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Seasonal occurrence and abundance estimation of sei (Balaenoptera borealis) and other cetacean species in Golfo San Jorge (Chubut Province, Argentina) to be regarded as a new whale watching site in Patagonia.

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ABSTRACT

In the past few years, different whale species have been increasingly observed in Golfo San Jorge. In Chubut province, Argentina, the occurrence of these whales and dolphins may attract the local community's attention as a potential resource for tourism-related activities, since the region has a long history of whale watching targeting the southern right whale (*Eubalaena australis*). To assess the viability of the site as a future whale-watching operation site systematic visual surveys have been conducted from September 2019 to October 2022. The observations were made from the top of a 160 m high cliff to assess the species' seasonal occurrence and relative abundance, following a scan method with the aid of a spotting scope. A total of total of 481 scans were performed in which both large whales and dolphins were spotted, including 1502 were sei whales (*Balaenoptera borealis*), 51 humpback whales (*Megaptera novaeangliae*) and 51 southern right whales (*Eubalaena australis*). Only one fin whale (*Balaenoptera physalus*) and two sperm whales (*Physeter macrocephalus*) were spotted during the scans. Regarding dolphins, the dusky dolphin (*Lagenorhynchus obscurus*) was the most common accounting for 114 individuals, followed by Risso's dolphins (*Grampus griseus*) with 92 and Commerson's (*Cephalorhynchus commersonii*) dolphins with 35. Also, two killer whales (*Orcinus orca*) and one Peale's dolphin (*Lagenorhynchus australis*) were sighted.

The Sighting per Unit Effort indicates that during the summer and autumn months the frequency of sei whale sightings increases. Sei whales were spotted while feeding on squat lobster, being one of the main observed behavioural states accounting for 30% of the observations. The main behavioural state recorded for humpback and southern right whale was socializing. In the case of dolphins also the Commerson's and dusky dolphins spend a fair amount of time feeding, while Risso's also spend time socializating. To obtain estimates of abundance of sei whales using the Distance method, transects were made on board a two engine aircraft surveying 427 kilometres in the central area of the gulf. Two flights were made, one in the low season (December 2021) and other in the high season (May 2022). During the low season 796 (CI 95% 232-2727) sei whales were estimated in a 5000km2 area. For May, this figure was estimated in 2777 (CI 95% 1809-4262). Golfo San Jorge could be regarded as a previously unreported feeding summer ground for the endangered sei whales. The continuation of this study will provide a better understanding of the habitat use and the factors that

influence seasonal patterns of rorquals in the area and generate baseline knowledge to contribute to the conservation and assist in developing management actions.

KEYWORDS: *Balaenoptera borealis*; SOUTH ATLANTIC; SEASONAL ABUNDANCE

INTRODUCTION

Golfo San Jorge is an area where in recent years the number of cetaceans, mainly of rorquals have significantly increased (Iñíguez et al., 2010; Páez et al., 2017; Páez, Riera, & Coscarella, 2018; Retana & Lewis, 2017; Reyes, 2006).

Every year rorquals can be observed close to the shore, and the little data available seems to indicate that whales are more abundant during the austral autumn. Little is known of the different species of rorquals in the Southwestern South Atlantic, except for the humpback whale (*Megaptera novaeangliae*). The humpback whale population of the WSA it breeds in the Brazilian coast, from Natal (41°S) to Cabo Frio (23°S), while the feeding grounds are off South Georgia and South Sandwich Islands have increased in the last decades (Bortolotto, Kolesnikovas, Freire, & Simões-Lopes, 2016). Another species that has shown evidence of an expansion is the sei whale (*Balaenoptera borealis*) although a few population estimates is available for the Southwestern Atlantic. In 2021 Weir et al. estimated for sei whales and unidentified baleen whales combined, the equivalent estimates were 916 animals (CV = 0.19; 95% CI [606,1,384].

