Use of MONICET data to observe the relation between sea water temperature and arrival and departure of *Stenella frontalis* (Cetacea, Delphinidae) in the Azores

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Summary

In order to understand the habitat of any species, it is important to understand the patterns of spatial and temporal distribution, and this paper presents a study on the temporal and spatial distribution of the Atlantic spotted dolphin, *Stenella frontalis*, associated with temperature parameters. This is intended to find changes in patterns of presence and abundance, based on a record of sighting patterns on the islands during the last 10 years from Whale-watching vessels. It should be noted that, during this time period, the average annual temperature has increased by more than one degree Celsius, starting in 2009 with an average annual temperature of 18.42ºC and reaching an average annual temperature of 19.8ºC in 2018. The whale-watching data from the MONICET platform were used to carry out this analysis, and it can thus be observed that this dolphin is distributed between small to large groups.

Introduction

The painted dolphin, spotted dolphin or Atlantic spotted dolphin (*Stenella frontalis*), belongs to the order Cetacea, suborder Odontoceti, family Delphinidae, subfamily Delphininae (Perrin, 2002), genus *Stenella*, containing 5 species (Perrin, 2002). This cetacean species was identified by G. Cuvier in 1829 (Perrin, 2002). This species was chosen because it has a seasonal distribution pattern (warmer months) but regular in the archipelago (Silva et al., 2013), mainly related to water temperature, since it can be seen to a greater or lesser extent every summer month.

General characteristics

The Atlantic spotted dolphin is a small, moderately slender dolphin, approximately 1.7 to 2.3 meters in length and with a life expectancy of 30 to 40 years. In addition, this dolphin varies in size and degree of spotting according to the geographic area in which it lives and its age, having a gray to bluish-gray base, with a strongly dark back, but lighter flanks to end in a white belly.

Distribution

S. frontalis is endemic to the tropical and warm-temperate Atlantic (Fig. 1; Perrin, 2002), from 45ºN to 35ºS in the west and on the coast of Africa from Mauritania to the south to at least Gabon in the east. It is common in the western North Atlantic and in the Gulf of Mexico and may also be common along the tropical Atlantic coast of Africa (Perrin, 2002).

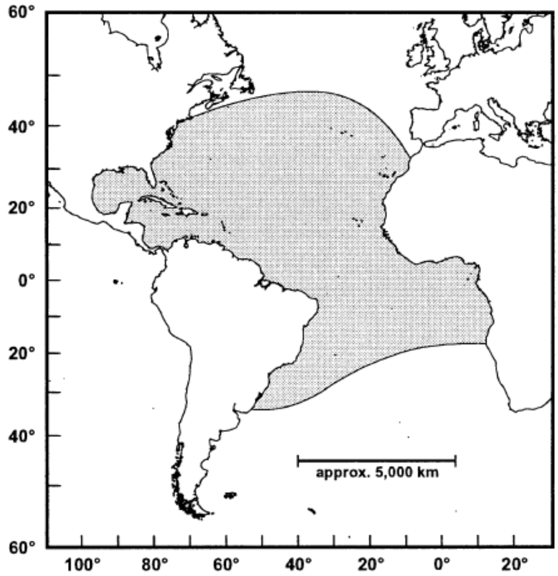

Figure 1: *Distribution of Stenella frontalis (Perrin, 2002).*

Ontogeny and reproduction

Newborns are born with a size of about 90-110 cm and have a skin "free" of spots. Dark ventral spots begin to appear approximately at weaning (2-3 years of age) (Perrin, 2002). As sexual maturity approaches, they increase in number and size, and light dorsal spots begin to appear. At the age of 3-4 years old, these dolphins enter the juvenile phase. In this phase, the characteristic spots (mainly discrete ventral spots and some light dorsal spots) of this species begin to appear. From the age of 8 or 9, the development of the spots accelerates, and some begin to fuse. In the adult phase, which begins with an approximate age of 16 years, the dark and light spots extend and join on the ventral and dorsal surfaces. (Fig.2).
The degree of development of spotting varies individually and geographically, being higher in animals of the continental coast (Perrin, 2002).

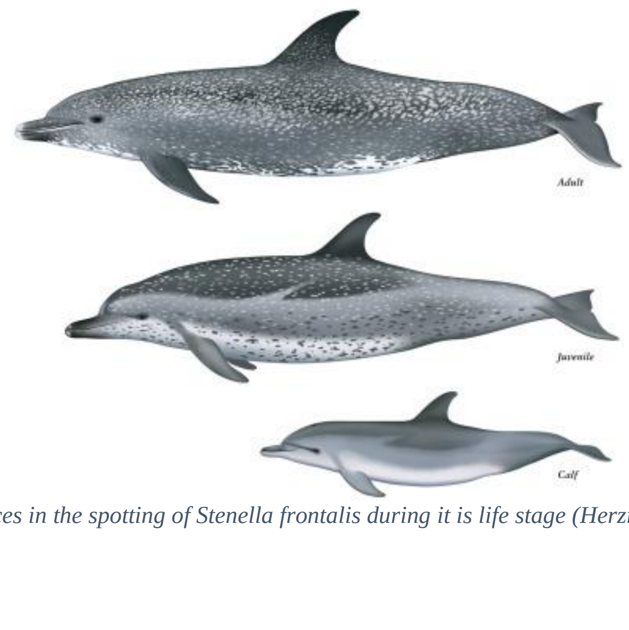

Figure 2: *Differences in the spotting of Stenella frontalis during it is life stage (Herzing & Perrin, 2018).*

