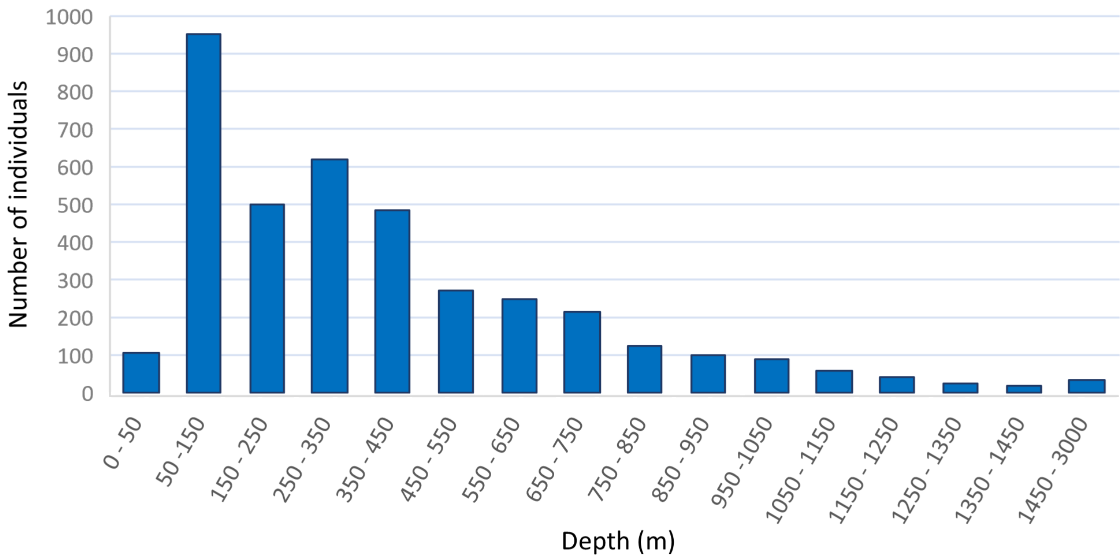

Figure 3.6. Distribution of common dolphins off São Miguel according to water depth intervals.

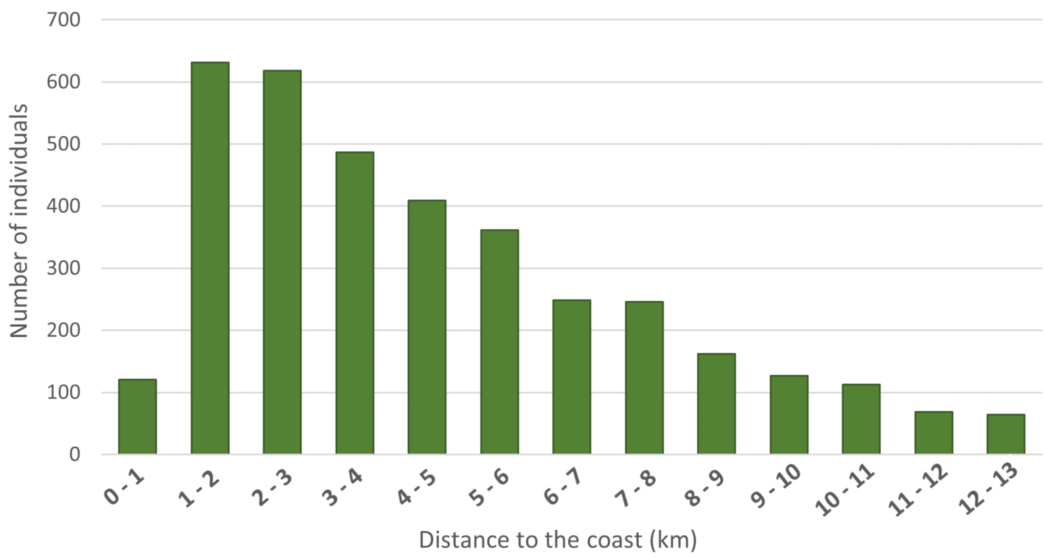

Figure 3.7. Distribution of common dolphins according to distance to the coast (given by km) of São Miguel. Most individuals are concentrated 5 km to the coast.

3.2. Photo-identification of common dolphins

A total of 5.698 pictures of common dolphins were taken between 2008 and 2012, 2014 and from 2016 until March 2020. There are no pictures from 2013 and 2015 that could be used for this work due to lack or bad quality photos. A total of 3.662 cropped pictures of fins were compared to the ones already in the catalogue.

The final catalogue is formed by 1018 pictures of dorsal fins of common dolphins. Most of them (50%; n=472) were left side, 42% (n=402) were right side. Only 72 dolphins matched both sides of the fin. These 72 common dolphins have corresponding pictures of each side in the respective folders (right and left) of the catalogue and therefore pictures are counted twice. In addition, 4 anomalously pigmented dolphins (two melanistic and two leucistic) were found and separated in a different folder.

For different counts of resightings and residency classification of individuals used in this study, we considered a total of 950 fins, counted from the number of individuals identified by their left, right and both sides (n=72) and number of anomalously pigmented individuals found.

In this study, 87% (n=830) of fins were not resighted within the 12-year study period (Figure 3.8 A). The remaining 13% (n=120) yielded 184 resightings, varying from one to nine recaptures of the same fin: 71% (n=85) once, 18% (n=22) twice, 6% (n=7) three times, and 5% (n=6) four or more times (Figure 3.8 B).

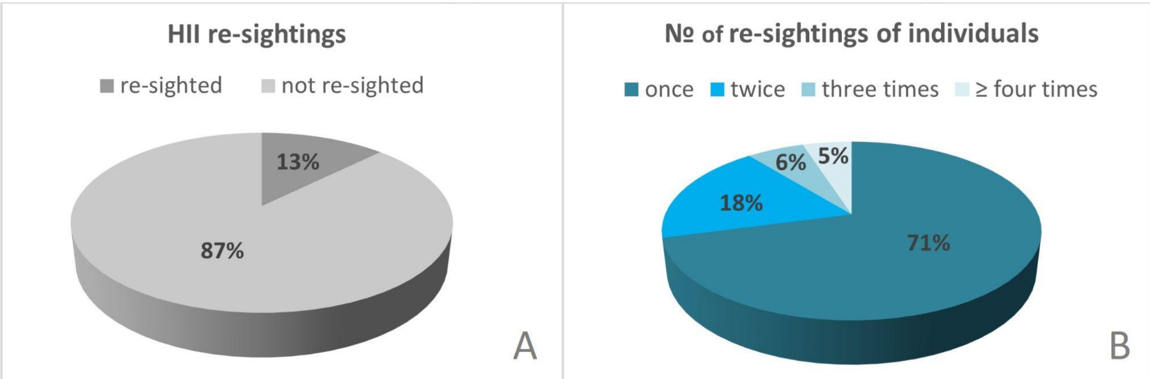

Figure 3.8. Percentages of HII common dolphins from the catalogue. (A) Percentage of total fins (n=950) in relation if they were resighted or not; **(B)** Percentage of number of resightings of identified fins (n=120; 13% of total resighted fins from Fig. 3.8 A).

The most resighted HII are shown in Fig. 3.9. These HII are well-marked and most of them have the combination of pigmentation pattern and nicks/notches. All of them are residents of São Miguel, seen in at least three different years of the study period (from 3 to 6 years). Period between first and last resightings of these individuals varied from 2 to 11 years apart. Individual DD008 (Figure 3.9 C) is the most sighted common dolphin off São Miguel, with 9 recaptures with a maximum time interval of 11 years between its first and last resightings.