Despite the observations of the increase in the sightings of rorquals along the Argentinian coast, no systematic surveys have been conducted to assess seasonal distribution and abundance for these species. The steady increase of rorqual sightings may in the future be regarded as a potential resource to perform whale watching activities. This is highly probably due to the long history on whale watching activities carried out in Chubut province for the last 40 years targeting southern right whales (Chalcobsky, Crespo, & Coscarella, 2017). For proper implementation and regulation of these activities, a better understanding of their seasonal patterns, behaviour and habitat use is needed.

MATERIALS AND METHODS

Study Area

The study was carried out in the coastal region of Punta Marqués, in the south of the province of Chubut (Figure 1).

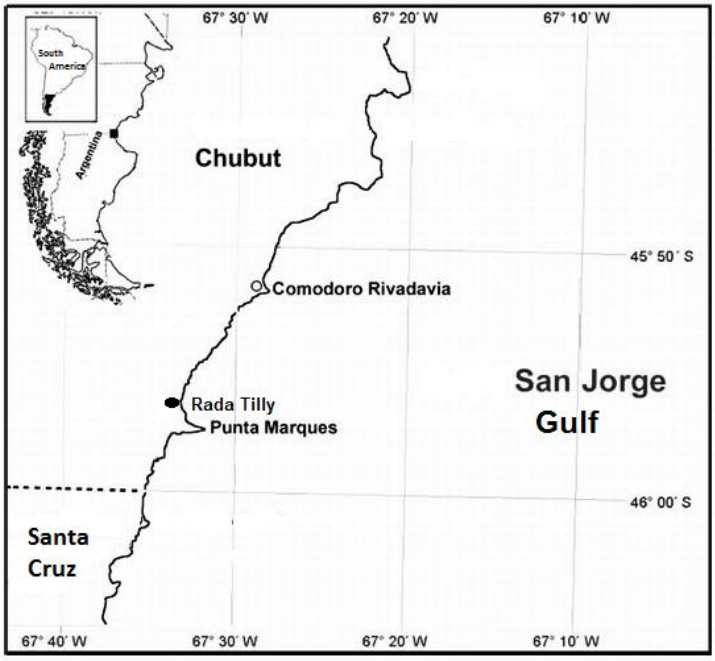

Figure 1. Punta Marques, Chubut province.

Relative abundance, seasonality and behaviour of cetaceans from a vantage point

Daily land-based observations were conducted from September 2019 to February 2022. The observations were made from the top of a 160 m high cliff that goes 2 km into the sea (45°57'32.7"S; 67°32'6.5"W). Fieldwork was conducted only when the environmental conditions (low wind intensity, sea state Beaufort ≤ 3) were appropriate for visual surveys. The area was scanned for whales using an instant group scan as described by Lehner 1998 and with the aid of a Celestron – Ultima 100–zoom 22-66x100mm. Two scans a day were performed, one during the morning and one during the afternoon. Each sighting was defined as an independent event and groups were defined as individuals swimming close to each other, within a 100 m of each other performing similar behaviour. For each group whales, swimming direction, behaviour, group size and bearing were recorded. Also, as ancillary information Beaufort state and wind direction were recorded and observations regarding the presence of whales no registered during the scan. In some scans, species determination of the rorquals was not conclusive. Nevertheless, they are likely to be sei whales, as the notes on the side of the data sheet register sei whales outside the scans. Also, as an independent way to confirm the species a UAV was flown over the closest whales and in every single case, they were sei whales. A similar situation was reported for the Malvinas/Falkland island, where all large rorquals sighted off the transect line were later identified as sei whales (Baines & Weir, 2020; Weir, Taylor, Jelbes, Stanworth, & Hammond, 2021). Again, reinforcing the fact that most indetermined rorquals were sei whales the mean group size presented no significant differences between both groups (t test, p=0.71) and hence all indetermined rorquals were assigned to sei whales.