Ecology

According to Benoit-Bird & McManus (2012) this dolphin is at the 4th level of the food chain. Its best-known prey includes squid, fish (including flatfish and clupeoids), crabs and hemiramphids and benthic invertebrates (holoturians), as well as possible nocturnal feeding of flying fish (Exocoetidae) (Perrin, 2002).
In the Azores, feeding aggregations with flocks of shearwaters (*Puffinus gravis* and *Calonectris diomedea*) occurred. Atlantic spotted dolphins gathered the small clupeid fish into a dense ball in a coordinated manner before feeding on them (Perrin, 2002).
Among its predators, sharks and Orcas (*Orcinus orca*) can be highlighted. In addition, they can also be attacked by different endoparasites. Another problem affecting these dolphins are contaminants in high concentrations such as polychlorinated biphenyls (PCBs) (Lavandier et al., 2019), dichloro-diphenyl-trichloryl-ethanes (DDT), chlordanes and isomers of hexachlorobenzene and hexachlorocyclohexane (Méndez-Fernandez et al., 2018). We can also highlight the acoustic pollution produced by ships which, although we do not have direct information on how it can specifically affect *S. frontalis*, could cause short or long term problems in its nature (Simmonds et al. 2014). Therefore, it is very important, as demand for this activity increases, to ensure that the whales and dolphins that are sought daily in the Azores during this process are not inadvertently harmed (Perrin, 2002).

Behavior

These animals are extremely intelligent and tend to have strong social bonds, although segregation often occurs by age and sex, forming groups of up to 60-100 individuals. Atlantic spotted dolphins frequently exchange rubbings with congeners of the same sex and age. Tactile and vocal signals may be concurrent. The association between mother and calf is very close during the first 3 years of the calf's life with other females in the same age class. Also, pregnant females form associations that last up to at least 2 years with females which had not had a previous relationship and who have given birth in the same year. There are also strong bonds between males. Finally, Atlantic spotted dolphins can socialize with humans (Perrin, 2002).
In spite of being a sociable species, it has been demonstrated that they cannot live in captivity and the data are not very encouraging, as they can try to take their own lives, for example, by stopping feeding (Perrin, 2002).

State of conservation

Atlantic spotted dolphins are captured in a small-scale subsistence fishery. They may be accidentally caught in purse seines, gillnets and shark driftnets (Perrin, 2002).
Currently, the Atlantic spotted dolphin, is an animal that is included in the Red List and observing the different categories where the animals are included, this dolphin is in the LC category (Least Concern).

Objectives

According to Fernandez & Azevedo (2019), Atlantic spotted dolphins are observed in the Azores between June and December, with the highest sighting rates around August, when the water is warmer. Therefore, between January and May there are no sightings, as the water is too cold. They are usually seen in large groups of up to several hundred. The objective is to observe why *S. frontalis* are only the hot months (summer) and not the cold months (winter).

Materials and methods

Area of study

The area selected to carry out the study of the species of *S. frontalis* has been the archipelago of the Azores (volcanic islands), in the middle of the North Atlantic Ocean. These islands are characterized by being under the permanent influence of the Azores anticyclone, providing a sustained Ekman transport that facilitates convergence in regional oceanography. Most sightings occur on the island of São Miguel, belonging to the eastern group of the archipelago (characterized by westward propagation whirlpools that move away from the Azores Current). In addition, sighting data have also been used, but to a lesser extent, from Faial, Pico and Terceira, belonging to the central group of islands of this archipelago (characterized by the entry of meanders and filaments from the Gulf Stream) (Caldeira & Reis, 2017).
The specific location where the study has been carried out is between 36º00'N at 40º00'N and 24º00'W at 32º00'W (Figure 3).

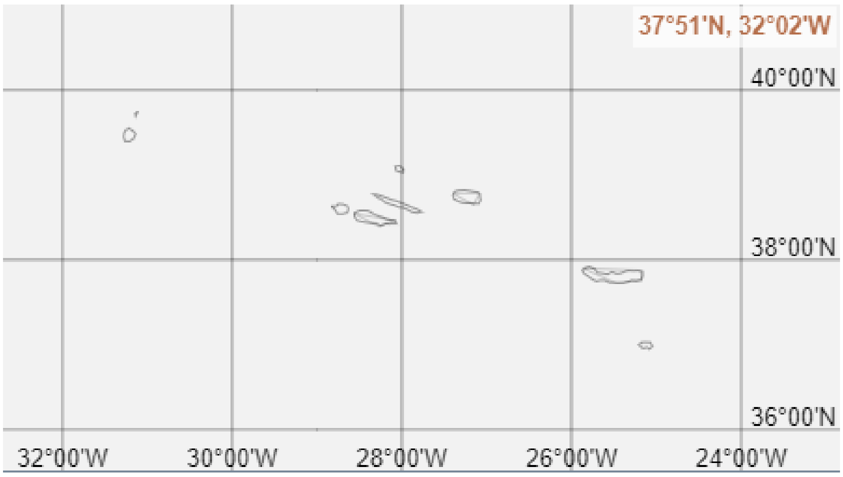

Figure 2: *Location of the Azores archipelago with it is exact coordinates. Place of publication: ("Giovanni", 2019).*

Data collection

In order to carry out this study, the data collected by the MONICET platform(Fernandez & Azevedo, 2019) were used. This platform collects the data thanks to the fact that it is linked to the Whale-watching tourism companies in the Azores Archipelago. As this study focuses on one species of dolphin, data on *S. frontalis* were filtered and collected from this platform.