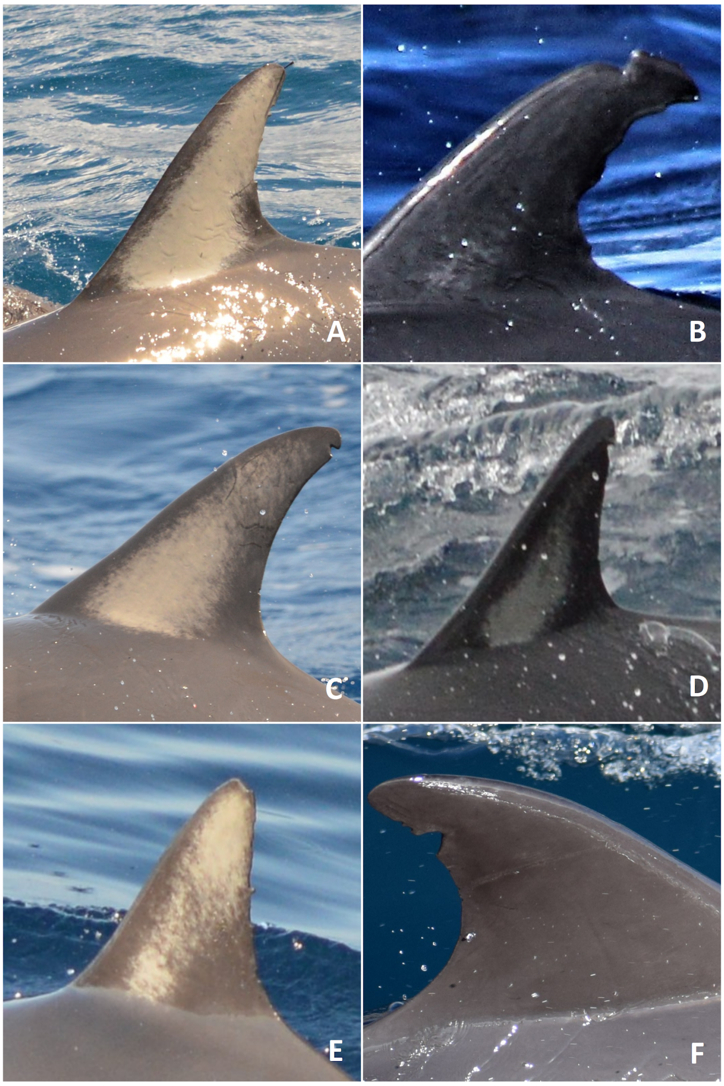

Figure 3.9. Most resighted common dolphins off São Miguel island. (A) DD001 (7 times); **(B)** DD003 (4 times); **(C)** DD008 (9 times); **(D)** DD016 (4 times); **(E)** DD089 (6 times); **(F)** DD115 (4 times).

In addition, when the individual had high distinctive nicks on the edge of its fin, we compared it to its opposite side folder, which helped to find many matches that could not be found if the comparison of both sides was not considered. This happened to 16 individuals (13% of 120 resighted individuals) in this work (DD075, DD143 DD167, DD179, DD199, DD234, DD270, DD297, DD314, DD322, DD325, DD350, DD353, DD372, DD391, DD474), which have only found a match because of the comparison of edges (Figure 2A in Appendix).

Of the 120 resighted common dolphins, 45% (n=54) were sighted within a year. The remaining, regarding the period of years between their first and last resightings (Figure 3.10), 15% (n=18) had a year of difference, 11% (n=13) had five years of difference, 8% (n=10) had three years, 7% (n=8) had two and six years each, 6% (n=7) had four years and two individuals had 11 years of difference. The two individuals (DD008 and DD139) with 11 years of difference were both first sighted in São Miguel in 2008 and last sighted in 2019, on different dates.

Moreover, some individuals of the catalogue acquired new marks on their fins with new recaptures over the years (Figure 3A in Appendix). Fins found in this study have also shown great variability in fin coloration patterns, from little or no coloration to all white fins (Figure 4A in Appendix).

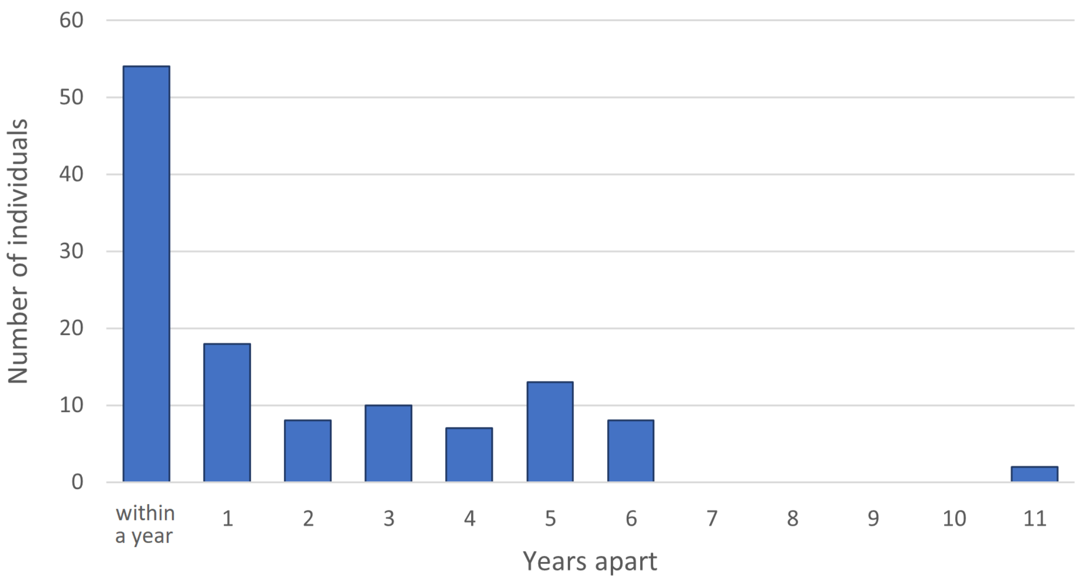

Figure 3.10. Relation of resighted individuals (n=120) with period between first and last resightings, from individuals seen within a year to individuals with eleven years of difference between first and last resightings.

Four anomalously pigmented common dolphins, two melanistics (all-black individuals) and two leucistics (all-white/grey individuals), were photographically registered during the study period. Nevertheless, comments written in the field on the sightings data sheet reported more anomalously pigmented dolphins, but were not captured in photos. The two melanistic dolphins were sighted with 17 days in between (Mel_DD001, 23rd May 2019,

Figure 3.11 A; Mel_DD002, 9th June 2019, Figure 3.11 B). Two leucistic common dolphins were found with a light-grey body, also with 17 days in between sightings (Leu_DD001, 26th May 2014, Figure 3.11 C; Leu_DD002, 12nd June 2014. Figure 3.11 D). We cannot exclude the possibility of the melanistic and leucistic individuals found of being the same individual, although we cannot guarantee this due to the lack of better pictures.