A relative abundance index defined as sighting per unit effort (SPUE) was calculated for cliff-top surveys (Mariano Alberto Coscarella, Dans, Garaffo, & Crespo, 2012). SPUE was measured

as number of scans with whales/dolphins over the total number of scans. For comparison purposes, SPEU for the different species was calculated for each month as:

$$SPUE_i = \frac{N^{\underline{o}}\ of\ animals\ of\ species_i\ in\ month_j}{N^{\underline{o}}\ of\ scans\ in\ month_j}$$

Abundance estimation from aerial surveys

The data were obtained using population sampling through linear transects applied to animals that are observed in groups. The design of the survey was done using Distance Software (v.7.1) in order to get the maximum area coverage (Thomas et al., 2010). The area was determined using accessory information on sightings of whales along the coast of Golfo San Jorge (data not shown). The final flight design was a zig-zag with variable angles; this design minimizes the travel time between transects and minimizes fuel consumption (Schiavini, Pedraza, Crespo, González, & Dans, 1999). The method assumes that all animals will be observed in the transect line (under the plane the probability of detection g (0) = 1) and less far from it. To estimate the density of animals in the area, it is necessary to adjust detection functions, incorporating covariates (if necessary) that allow for better adjustment and reduce the coefficient of variation of the estimates (Buckland et al., 2001)

The density of the whales was estimated using the standard methods of distance sampling applied to groups of animals (Buckland et al., 2001). The data was analysed using the DISTANCE (v.7.1) (Thomas et al., 2010). Essentially, Then, the density is estimated using the following equation:

$$D = \frac{n * Es}{2l * ESW}$$

where n is the number of sightings, l is the total search effort and Es is the average group size and EWS is the estimate of the effective strip width that the program calculates from adjusting the detection function to the distribution of perpendicular distances to the sighted group of whales. This estimate does not include animals that are not observed in a blind strip on each side under the plane because the plane windows of the aircraft do not allow the detection of animals at angles closer to the transect line. Data were left truncated at 80m including the blind strip on each side permit the detection of animals at angles closer to the transect line.

The aircraft used was a Twin Otter belonging to the Argentine Air Force (Fig. 2). Flights were carried out considering the information gathered from cliffs in two times in the year: one in a putative low abundance season (November 2001) and a high abundance season (May 2022) (M. A. Coscarella & Riera, 2022). Flights were performed at a steady altitude of 500 f and speed of 90 ktns. Data gathered included species, number of whales/dolphins comprising the group, angle, and behavioral state whenever possible. Distribution maps were generated using QGIS 2.8.1. (QGIS Development Team 2016) in order to identify high density areas.

Figure 2: Aircraft used during the aerial surveys with the crew and observers.

RESULTS

Seasonal variation and relative abundance

A total of total of 481 scans were performed in which both large whales and dolphins were spotted, including 1502 were sei whales (*Balaenoptera borealis)*, 51 humpback whales (*Megaptera novaeangliae*) and 51 southern right whales (*Eubalaena australis*). The mean size of the group was 1.99 (SD=1.55) individuals for the sei whale with a maximum of 15 individuals in the same group; 1.15 (SD= 0.37) individuals for humpback whales with the larger group comprising only 2 individuals, and 1.88 (SD= 0.89) for southern right whales with a maximum of 4 individuals per group. Only one fin whale (*Balaenoptera physalus*) and two sperm whales (*Physeter macrocephalus*) were spotted during the scans. Regarding dolphins, the dusky dolphin (*Lagenorhynchus obscurus*) was the most common accounting for 114 individuals, followed by Risso's dolphins with 92 and Commerson's dolphins with 35. The size of the groups was respectively 14.25 (SD=11.59), 7.66 (SD=4.62) and 3.18 (SD=1.78). Also, two killer whales (*Orcinus orca*) and one Peale's dolphin (*Lagenorhynchus australis*) were sighted. Additionally, 344 dolphins were recorded but no specific determination was possible. The number of scans performed each month is shown in Figure 2.