These companies generally carry out contactless observation activities, so that their clients can observe cetaceans in their natural environment. In addition, these companies related to the MONICET platform collect the data in a standardized format for the subsequent creation of a table with samples of different parameters that can be divided into four fields:

- Information about the company (boats, lessor, guide...).
- Atmospheric information (sea state, visibility).
- Effort data (time and GPS location).
- Overview of the sighting (species, general behaviour, number of individuals...).

The method used by these companies for the location of cetaceans consists of the work of various surveillance posts distributed along the coast of the islands (mainly in the south of these), which warn and inform the approximate location of ships in the area.
Therefore, this study uses a non-random method of direct observation of a primary source, as sightings are not entirely incidental, but are intentionally sought.
This method of study can lead to a distorted representation of reality, for several reasons. The main reason is detectability, since some of these species can be detected more easily than other species of cetaceans (usually dolphins are easier to observe than whales). Another reason that may lead to misrepresentation is the difference in sampling distribution or an error in methodology due to the limited duration of cetacean sighting expenses. Finally, such distortion may be due to human error and misinterpretation by the workers of these sighting companies (Fernandez, 2018).
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Moreover, there was an inconvenience in recording or not the RA variable (sudden sighting). Because RA can represent data between IA (beginning of the sighting) and FA (end of the sighting). In this case, it should not be taken into account when carrying out the analysis. However, if RA represents a sighting that occurs between FA and F (end of journey), it should be taken into account. With such a large number of data provided, the detection of the RA variable that should be accounted for becomes very costly. Therefore, a generalized study of this variable was made throughout the years provided, reaching the conclusion that in most of the RA cases it is represented as in the second case. Finally, all those data in which there is an AI or AR of *S. frontalis* were considered.

Data Processing

With the data obtained from the MONICET platform on the species to be studied (*S. frontalis*), 3 analyses have been carried out.
In the first place, marine surface temperature (SST) estimates were analysed (values), in order to know with which values *S. frontalis* individuals begin to appear in the waters of

the archipelago (these data were obtained from the GIOVANNI online environment, giovani.gsfc.nasa.gov) and later, work was carried out with Excel and Panoply to extract the different temperature values. These data were then compared with the available bibliography and it was verified whether these data obtained from MONICET match. For this purpose, the first and last month in which there are more than five sightings were compared with their respective mean temperatures. Finally, an average of these temperatures was calculated, and an average arrival and departure temperature was obtained.

Secondly, an analysis was made based on the comparison of the percentage of departures in which there were positive sightings of *S. frontalis*. For this purpose, only months with more than 20 trips were taken into account, in order to eliminate variations due to sample size. In addition, the average temperature calculated in the previous section was used and with the help of Excel the graphs presented in the results section were made.

Finally, an examination of the count of the number of individuals in each sighting and whether there is any annual or interannual pattern in the size of the groups was carried out. In principle, an attempt was made to perform this section with the mean and the standard deviation, but it was observed that the error was too large so, since there were many data, program R was used to perform calculations with the median and quartiles 1 and 3.

Results

Arrival and departure temperature

In the first analysis, temperature data and data on the arrival and departure of individuals to the archipelago were analysed. Several tables were created for this purpose. On the one hand, table 1 represents the average temperature corresponding to the first month of the year in which there have been more than 5 sightings and it can be seen that they usually appear over the months of June and July and with an average temperature of 20.66ºC. On the other hand, table 2 represents the average temperature corresponding to the last month of the year in which there have been more than 5 sightings, where you can see that they usually disappear over the months of September, October and November and an average temperature of 20.92 º C.

It can also be observed that the variations in the average temperatures of each month of arrival and departure are very large and, therefore, no specific result can be obtained from this.

Table 1: *Average temperature corresponding to the first month of the year in which there have been more than 5 sightings of Stenella frontalis.*

Year	First months with more than 5 sightings	Average temperature (ºC)
2009	6	18.7
2010	7	22.4
2011	6	19.8
2012	6	19.4
2013	6	19.6
2014	6	20
2015	7	22.9
2016	7	22.5
2017	6	19.9
2018	6	21.3
Average	6.3	20.7

Table 2: *Average temperature corresponding to the last month of the year in which there have been more than 5 sightings of Stenella frontalis.*

Year	Last months with more than 5 sightings	Average temperature (ºC)
2009	10	16.3
2010	11	19.3
2011	10	21.6
2012	10	20.6
2013	11	19.2
2014	9	22.1
2015	10	20.2
2016	9	23.2
2017	10	22.7
2018	9	24.2
Average	9.9	20.9

Relationship between temperature and the appearance of Stenella frontalis

For the second analysis, the mean ocean surface temperature was compared with the appearance of *S. frontalis*.

Figure 4 shows that the temperature distribution over the ten years (2009-2018) in their respective months, where the convergences represent the cold months with temperatures ranging from 15-17ºC approximately, while the divergences represent the warm months with temperatures ranging from 22-25ºC approximately. In addition, a trend line can be seen that tends to increase over the years, which is very important, since this increase in ocean temperature is due to the increase in the average temperature of the Earth.