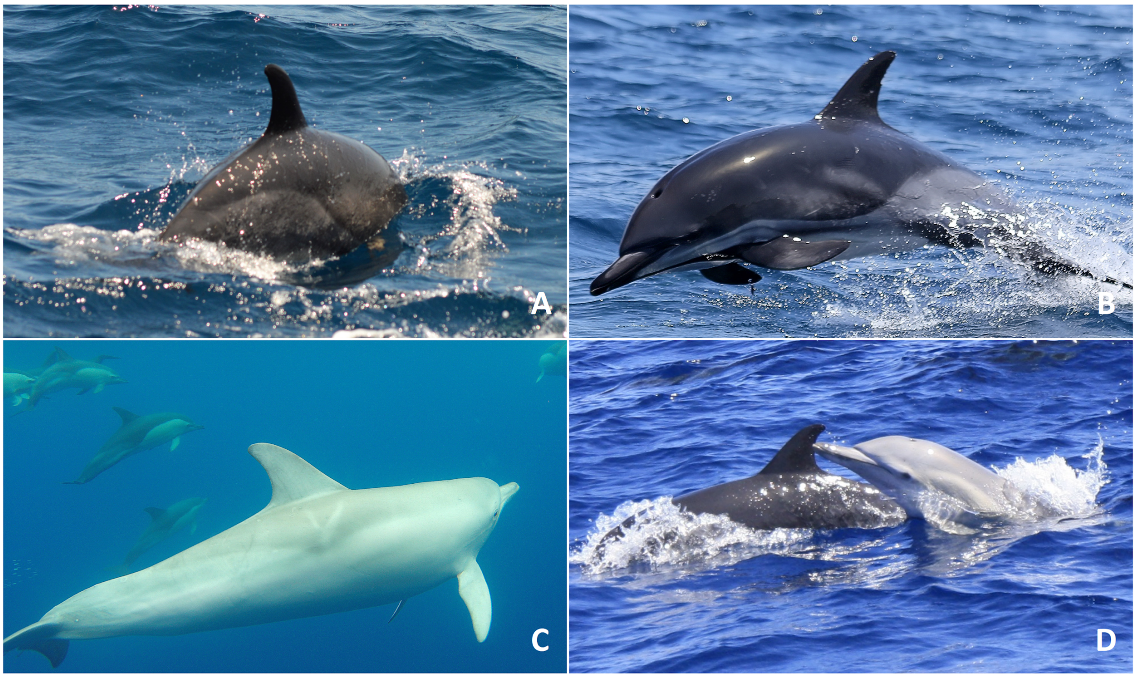

Figure 3.11. Anomalous pigmented common dolphins found in the study. (A) Mel_DD001 seen on 23rd May 2019; **(B)** Mel_DD002 seen on 9th June 2019; **(C)** Leu_DD001 seen on 26th May 2014; **(D)** Leu_DD002 sighted on 12nd June 2014.

3.3. Individual association between common dolphins off São Miguel

Nine associations between individuals were detected in the study period, as dolphins sighted together more than once (Table 3.1). Individuals DD115 and DD119 were sighted together three times, on 3rd, 4th and 10th of January 2020. Individual DD116R was added to the association for being sighted with DD115 and DD119 on 3rd and 10th January of 2020, and therefore they likely belong to the same group. Other associations found with individuals sighted together at least twice, are likely to form stable links for longer periods. However, more data is needed to confirm long-lasting associations between individuals or for group identification. Four associations (A5, A6, A7 and A9) were resighted in different years, with A6 resighted after four years. The other five associations were resighted within a year, with 2 groups (A2 and A8) seen again in different seasons and 3 groups (A1, A3 and A4) seen in the same season. The associations can be seen in Fig. 3.12 according to their respective GPS location of the day they were sighted.

Table 3.1. Common dolphin associations found in São Miguel. Id column shows the code of the dolphins identified in each association; and dates correspond to the day when the individuals in "Id" were found together.

Association	Date	Id
A1	03/01/2020	DD115
	04/01/2020	DD116R
	10/01/2020	DD119
A2	15/05/2014	DD101
	16/06/2014	DD235
		DD320
		DD381
A3	24/09/2019	DD451R
	22/10/2019	DD470
A4	24/09/2019	DD166
	26/09/2019	DD378R
		DD456R
A5	24/09/2017	DD089
	23/04/2018	DD181
A6	17/05/2014	DD008
	23/04/2018	DD021
		DD089
A7	24/09/2019	DD112R
	03/01/2020	DD199
A8	15/05/2014	DD153R

	17/08/2014	DD329
A9	07/02/2019	DD115
	03/01/2020	DD120R

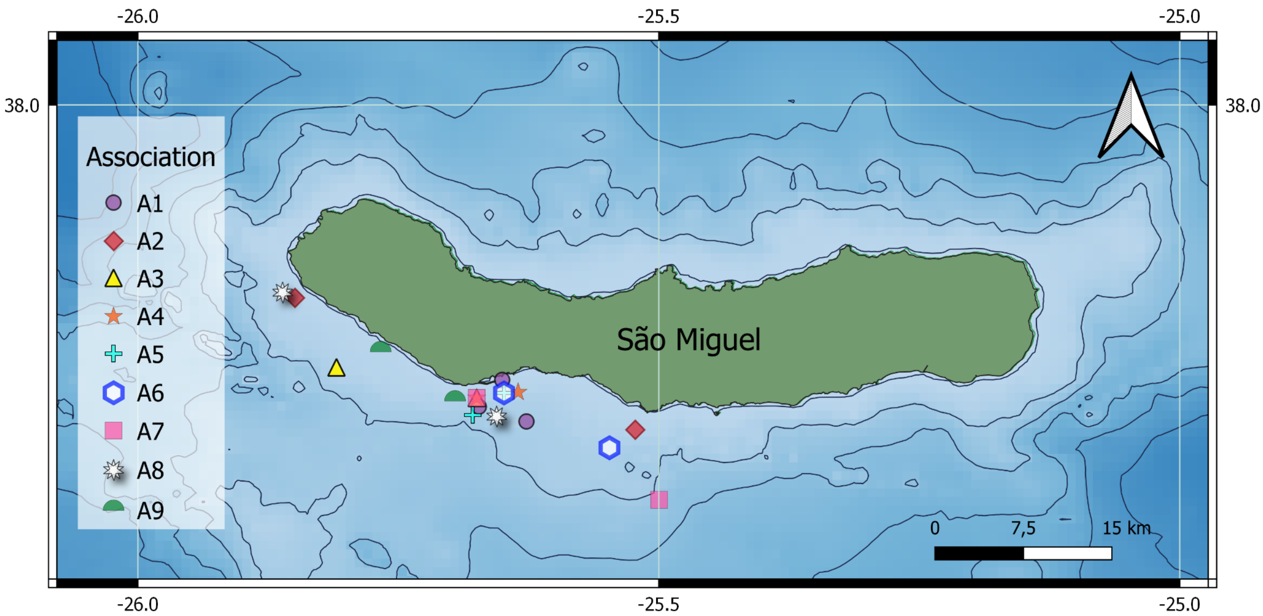

Figure 3.12. General distribution map of individual associations, found close to the coast of São Miguel.

3.4. Residency patterns of common dolphins in São Miguel

3.4.1. Time of permanence

The time of permanence around São Miguel was checked for 42 of the individuals photographically identified. The remaining 78 individuals were resighted two or more months later (even years apart) with no resightings in between. Therefore, they were not considered in this analysis.

The time of permanence found for the considered common dolphins varied from 1 to 10 weeks (average of 3,1 weeks; sd = ± 1,7). A quarter of the individuals (25%; n=10 of 42) were present in the area for a week, while 22% (n=9) remained for three weeks (Figure 3.13). Longer stays were found for 19% of the individuals (n=8), who remained in São Miguel for five weeks. Common dolphins with the longest time of permanence were DD101 (almost 10 weeks; 64 days) and DD016 (8 weeks; 53 days).

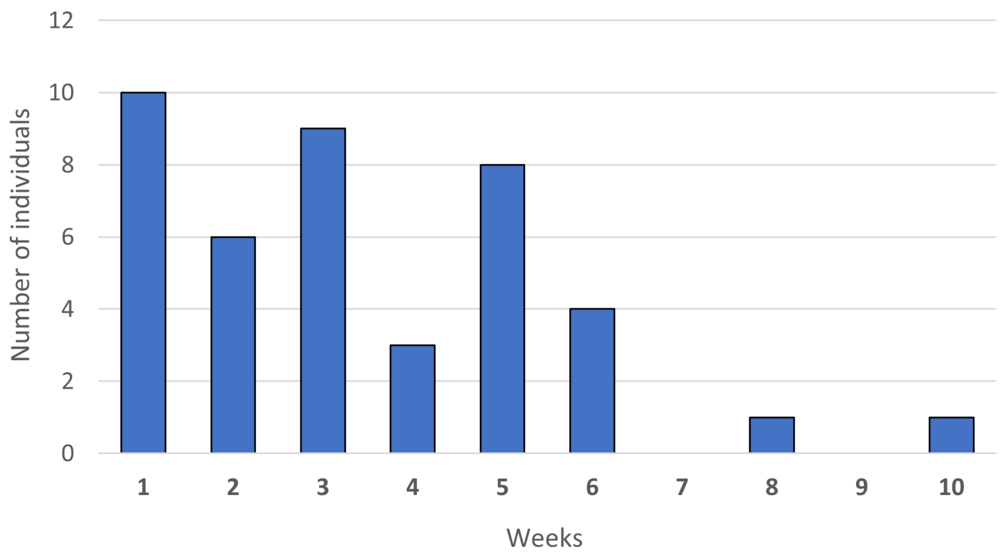

Figure 3.13. Time of permanence given by weeks of common dolphins around São Miguel.

3.4.2. Residency patterns

Although we cannot provide an exact number of single individuals in the catalogue, a total of 950 fins were counted in order to check their general residency.

From all fins of the catalogue, 87% (n=830 of 950) were sighted only once and the remaining 13% (n=120) were seen more than once. The ones sighted only once are considered transients. Of the 13% resighted individuals, 47% (n=56) are considered residents, 43% (n=52) are transient and 10% (n=12) are seasonal residents (SR) (Figure 3.14 A).

In relation to residents (R), about 77% (n=43) were sighted in two different years, while 18% (n=10) were seen in three years and 5% (n=3) were seen in four or more different years (maximum six years) (Figure 3.14 B). Only two individuals (residents DD008 and DD139) were sighted in all seasons of the year, in different years.

Of the twelve individuals who were considered as seasonal residents (SR), 42% (n=5) of individuals were seen in summer. About 25% (n=3) were sighted in winter and others 25% (n=3) were seen in spring (Figure 3.14 C). Only one dolphin was sighted in autumn. Eleven SR individuals were seen in two different years and only one (DD425) were sighted in 3 different years but the same season. Data of seasonal residency is insufficient for deeper analysis of season preference of common dolphins.

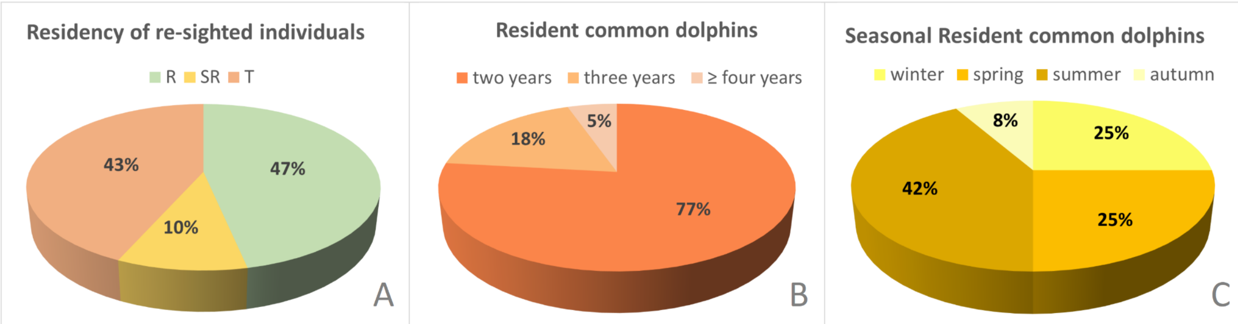

Figure 3.14. Percentages of residency patterns considering only resighted common dolphins in São Miguel (n=120). (A) Percentage of resident, seasonal resident and transient resighted dolphins identified off São Miguel; **(B)** Percentage of resident common dolphins sighted in two, three or more years; **(C)** Percentage of season-related residents per season.

The monthly SR (monthly sighting rate) was calculated for all fins (n=950) with minimum value of 0,007 and maximum 0,055 (average = 0,008; sd = ± 0,004). Monthly SR was very low (0,007) for most of the individuals identified (89%, n=843), as they were sighted in only one month during all the study period, with or without recaptures within this month. Eighty individuals (8%) had a monthly SR of 0,013 and 15 individuals (2%) had 0,02. Highest monthly SR, which corresponds to those sighted in more months, had maximum value (0,055) for two dolphins (DD001 and DD008) sighted in a total of 8 months in different years.

4. Discussion

4.1. Spatio-temporal distribution of *Delphinus delphis* in São Miguel

D. delphis is the most sighted cetacean species in the Azores in most reported studies. Their presence in the Azores and therefore, in São Miguel, is considered year-round (Silva *et al*. 2003; Alves *et al*. 2017; Correia *et al*. 2019; González García, 2019). However, intra and interannual differences in their temporal distribution were found. Monthly ER of *D. delphis* in São Miguel was higher from December to March (mostly winter months). However, the highest number of whale watching trips of this study occurred in June, July and August, when accordingly, were registered more sightings of common dolphins. Nevertheless, summer months were the ones with the lowest monthly ER.

The fact that winter months showed a higher monthly ER and in warmer months presented lower ER, agrees with Silva *et al*. (2003; 2014) and González García (2019), which recorded in the Azores lower encounter rates of common dolphins from April to September, warmer months. However, we acknowledge opportunistic data limitations and one of the main reasons common dolphins have highest ER in winter may be influenced by the less number of trips carried in this season. For instance, since the encounter rate is defined by the number of sightings divided by the number of trips, if we have one trip in a whole month and a common dolphin is sighted, the ER will be high. A higher number of trips (and a more consecutive number of days) would be more profitable in future research for more reliable information. Similarly, in Madeira (another Macaronesian island), common dolphins ER are higher in winter and springtime (Saavedra *et al*., 2018). The Madeira archipelago is separated from the Azores by about 900 km and common dolphins are considered seasonal visitors in this place (Quérouil *et al.*, 2010).

Goold (1998) recorded few or even absence of short-beaked common dolphins in the Irish Sea during winter. Nevertheless, previous studies found the absence of *D. delphis* in colder months, in Bay of Biscay, while at the same time its abundance increased considerably next to English Channel (Kiszka *et al*., 2007). Therefore, while in wintertime this species may be absent in other areas (i.e. Bay of Biscay or Irish Sea, etc.) at the same time it can be using habitats such as the Azores or other places, which can explain the increased sighting proportions in this season. These fluctuations and migration patterns seem to be related to common dolphins following their prey patches, influenced by primary production (PP) and water temperature (Neumann & Orams, 2005; Kiszka *et al*., 2008).

Higher PP is usually related to higher concentration of nutrients, which might be enhanced by different oceanographic features, including currents, thermal fronts and eddies (Constantine & Baker, 1997; González García, 2019). In the south of the Azores, the Azores Front system provides a very dynamic oceanography to the region, both because of the front itself, and because of the eddies released from the mainstream (Sala *et al*., 2016; González García *et al*., 2018). These eddies usually reach the southern islands of the archipelago (i.e. Santa Maria and São Miguel), enhancing and aggregating primary production, and therefore, the subsequent levels of the trophic chain (Santos *et al*., 1995; Macedo *et al*., 2000). On another hand, the abrupt bathymetry of the archipelago favours retention of particles in these waters, providing good opportunities for marine life, including common dolphins, to live around oceanic islands such as the Azores (Sala *et al*., 2016).

Therefore, dynamic environmental variables such as sea temperature or chlorophyll concentration (generally used as a proxy for primary production) may influence common dolphins' distribution in São Miguel. These variables change over time and dolphins may respond to these changes accordingly, showing differences within and between years (Silva, 2007). In addition, Silva *et al*. (2014) highlights the fact that common dolphin's displacement in Azores coincided with the presence of the Atlantic spotted-dolphin, *Stenella frontalis*, suggesting that they have distinct prey preferences, which may complement the explanation of common dolphin's low ER in warmer seasons, while spotted-dolphins are seen mainly in April to October (Quéruoil *et al*. 2008; Fernandez *et al*., 2009; Cruz *et al*., 2016).