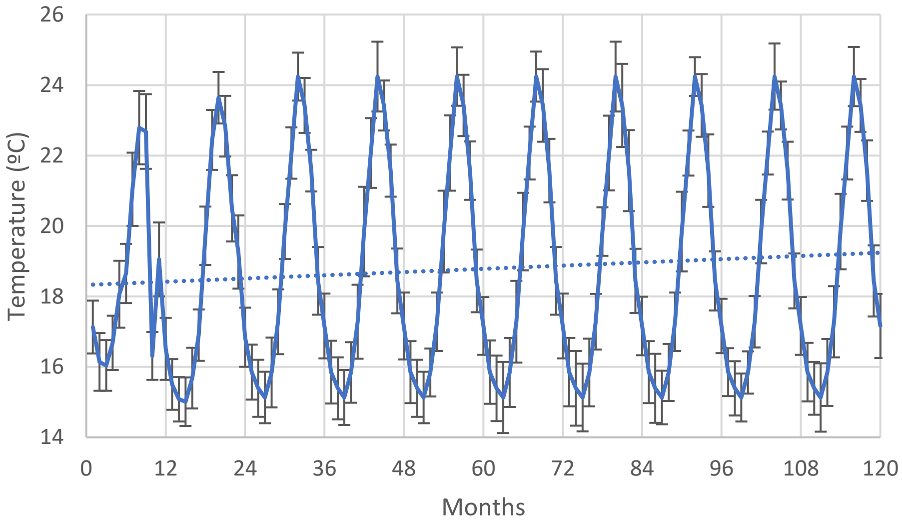

Figure 3: *Average monthly temperature from 2009 to 2018, from left to right. The x-axis numbers represent the cumulative months from January 2009 to December 2018.*

After the analysis of the temperature data and the study of the sightings of *S. frontalis*, it was possible to create figure 5, which represents the percentage of sightings of these dolphins, and it can be observed that they begin to be more frequent during the months of June-July, when the temperature of the water surface is around 20.66ºC (although there are exceptions, since they have been observed in cold months, but on a very small scale). On the other hand, it can be noted that the peak usually occurs in August mainly, as the temperature is around 22-24 º C (although there are exceptions such as, for example, 2012 when the month that had more sightings was July and not August).
As of this month, sightings of this dolphin usually begin to decrease, being the last month October mainly (there are exceptions since there have been years in which these dolphins have left the archipelago in September or November). The disappearance of this species of dolphin is due to the fact that the temperature of the water surface begins to decrease with the minimum average temperature of the last month being 20.92ºC.

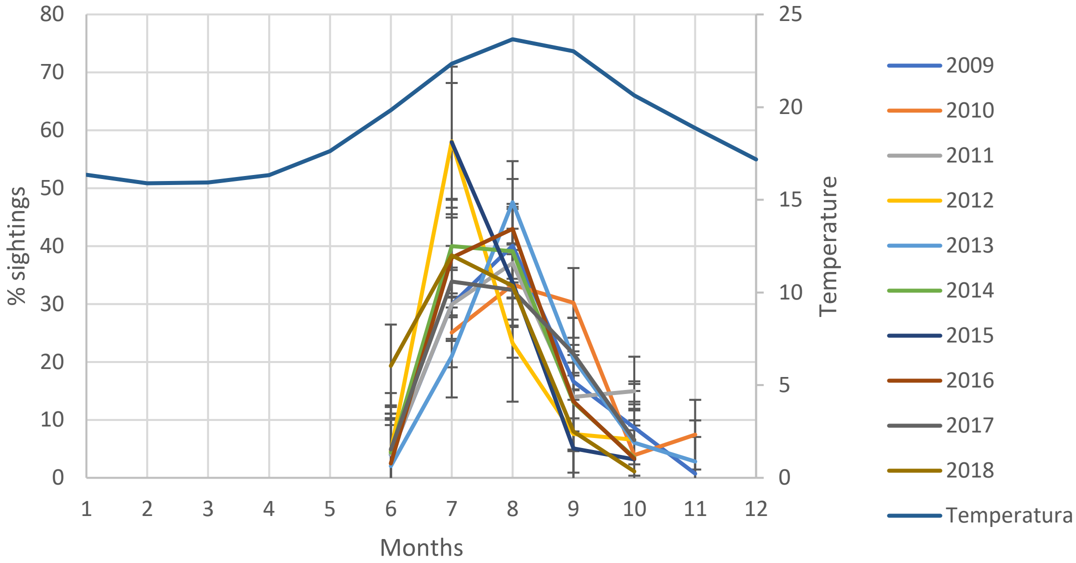

Figure 4: *Graph of the percentage of positive sightings of Stenella frontalis from 2009 to 2018.*

Next, figure 6 can be observed, which represents the percentage of dolphin sightings, but instead of being divided by years as in figure 5, in this figure the months have accumulated from January 2009 to December 2018. You can observe a variation between 30 and 60 % of the sightings are *S. frontalis*. In addition, it has a trend line that tends to increase

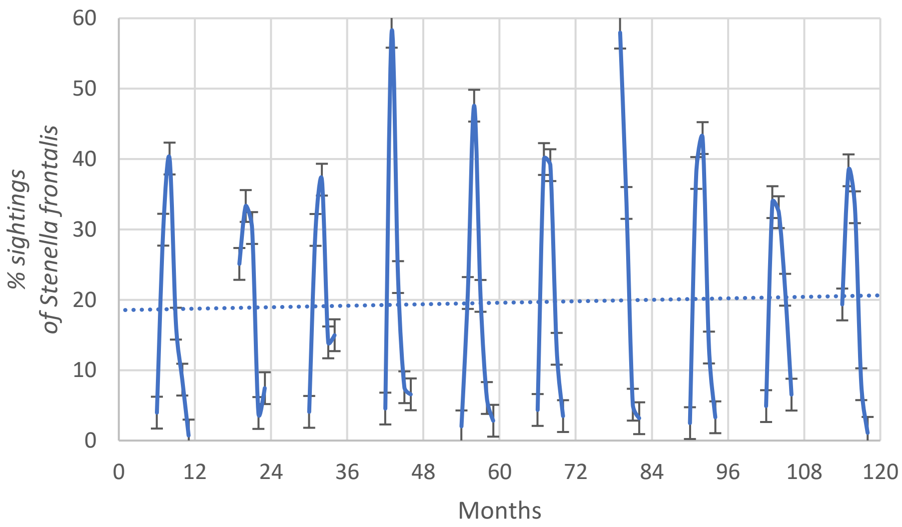

Figure 5: *Graph of the percentage of positive sightings of Stenella frontalis from 2009 to 2018 (from left to right). The numbers on the x-axis coincide with the cumulative months since January 2009.*

Therefore, after the study of the previous two graphs, the percentage of sightings with respect to temperature was studied, in order to thoroughly observe if the percentage of these sightings increases or decreases with the said temperature.
Thus, if we observe figure 7 at temperatures below 20ºC, the percentage of sightings is very low, while, if we analyse temperatures above 20ºC, we observe a quite significant increase in the percentage of sightings. In addition, it can be seen that the growth that follows this graph is exponential.