Calves were present year-round, although with higher ER in summer and autumn. Probably higher water temperatures during summer months, food availability (schooling fish is likely to increase in abundance with some time lag after the spring bloom) and even the larger group size, could favour the successful growth and development of common dolphins' calves. Despite Urian *et al*. (1996) did not find a significant relation between SST and frequency of birth, they affirm that breeding in cetaceans can be indirectly influenced by water temperature by affecting distribution and availability of prey, and thus timing of birth in some areas. In general, even though dolphins can reproduce and give birth in different seasons, birth timing seems to happen mostly in summer worldwide, according to previous studies. In the South Hemisphere, the occurrence of common dolphin calves in the Bay of Islands (New Zealand) peaks in January, when it happens to be the hottest month in summer

(Constantine & Baker, 1997). In the North Hemisphere, in the Eastern North Atlantic (Mediterranean sea, Macaronesian archipelagos, Portugal mainland and north-west Africa), occurrence of common dolphins' calves seem to follow the same timing pattern, with calves occurring mainly in summer (Cañadas & Hammond, 2008; Correia *et al*., 2019). Moreover, our results agree with González García (2019), who also found higher ER of common dolphins' calves in warmer months in Azores, especially in July, August and September.

In this study, even with different monthly ER, calves year-round presence throughout the year indicates that mating happens frequently within most groups seen in the island, reflecting São Miguel as a good calving and feeding place. For instance, groups with adult females with calves tend to visit regions with high concentrations of resources due to energetic demands of lactation (Gubbins, 2002).

Photo-identification has been previously used to check the seasonality of calves in common dolphins and in other species (Neumann & Orams, 2005; Jefferson *et al*., 2011). However, photo-id methods in this study have not shown much success in capturing the presence of calves. Data registered on a datasheet on board regarding the group composition (presence of adults, juveniles or calves within the group sighted) provided a better overview of calves presence, as they are not always photographed even when they are seen. Calves do not usually have enough marks to be photo-identified (and therefore recognized in other sightings). Therefore, they are not the focus of photo-id and thus are excluded from these studies to avoid errors in identification (Eisfeld, 2003; Shane, 2004; Silva, 2007).

In addition, common dolphins were sighted on a 47,1 ± 64,9 average group size in this work and it is almost impossible to take pictures of every single individual, in which it can happen to lose many individuals with this. Common dolphins were seen in larger groups in summer and autumn months, when they have the lowest ER. In winter, when they have the highest ER, groups sighted were smaller. In fact, as previously suggested, the higher ER of calves during warmer months, could be one of the reasons for bigger groups' seasonality.

Most common dolphins were found close to the island, within a 5 km distance from the coast of São Miguel and in a water depth up to 450 m. Our results are influenced by the weather conditions of São Miguel. In summer, when weather conditions are more favorable, boats on trips have more opportunity to travel further from the coast. Our study area regularly covers the south of São Miguel, as during the study period whale watching trips run by Futurismo were mostly conducted from their main base port in Ponta Delgada, although occasional sightings were also recorded in the north coast, during trips which departed from Rabo de Peixe. The commercial purpose of the whale watching trips may favour sightings of common dolphins closer to the coast, biasing the spatial distribution of recorded sightings. However, it is of importance to note that, under the same methodology and effort in other surveys by Futurismo, not all the species present this coastal distribution, which reinforces the preferences of common dolphins for this area, although further and deeper waters might be underestimated.

In addition, previous studies have recorded a higher number of encounters of *D. delphis* in shallower waters, although in the Azores archipelago they are well distributed with intermediate (500-1500 m on average) water depths, inshore and offshore (Silva *et al*., 2014). In the archipelago, they were mostly found in inshore shallower waters (<400 m) by Silva *et al*. (2003) and González García (2019). Moreover, compared to other species by Morato *et al*. (2008) common dolphins were found in high abundance next to Azores seamounts in a very shallow summit to feed on tuna, due to enhanced productivity in this area. Therefore, it is possible that common dolphins found in São Miguel can be using inshore/shallower regions as preference areas for foraging.

In the South Africa coast, Caputo *et al*. (2020) study have not found significant correlation between water depth and ER or group size. Seasonal differences of depth preferences were found, with common dolphins closer to the coast in winter, as it has been reported in New Zealand (Constantine & Baker, 1997). In contrast, in Ireland, common dolphin's abundance and distribution was greater and closer to the coast in warmer months (spring and summer) and scarcer and further from the coast in colder months (Goold 1998).

4.2. Photo-identification of *Delphinus delphis*

Effort intensity and extensive photo-identification work has shown success in many studies of marine mammals (Bearzi *et al*., 2008; Silva, 2007). Our 12-year study provided new information about common dolphins off São Miguel. However, we must bear in mind that until recent years, *D. delphis* was not a focus species for photo-identification and it is not the main target in whale watching in the island. Therefore, the creation of a catalogue may encourage more research on common dolphins, using this one as a reference. Catalogues also facilitate comparison of individuals between distant regions, i.e. collaboration between researchers in order to match sightings of individuals separated by thousands of kilometers and by years (Mann, 1999).

Common dolphins do not show many nicks, scars and notches on their dorsal fins and thus are considered as poorly marked delphinids, in comparison to bottlenose dolphins (Neumann *et al*., 2002; Pawley *et al*., 2018). Using well-marked individuals provides more certainty of recognition in recaptures. Furthermore, the different patches of coloration in adult's dorsal fins have shown great variability between dolphins and remain stable over time (Pawley *et al*., 2018). Due to its stability, establishing levels of fin coloration of common dolphins can be used as a suggestion to improve further catalogues (including this catalogue in the future).

For common dolphins, both features, recognizable marks and special coloration, characterizes Highly Identifiable Individuals, which greatly improve identification success and reduce uncertainty. In this study, poor quality pictures were rejected to avoid misidentification and increase reliability of photo-identification results, even if the individuals clearly presented a notch, a different shape of dorsal fin or even a different coloration.

We used 950 fins for different counts made in this study. However, we could not define a specific total number of identified single individuals in the catalogue, because there is a possibility of more individuals having a matching side on the opposite folder, e.g. individuals on the left side that can be the same individual on the right side and we could not connect them.

Identifying a dolphin with both sides of the dorsal fin increases chances of re-sighting the individual. However, matching both sides was particularly difficult, as dorsal fin coloration is not symmetrical in both sides, and edge trace is not always enough. However, great variety of marks were found on individuals' dorsal fins of the catalogue, i.e. with scratches, nicks, notches and shapes or even no fin at all (DD023R) (Figure 4.1 F), and this largely improved matching success (Wells, 2009; Jefferson *et al*., 2011; Berrow *et al*., 2012), as seen with 16 (out of 72) of the individuals only identified by both sides in this study. These types of marks could have been caused by intra and interspecific interactions. The latter includes, for example, aggressive interactions, since mixed-species associations are common (Frantzis & Herzing, 2002; Stockin *et al*., 2009). Intraspecific interactions, i.e. caused by other common dolphins (such as male-male competition for females), are usually related with bites and tooth rake marks, and they are considered common between groups of odontocetes

(Heyning, 1984; Scott *et al*., 2005; Bamford & Robinson, 2016). Other types of marks, such as particularly strange shapes of fins (e.g. *Hector,* DD238R; Figures 4.1 C), or even absence of the entire dorsal fin (DD023R) might probably be caused by anthropogenic activities such as boat strikes or fishing gears (Martinez & Stockin, 2013; Meissner *et al*. 2015). The presence of different scars and marks analysed with photo-id are used to assess cetacean-fishery interactions, since this is one of the main reasons of death and stranding in cetaceans (Kizska *et al*., 2009; Cuvertoret-Sanz *et al*., 2020).