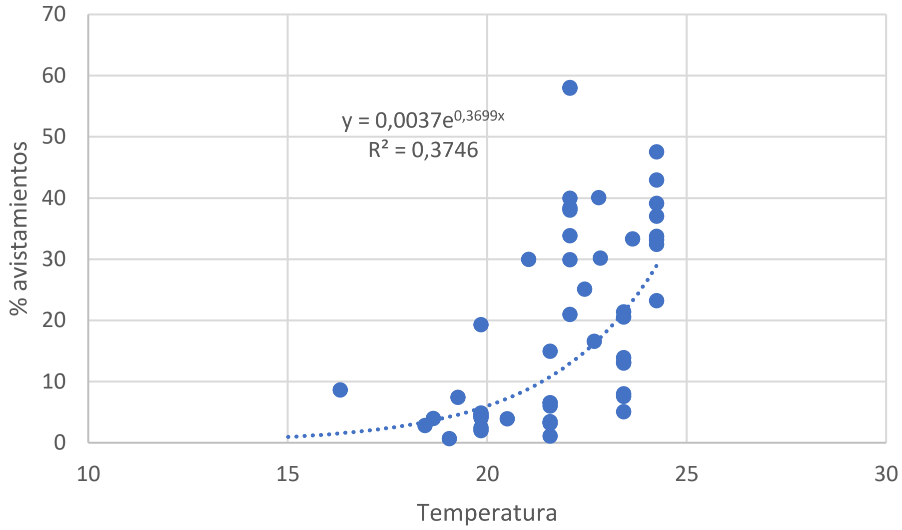

Figure 6: *Percentage of sighting compared to temperature.*

Group size

For the third analysis, we compared the size of the groups that form these dolphins throughout the different months. For this purpose, the data were not separated by different years as in the previous analysis, but rather joined together.

Thus, this study attempted to make the average and standard deviation for each month with respect to the 10 years (2009-2018). But it was observed that both the positive and negative error was too big and, therefore, they could not be reliable data. Therefore, to calculate figure 8, the median and the different quartiles were used (to calculate the positive error, the median was subtracted from the quantum 3 and to calculate the negative error, quartile 1 was subtracted from the median).

In figure 8 it can be seen, as we mentioned before, that these dolphins appear in June approximately and usually leave the area in November approximately. In addition, a straight line of increasing trend can be observed, so that in June the sizes of the groups are smaller, with an approximate size of 45 individuals, while in November the sizes of the groups are larger, with an approximate size of 100 individuals.

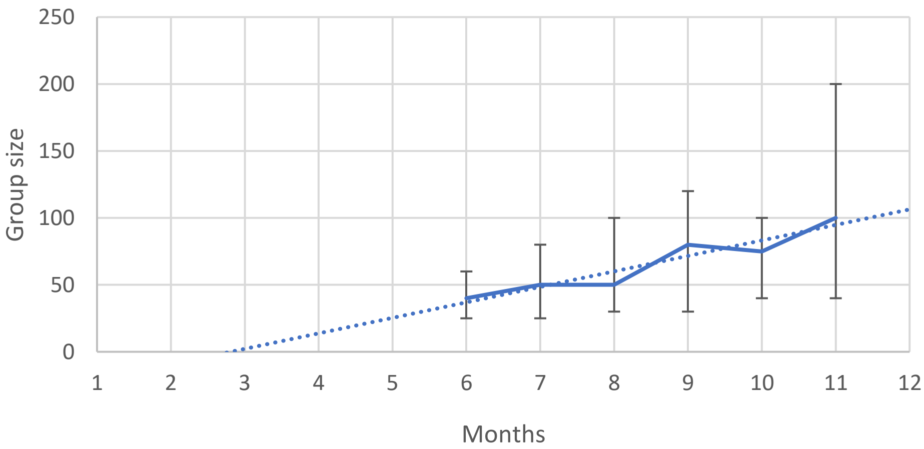

Figure 7: *Size of groups from 2009 to 2018 compared to months.*

Discussion

Temperature

From the results obtained, an increase in sea surface temperature of approximately 1-1.5ºC can be observed over the 10 years. Spatial variations in sea surface temperature are mainly studied under the greenhouse gas emissions scenario (Xie et al., 2010), however, there is evidence as to the cause of this temperature increase, as the main problem is anthropogenic (IPCC, 2018).
Therefore, the atmospheric concentration of carbon dioxide (CO_2) has been steadily increasing since the Industrial Revolution and will continue to increase in the coming years (Xie et al., 2010). Increasing concentrations of CO_2 and other greenhouse gases (there is general agreement that the radioactive effect of increasing atmospheric concentrations of these gases will cause an increase in the Earth's temperature (Cane et al., 1997) are considered to be the main cause of this increase in surface temperature caused mainly during the twentieth century and it is predicted that the pace of globalization will accelerate (Xie et al., 2010), producing changes that affect the climate as a whole.
For this reason, the seasonal trends and variability obtained from observations of inorganic carbon in the ocean have been extensively studied.
During these studies, hydrographic properties have been taken into account, which are characterized by seasonal oscillations in their values of surface temperature and salinity. Therefore, annual cycles are driven by seasonal changes in surface temperature and wind. For this reason, in winter the convective mixtures reduce the surface temperature, increasing its density (Santana-Casiano et al. 2007).
With the increase in surface temperature and the reduced effect of trade winds, a thermal stratification appeared (between April and October), producing a variation in the depth of the mixed layer (Santana-Casiano et al. 2007). González-Dávila et al. 2003 demonstrated that this winter confluence gave rise to a nutrient pump over the euphotic zone, favouring the appearance of phytoplankton. In addition, it could be seen that, during the summer thermal stratification, there was no contribution of nutrients within the euphotic zone. On the other hand, during the winter, an increase in nitrate and phosphate concentrations was observed, producing a maximum of chlorophyll at depth (Santana-Casiano et al. 2007).
The experimental pHT data obtained corroborate the acidification of the surface waters of the Atlantic Ocean, with an interannual decrease of 0.0017 ± 0.0004 pH units per year^{-1}. This variability is related to temperature variability. For this reason, the lowest values occurred during winter convective mixing, and increased during summer thermal stratification. This decrease in sea surface water pH is closely related to the increase in CO_2 pressure (Santana-Casiano et al. 2007).
In addition, it can be commented that the dissolved organic carbon of the surface layers also had a seasonal variability giving the lowest values in the winter months and the highest values in the summer months. Therefore, this seasonal variability of dissolved organic carbon is related to the variability of pH and alkalinity. In this sense, the decrease in pH per year corresponds to an increase in CT (Santana-Casiano et al. 2007).
Therefore, two different environments were observed after contemplating surface temperature and salinity anomalies. First, cold water periods reflect changes in vertical mixing and/or water body characteristics due to changes in water circulation. This seems

to be related to seasonal changes in the position of the subtropical gyre, also associated with the phenomenology of climatic variability (Santana-Casiano et al. 2007).
Then, during the characteristics of the first environment (cold water periods), a deeper mixed layer could be observed that could explain the relationship observed by González-Dávila et al. 2003, where nitrate concentrations in the winter mixed layer and chlorophyll a concentrations are very high if compared with the values of the years in which the mixed layer was shallow. These results show that a deeper vertical mix (figure 9), with higher concentrations of nutrients going to the higher layers during winter anomalies may explain the high chlorophyll concentrations due to higher primary production rates (Santana-Casiano et al. 2007).

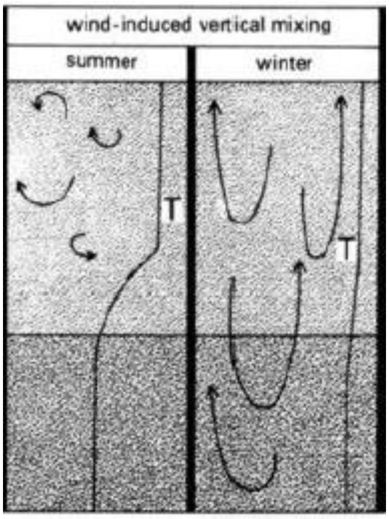

Figure 8: Vertical mixture induced by wind and thermocline (T) during summer and winter climates (Meadows & Campbell, 1988).

Food chain

It can also be observed that these dolphins tend to leave the archipelago with an average temperature of 19-20ºC. But in recent years, they are leaving with an average temperature between 22-24ºC, so it has been considered that the temperature does not directly affect the dolphin, as was originally thought (they needed warm water to live properly in that water) but indirectly, as this can affect an increase in primary producers (if there is a supply of nutrients), through the stratification of the water column.
Therefore, a study conducted during a spring upwelling of phytoplankton in the North Atlantic showed that the timing of the spring upwelling varied from year to year. Similarly, the timing and duration of the outcrop peak varied from year to year. The highest concentrations of chlorophyll a were measured from February to April (Figure 9, Visser et al. 2011). The lowest concentrations of chlorophyll a were measured in the period between June and October, when the minimum annual levels of chlorophyll a ranged from 0.07 to 0.1 mg m-3. The product-moment correlation of Pearson chlorophyll to weekly versus SST: $r = -0.73$, $n = 135$, $p < 0.0001$), indicating that these waters have a strong stratified surface and depleted in nutrients throughout the summer and early fall (Visser et al. 2011).

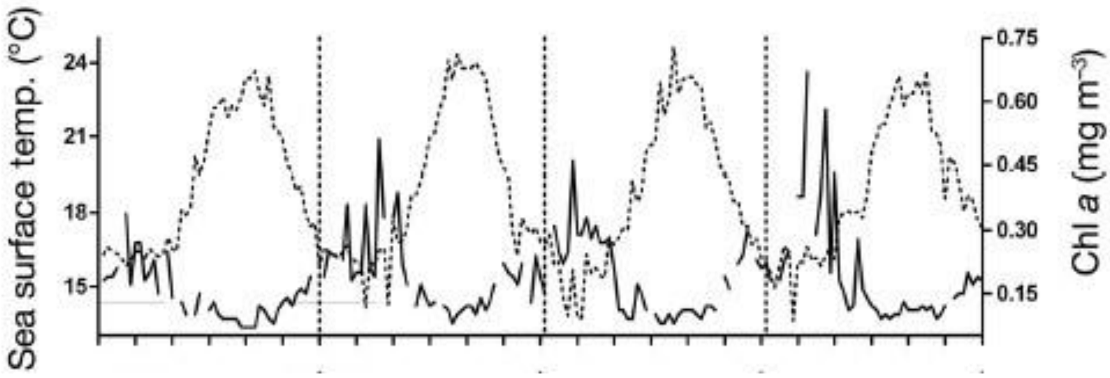

Figure 9: Temporal variation in TSM (discontinuous line) and concentration of chlorophyll to (solid line) (Visser et al. 2011).