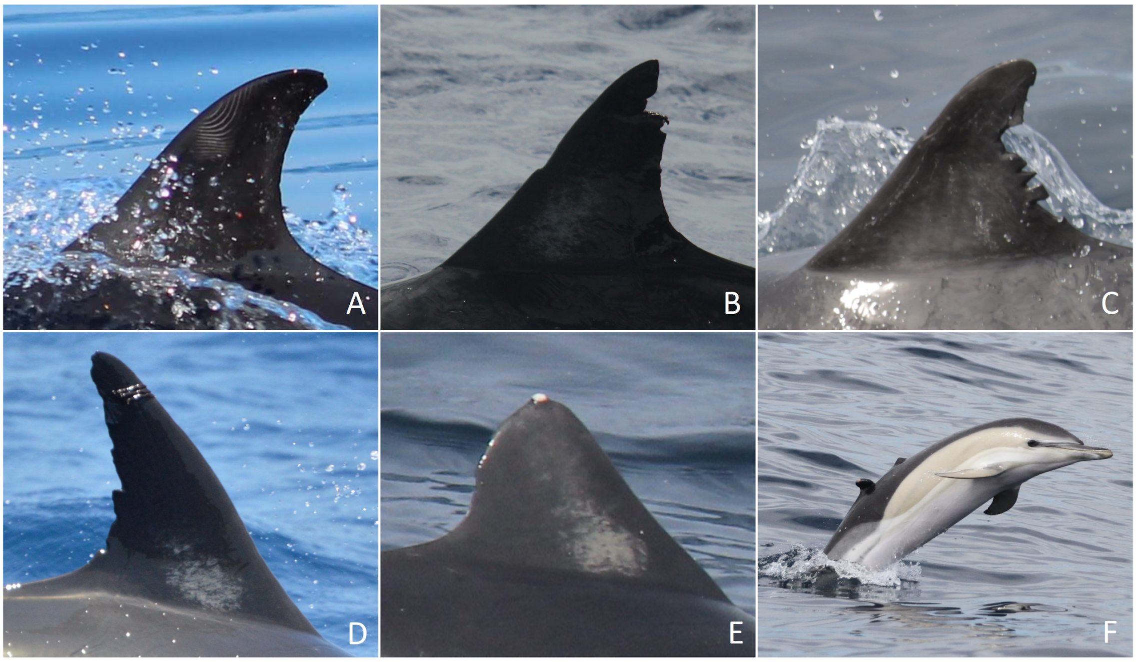

Figure 4.1. Different marks, nicks, shapes or absence of dorsal fin of common dolphins from the catalogue. (A) DD481; **(B)** DD314; **(C)** DD053; **(D)** DD254R; **(E)** DD238R, *Hector*; **(F)** DD023R.

In relation to the anomalously pigmented common dolphins, both individuals Leu_DD001 and Leu_DD002, according to the pictures taken, have dark eyes and light-grey coloration, which confirm them as real leucistic and not albino animals (Fertl & Rosel, 2009). Dorsal fins could not be compared between the pictures of the two individuals due to the angle of the photograph, which does not allow the dorsal fin of Leu_DD002 to be seen (Figure 3.11 D). The quality of the picture from the melanistic found on 23rd May 2019 (Mel_DD001) was not sufficient to be compared to the dorsal fin picture of the 9th June 2019 (Mel_DD002). However, we cannot exclude the possibility of melanistic and leucistic individuals here being the same individual, for each case, due to the proximity of the two sighting dates for melanistic and leucistic individuals (both sighted with an interval of 17 days), and the absence of clear characteristics to distinguish between them.

Although short-beaked common dolphins are found worldwide and in great abundance, there are few records of anomalous pigmentation for this species (Würsig *et al*., 2009). For leucistic common dolphins, different grey-sided individuals have been recorded in Mercury Bay and Hauraki Gulf, New Zealand (Neumann *et al*., 2002). All-black individuals (melanistic) are not as rare as anomalous lighter pigmented common dolphins and were reported in Cavalli Islands (New Zealand), San Francisco (United States), Baja California (Mexico) and in Les Moutiers en Retz in Bay of Biscay (France) (Perrin *et al*., 1995; Visser *et al*., 2004; Alves *et al*., 2017; Carwardine, 2019). In Portugal, Alves *et al*. (2017) had recorded both melanistic and leucistic common dolphins for Madeira archipelago. Leucistic and melanistic individuals off São Miguel were already recorded by Futurismo, for social media/online journal purposes (Whale Watching Azores, 2014; 2020). The present work is the first official record of anomalously pigmented common dolphins in Azores archipelago, for melanistic and leucistic conditions.

4.3. Individual association between common dolphins off São Miguel

Quite often, dolphins are resighted together in nature with the same individuals (Dudzinski & Ribic, 2017). In this study, only two individuals (DD115 and DD119) were sighted together three times. The other associations detected were re-sighted together only twice. Three individuals (A6: DD008, DD021, DD089) were resighted together after four years. The long time period between sightings of dolphins seen together can support the existence of long term and stable associations, or in other words, the existence of groups rather than random associations (Stanton & Mann, 2012; Dudzinski & Ribic, 2017). Other associations (A5, A7, A9), seen together after one year, also support the idea of alliance formation. Individual DD008, which had 11 years between first and last sighting, belongs to A6 (Table 3.1) and seems to continue with the same group, whose individuals were found together four years later. Groups can last from months to decades, reflecting group fidelity of some individuals (Karczmarski *et al*., 2005; Acevedo-Gutiérrez, 2008). In addition, the individual DD008 may have or may have not belonged to another group before the year of 2014, but only enough previous data could confirm that.

All associations, at some point, were found approximately at the same area (close to Ponta Delgada) and this can reflect on possible mixing between groups in the past and future sightings in this region, not necessarily in associations in this study. Occasional associations between different groups are seen in cetaceans, resulting e.g. in aggressive behaviors or even exchanging of individuals (Karczmarski *et al*. 2005). Individuals might change groups during their lifetime, with association with different individuals and immigrants/emigrants in each group in order to keep a healthy genetic diversity, as a fission-fusion social system, varying the group size number over time (Bruno *et al*., 2004; Dudzinski & Ribic, 2017). For individuals DD089 and DD115, seen in other associations, it does not necessarily mean they may be exchanging to other groups, but it is probable that new individuals could be exchanging to theirs or the other way around. On the other hand, there's a chance that individuals DD181 (found with DD089) and DD120R (found with DD115) simply could not be photographed on other occasions.

There is also a chance that these individual associations found close to Ponta Delgada can belong to the same large group, although we could only provide this information with further analysis. Cetacean grouping provides benefits related to foraging efficiency and reducing predation, blending small groups to form a larger one (Dudzinski & Ribic, 2017). Groups can also have costs for individuals due to intern competition, whether for food resources or for mating opportunities, which can result in split (Acevedo-Gutiérrez, 2008). The results given here are a first approach of associations of individuals and therefore are not enough for defining common dolphin groups in São Miguel. However, we provide the first evidence with analysed data to support the existence of long-term stable associations between common dolphin individuals around São Miguel. Further data would likely increase resighting numbers over time, reducing uncertainty when detecting the individual associations, and allowing defining the social structure of common dolphins around São Miguel.

4.4. Residency patterns of common dolphins in São Miguel

4.4.1. Time of permanence

A short time of permanence, as seen by 67% of individuals considered for this analysis that spent four weeks or less, can be related to migration for some individuals, e.g. the ones only passing by the island; or competition between groups, e.g. aggressive behaviors related to defense of their site fidelity (Karczmarski *et al*., 2005). A long time of permanence, seen by 33% of individuals that spent five weeks or more, suggests good ecological features and habitat type, as these are among the primary factors influencing dolphin behavior patterns (Campbell *et al*., 2002).

The opportunistic data and lack of photos of all individuals sighted daily interferes with these results. Not having pictures from a day does not necessarily mean that this dolphin was not present. The fact of going out on whale watching trips on consecutive days gives us good chances to collect more reliable information, even though at the sea it is almost impossible to take pictures of all dolphins, especially when groups are big and sea conditions not perfect. There are many possibilities to explain why we did not resight an individual. Perhaps he did not come back to the island, or he was there that day, with the same group, but no pictures of him were taken. Also, maybe there is a picture of it, but it has a bad quality or was taken from a distance so that he cannot be seen very well and thus was discarded from our photo-id analysis. Results given here are also a first insight of minimum time of permanence of common dolphins in São Miguel.

4.4.2. Residency of common dolphins in São Miguel

We agree with Silva *et al*. (2014) who have already confirmed that *D. delphis* is a resident species in the Azores, i.e., common dolphins are found year-round off the island; and with González García (2019) who confirmed this species as resident in São Miguel.