Since not enough information was found on trophic chains involving *S. frontalis*, information was collected on a dolphin of the same genus (*Stenella longirostris*) to make a small comparison and know how it could interact in the respective trophic chain.
Therefore, using an analysis of trophic dynamics, it was found that the frequency and intensity of the spatial changes of the aggregations in each of them of a food chain in which phytoplankton, copepods, mesopelagic micronecton and dolphins are involved were the most important for predicting the variation in the adjacent trophic chain (Benoit-Bird & McManus, 2012). Organism patches had disproportionate impacts on the biomass of organisms within them. The results represent resource limitation, mediated by the regulatory structure of patch dynamics in each trophic step of this ecosystem, as well as the foraging behavior of the top predator. Due to its high degree of heterogeneity, ecosystem-level effects of such an irregularity may be common in many pelagic marine systems (Benoit-Bird & McManus, 2012).
In habitats where experimental manipulation of trophic levels is not possible, positive correlations in standing biomass to consumers and resources are used as evidence for regulation of the food web by limiting food (McQueen et al. 1986 fide Benoit-Bird & McManus, 2012). Positive correlations between aggregations at adjacent levels in this pelagic food web support the control of organisms at each step of their feeding, or a bottom-up force domain in this ecosystem, however, only if irregularity is considered (Benoit-Bird & McManus, 2012). Similar analyses in which the biomass of organisms was used, the approach taken to examine the forcing of trophic relationships showed that the biomasses of organisms at adjacent trophic levels were consistently weaker correlated with the aggregations of organisms, and in some cases correlated negatively (Benoit-Bird & McManus, 2012).
The abundance of dolphins at the study site and their aggregation behavior can be predicted based on phytoplankton aggregation characteristics that provide an estimate of the total strength of the bottom-up effect, due to the consistent positive correlations at each stage of the food chain (Benoit-Bird & McManus, 2012). While phytoplankton biomass correlated negatively with dolphin abundance, as well as with aggregation intensity, it predicted only 34% and 42% of variability. Respectively, the abundance of phytoplankton layers correlated positively with both dolphin abundance and aggregation intensity, explaining 54% and 57% of their variability, respectively (Benoit-Bird & McManus, 2012).
It was noted that top-down effects increasingly explained variability in consumer aggregations at higher and higher trophic levels. This contrast with previous studies suggests that resource limitation should have the greatest effects at the bottom of the food chain, while predator control should have the greatest influence near the top of the food

chain (Benoit-Bird & McManus, 2012). The difference can be explained by the different effects of consumers and resources in open pelagic systems that are fully connected to the surrounding environment of those that can approach steady-state balances, particularly when considering shorter time scales than consumers' reproductive scales (Benoit-Bird & McManus, 2012).
The increasingly strong correlations we see with movement in the food chain are likely to be associated with a parallel increase in the mobility of organisms (Benoit-Bird & McManus, 2012), allowing closer coupling between consumers and their prey through larger scale movements to find and better use food resources. Behavioural responses may also explain why it was observed that the strength and frequency of resource aggregations rather than their absolute biomass are strongly correlated with the consumer, as foraging success is more strongly related to local prey density than to total prey abundance (Benoit-Bird & McManus, 2012).
Our data show that organism aggregations can have disproportionate effects on the biomass of organisms in them, revealing the role that patch dynamics can play in regulating processes in a food web. In this system, irregularity increased the relative importance of resource limitation at all trophic levels. The ecosystem-level effects of such a dispersal may be more common in pelagic marine systems, where both the habitat and the organisms living in it show great spatial and temporal heterogeneity on a range of scales (Benoit-Bird & McManus, 2012), and there is great potential for both passive and active consumer movement in relation to resource distribution. Recent evidence shows that food heterogeneity is critical to the survival and recruitment of predators in the marine environment when food availability is low (Benoit-Bird & McManus, 2012) and therefore special attention should be paid to irregularity when investigating resource limitations.
Quantification of the processes that control the abundance of organisms in marine systems is necessary to assess ecosystem resilience, understand the ecological impacts of fishing, effective management of exploited species, and predict and mitigate the impacts of climate change (Benoit-Bird & McManus, 2012).

Group size

An increase in group size has been observed over the months in which they are seen in the Azores. Therefore, in the months that they begin to appear, the size of the groups is smaller than the groups that tend to leave in the months between September and November. As previously happened with the dolphin *S. frontalis,* there is very little information, so data has been collected on different types of cetaceans to make a small comparison and know how it could influence the dolphin studied, although such data would not be completely reliable, since it must be borne in mind that not much research has been done on the subject and therefore these investigations are still rare.
Therefore, the different investigations on the variability of the size of the group of different dolphins used intraspecific comparisons. For this purpose, the variables of the physical environment, diet and life history of the species were considered in the analysis. Also, it is important to consider intraspecific variation in social systems because such flexibility requires behavioral mechanisms from which the observed variety emerges in an interaction of behavioral mechanisms with the environment during ontogenetic development (Gygax, 2002).

Different intraspecific studies have found that larger groups use less energy during prey captures, assist in detection and defense against predators, and assist in the defense of territory, females, or food resources. However, larger groups face a higher level of competition for food, are easier for their predators to perceive, and need more time in social communication to maintain cohesion within the group (Gygax, 2002).