In this study, the lowest monthly SRs, and consequently low frequency of resightings, characterizes the group of transient common dolphins. They could be only passing by the archipelagos and therefore are considered non-residents, as the individuals seen once during the study period or the ones with low time of permanence (Zolman, 2002; Toth *et al*. 2010). The time of permanence of transients seen in only one season, may be influenced by different factors, e.g. inter and intraspecific competition and larger groups demanding more space and the need to range different and further areas to supply its needs (Acevedo Gutiérrez, 2008). For transients seen in two or three different seasons, food resources in this habitat could be relatively abundant, supporting dolphins year-round (Scott *et al*. 1990). Also, although transients in this study were resighted within a year, we may not exclude the possibility of them being classified as residents with future photo-id studies, especially the individuals seen in two or three seasons in a year. Moreover, some transients can be considered actually as SR or residents, although they were not sighted and thus we do not have resightings of them to confirm this, considering them as transients based on the current data.

Despite the low number of season-related (SR) residents in this study, many delphinids have seasonal migrations of thousands of kilometers, commonly reported in literature, such as in Florida, US (Mann, 1999; Balmer *et al*., 2008). The fact of dolphins regularly returning to the island in a certain time in consecutive years supports its classification, which happened to only 4 out of 12 season-related residents (DD023, DD114, DD120R, DD425).

Most of these seasonal residents were found in the summer, although it is the season when common dolphins in this study had the lowest monthly encounter rates. The higher number of SR individuals in summer is probably related to the higher number of trips made in this season and therefore, the high number of individuals identified in summer and photos taken in this season. However, there are records of common dolphins having more preference for the summer season (Constantine & Baker, 1997). This seasonal residence pattern is related to favorable environmental factors on a seasonal basis and previous studies in northeast of New Zealand (Bay of Plenty, Hauraki Gulf) and the east coast of United States (South Carolina and New Jersey) affirm that water temperature, and thus prey availability, seasonally change, and therefore dolphins' movements may follow these patches (Mann, 1999; Neumann, 2001; Neumann *et al*., 2002; Zolman, 2002; Toth *et al*., 2010).

Individuals DD008 and DD139, which presented the longest recaptures in this work (11 years), are considered residents of São Miguel island, specially DD008, which was resighted nine times over 11 years since it was first seen in 2008. Resident DD008, although resighted nine times in eleven years, presented a time of permanence of only four days in São Miguel. This record suggests that DD008 can be using the island for small periods in different seasons every year. This was also seen by Neumann & Orams (2005), where they suggest that these individuals have an annual cycle that makes them come back to the island for at least a few days every year, rather than staying in the area for extended periods. Also, the time of permanence of DD008 was the only one to be recorded twice, sighted on 21st and 24th January 2014 (four days) and on 19th and 20th September 2018 (two days). However, due to opportunistic limitations, there is a chance of DD008's permanence being longer, although we do not have more pictures to prove it.

Nevertheless, residency of some individuals in this study was not related to the high quantity of recapture numbers. There are individuals resighted only once and still are considered residents in São Miguel according to our definitions, e.g. DD180, DD234, DD300 and DD444. These dolphins present five and six years of difference between their first and last sighting. Therefore, analysis of longest recaptures of common dolphins using photo-id helped to support the residency of these individuals because of how many years later they were resighted in the island. It does not mean that they were not present on the island before, only that they were recorded again years later, leaving a large gap between sightings, as seen by Stevens (2014). Regardless, resident common dolphins that spent different seasons and years and therefore a great part of their lives in São Miguel reflect the island as a potential favorable habitat for *D. delphis*, whether for foraging or reproduction.

5. Conclusions

Short-beaked common dolphins *(D. delphis)* is the most sighted species in the archipelago and it is present year-round in São Miguel. It presents higher encounter rates in colder months (December to March), and lower ER from April to October. Calves were present year-round but with higher ER in summer, probably because of higher water temperatures and food availability during summer. Groups are larger in this season due to the new calves and immigrants from other groups. Generally, common dolphins are sighted mostly close to the island, probably to follow prey patches.

The obtained photo-identification catalogue for common dolphins of São Miguel include 1018 photos of HIIs, including 472 left side dorsal fins, 402 right dorsal fins and 72 individuals identified by both sides, which will be easily recognizable by other researchers in the Azores archipelago and abroad. The catalogue includes different nicks, notches, shapes, pigmentation patterns of fins and the first official record of anomalously pigmented common dolphins in the Azores archipelago.

Here we present the first evidence of resident individuals of common dolphins in São Miguel, with resighting intervals of up to 11 years of resightings. We classified 56 individuals as residents, occurring in different seasons and in more than two years. The minimum time of permanence for some of the individuals identified around the island was analysed, whether if they spend at least a week or almost two months around São Miguel, with an average of three weeks. Azores and thus São Miguel, is a privileged region compared to surrounding oceanic areas for having high concentration and retention of nutrients due to a varied bathymetry and its interaction with a dynamic oceanography. The complexity of habitats in the archipelago supplies resources to support common dolphins year-round, including resident and non-resident individuals.

Individual associations could be seen and used to check for stable or long-lasting social bonds between individuals sighted together years later. The associations were found closer to Ponta Delgada and we suggest that likely most of them might belong to a single larger group that splits and blends over time for foraging efficiency, for maximizing successful mating opportunities or enhancing survival within the group. Our findings suggest potential preliminary associations and groups, baseline information for further studies to properly identify different groups and analyse social structure of common dolphins around São Miguel.

Data used in this study were collected over twelve years of whale watching trips conducted by Futurismo. We acknowledge that the use of opportunistic data has several limitations which can influence our results, although many of them agree with previous studies assessing common dolphins. However, opportunistic data collection using whale watching still is the most affordable way of collecting as much useful information about cetaceans as possible at sea, on a long term basis and with a regular cover, becoming essential information to better understand ecology and distribution of cetacean species. Information given here will provide important baseline data to support further studies, including residency and spatio-temporal patterns, tracking individuals based on photo-identification. In fact, using this study and our catalogue as a reference may encourage more research on this species in the Azores archipelago.

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Appendix

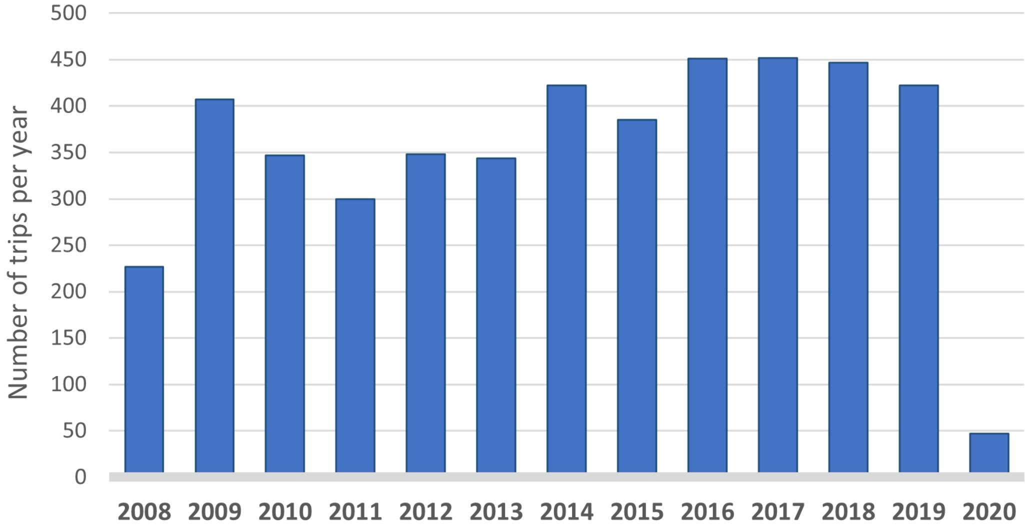

Figure 1A. Number of trips carried by Futurismo from 2008 to 2020.

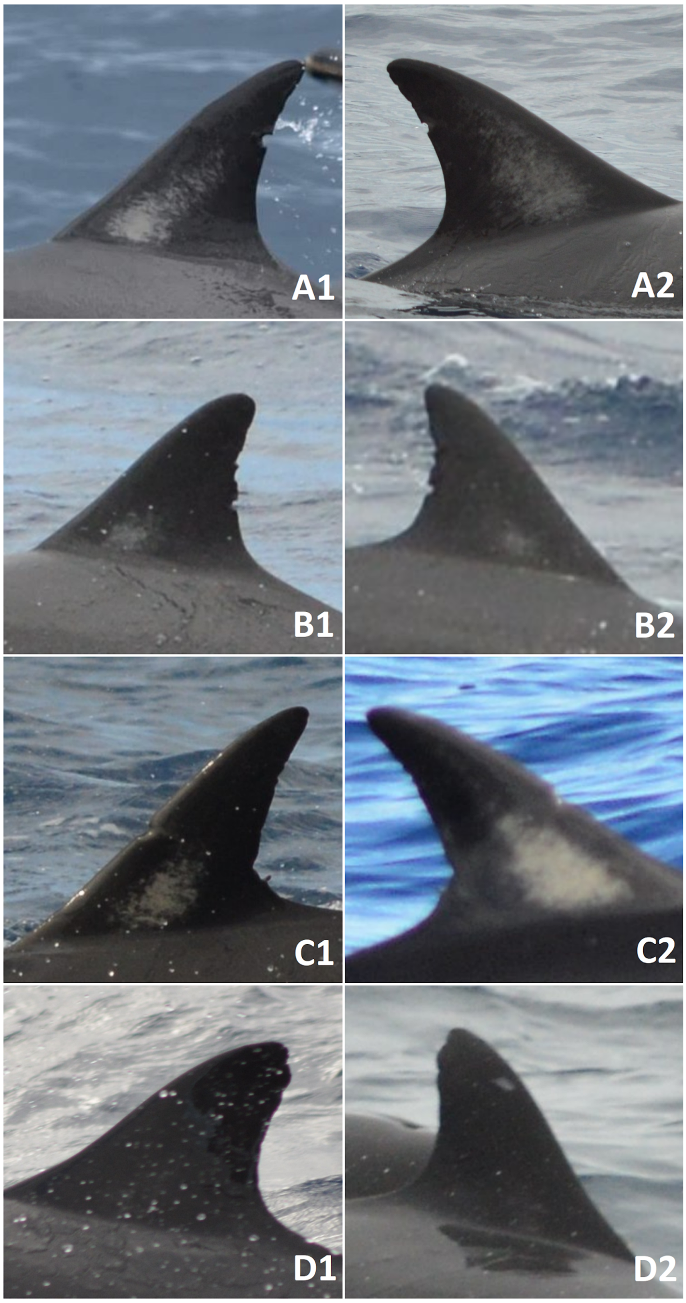

Figure 2A. Example of individuals that could only find a match by comparing right and left sides in the catalogue. (A) DD234; **(B)** DD350; **(C)** DD474; **(D)** DD353.

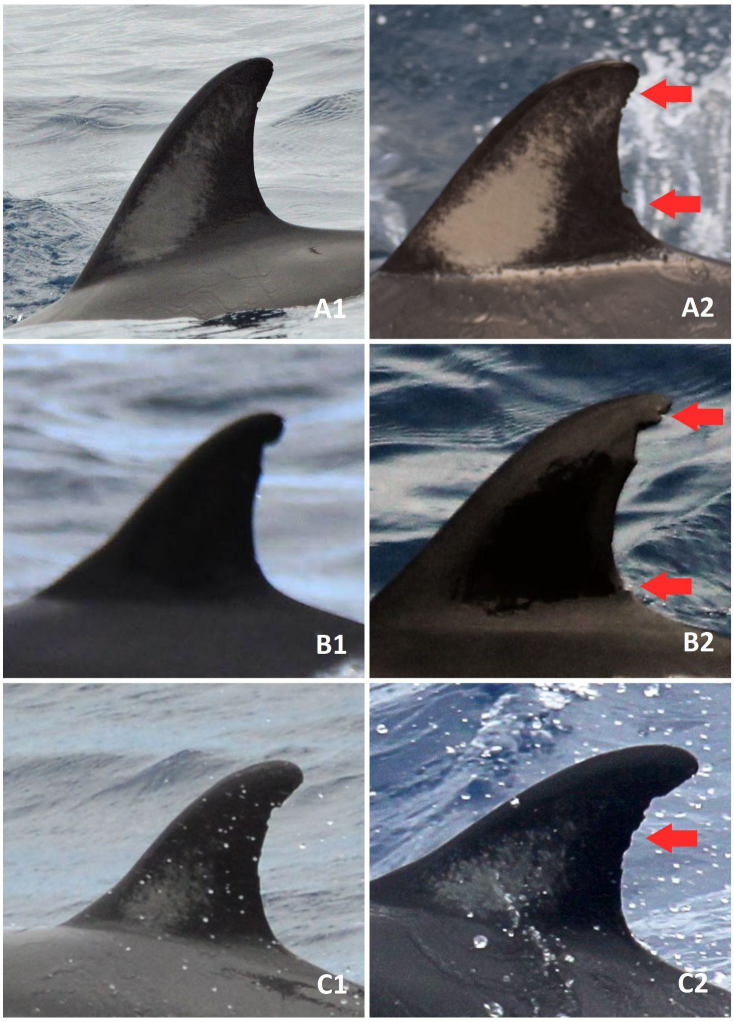

Figure 3A. New marks found in recaptures over the years. (A) DD160, 1) 17th August 2014, 2) 10th January 2020. **(B) DD004**, 1) 8th April 2014, 2) 22nd June 2018. **(C) DD120**, 1) 22nd August 2014, 2) 20th June 2019.

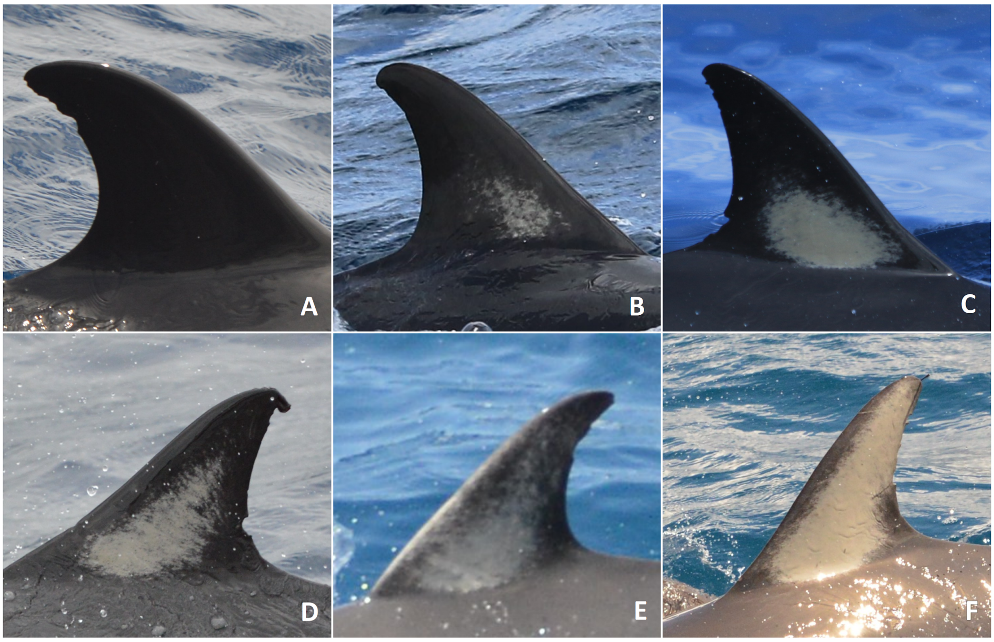

Figure 4A. Variations of fin coloration found from different individuals in the catalogue. (A) DD360R; **(B)** DD067R; **(C)** DD075; **(D)** DD423; **(E)** DD431; **(F)** DD001.