In order to understand well the dependence of group size with reference to ecological parameters, they were separated into several sections as discussed above.

First, group size was related to susceptibility to predators. Where it could be assumed that group size correlates negatively with animal size and positively with habitat openness (small animals and animals in open water are more vulnerable to predators) (Gygax, 2002).

Second, group size was related to diet, making this study complicated. For this reason, food-related variables are difficult to interpret without a more detailed knowledge of the behavioural strategies used in prey capture and prey distribution and their predator avoidance strategies (Gygax, 2002).

In addition, it can also be highlighted that these mammals, which are highly social, after the effects of different environmental disasters (human or natural) such as alterations in behaviour, death of individuals, emigration, immigration and changes in the abundance and distribution of food and demographic changes, can damage and disturb social structures (Elliser & Herzing, 2013).

Therefore, it is difficult to know what relationship our dolphin has to make the groupings it makes, since, in the study of different cetaceans, no group of species seems to have the same dependence on the size of the group. It is therefore surprising that species show group size dependence on many variables at the same time or on almost no variables at all, and it is obvious that group size seems to depend on different sets of variables in each species (Gygax, 2002).

As this is the case and considering the different results, we must say that, with only the MONICET and SST data, it is difficult to carry out an exact study, since there are deficiencies in some branches explained during the work, such as, for example, trophic chains and the reason why the groupings are greater in the months when they leave archipelago. For this reason, it would be necessary to look for a different methodology or to look for more data on other parameters that can be related and used for *S. frontalis*. In addition, the temperature data used are the averages of each month during the 10 years' work, so we should try to reduce that time to days or hours to reduce the error that could be deduced from those operations.

For future research, it would be convenient to investigate more about this species of dolphin, since, at present, there is very little information about it and during the research it has been necessary to establish a constant relationship with other dolphins of the same genus and even with dolphins of other genera. In addition, studies could be carried out on primary producers and chlorophyll in the archipelago and study the trophic chain of this dolphin to see if this is because it comes to the archipelago in summer or because it needs high temperatures to live without high levels of stress. It could also be observed if the trophic chain is dominated in a bottom-up or top-down way. Also, finally, it would be possible to study the size of the groups in a more structured way (for in the MONICET data, these numbers are reflected), since, knowing these data, it would be possible to know exactly if they reproduce in the area or congregate in the vicinity of the islands for food or something else.

Conclusions

We can affirm that temperature affects the distribution of the Atlantic dolphin detained in the Azores. This species appears in these islands when the water exceeds 20ºC approximately and comes out when the temperature returns to that average temperature. Although the temperature influences its presence since it is only found in summer, it is believed that it does not affect it directly, but indirectly. Given that this increase in temperature produces a stratification of the water that, after a great contribution of nutrients, is trapped, generating a growth of the primary producers, which through a bottom-up effect, produces an increase in the zooplankton and this makes the fish and dolphins increase respectively (this is not immediate, but it takes a while to observe this growth), due to an increase in food for each level of the trophic chain.

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Memoria del final de Trabajo de Final de Título

Actividades desarrolladas durante la realización del TFT:

- Búsqueda bibliográfica a través de Scopus, Faro, y Google Scholar.
- Obtención de datos de temperaturas a través Giovanni.
- Procesamiento de datos a través de Excel, Excel Xlsx, R y Panoply. Análisis de datos: elaboración de tablas dinámicas, análisis estadísticos e interpretación de resultados.
- Escritura de una memoria y presentación en inglés.

Formación recibida

- Procedimiento a seguir para entender los datos de MONICET de la zona de estudio.
- Uso de Excel, Excel Xlsx, R y Panoply para el análisis de datos.
- Escritura de una memoria y presentación en inglés.

Nivel de integración e implicación dentro del departamento y relaciones con el personal

La relación con el profesor José Manuel Viegas de Oliveira Neto Azevedo ha sido de lo más positiva posible. Llegué al profesor gracias a que me había comentado en una clase impartida por él que si quería trabajar con cetáceos tenía que acudir a él, y así hice. Este profesor me ayudó a desarrollar toda la tesis (desde cómo entender los datos, herramientas para tratar los datos, escribir la memoria, etc), por lo que les estoy muy agradecido.

Aspectos positivos y negativos más significativos relacionados con el desarrollo del TFT

La parte más positiva del TFT ha sido que por primera vez me he visto centrado en un proyecto serio que yo mismo he desarrollado, y a pesar de los múltiples imprevistos, al ser un trabajo que me interesa y me agrada, no se me ha hecho muy pesado dedicarle su tiempo cada día. Después de haber leído tantos artículos relacionados sobre los cetáceos, y los pocos estudios que hay sobre ellos, hace que me interese más y quiera seguir estudiándolos.

Como aspectos negativos del TFT, tengo que confesar que el estar cada día trabajando sobre el mismo tema no ha sido fácil. Aunque me gustaba lo que estaba haciendo, había momentos en los que me bloqueaba, y estancaba 2 o 3 días con lo mismo sin avanzar. Por suerte, siempre podía recurrir a mis tutores, de los cuales nunca me faltó nada.

Valoración personal del aprendizaje conseguido a lo largo del TFT

En mi opinión, el TFT me ha enseñado como realizar y escribir correctamente un artículo científico, siendo muy importante para conocer como trabajaría un científico, sobre todo después de haber realizado el Grado de Ciencias del Mar. Además, mis conocimientos sobre mi tema, desarrollado durante el TFT, han aumentado abriendo una puerta para futuros estudios y un posible camino profesional.