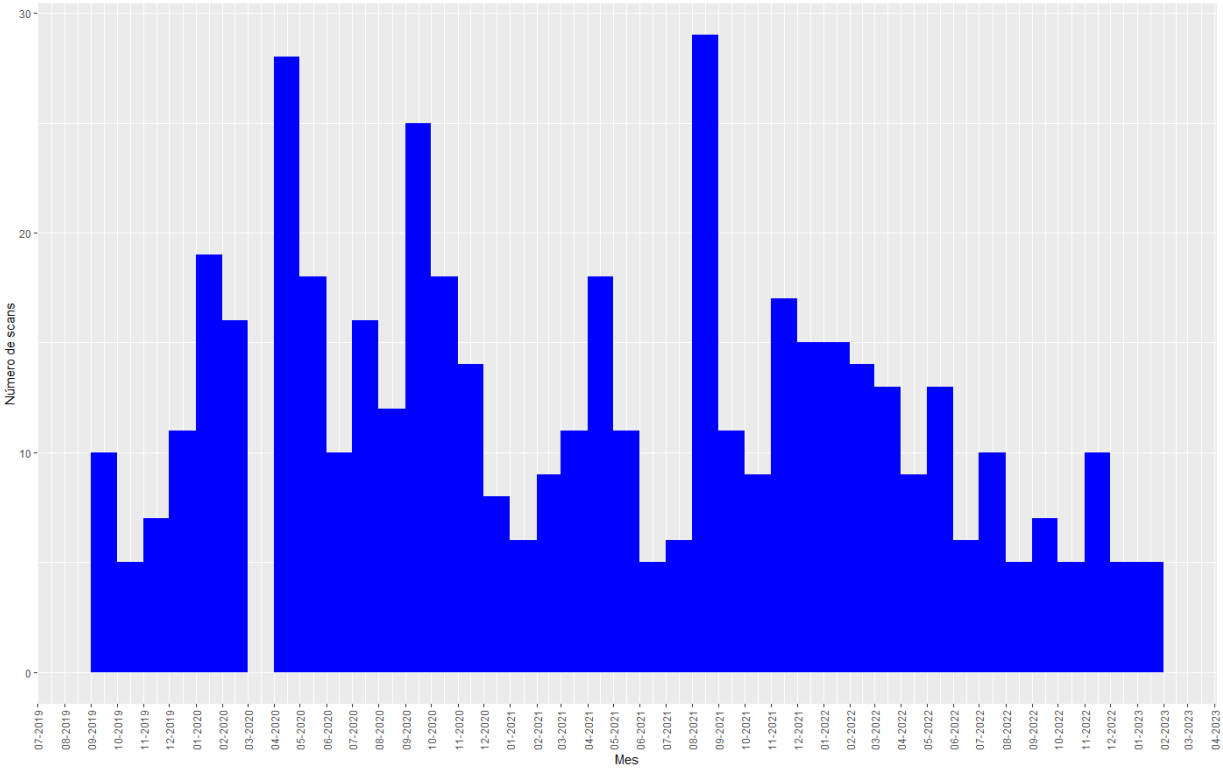

Figure 2. Number of scans (effort) by month.

Rorquals were present most of the year, except for August 2020 and 2021 and only humpback whales were sighted but in low numbers (Figure 3). Southern right whales are present from August to October, when rorquals seems to be at their lowest.

The SPUE increased every year in early autumn for the sei whales. During 2022 sampling season there is a peak of almost 20 sei whales/scan, which is extremely high. Nevertheless, between 2 to 10 sei whales are sighted on each scan, with counts as high as 54 individuals, and naked eye counts reaching up to 70. These figures are an order of magnitude higher than any other whale in the area. Sei whales present a yearly cycle with the lowest SPUE from July until December. From December and on, there is an increase in the relative abundance in the area, reaching its peak between April and June each year, although the SPUE varies from one season to the next. Southern right whales are in the area from July until September each year, but in low numbers. Humpback whales are present most of the years from February until September. Regarding fin whales, their presence in the area is exceptional, and only one individual was spotted. Nevertheless, there are records of this species in the area, both from the cliff-top (but not during a scan) and from boats, from January until March.

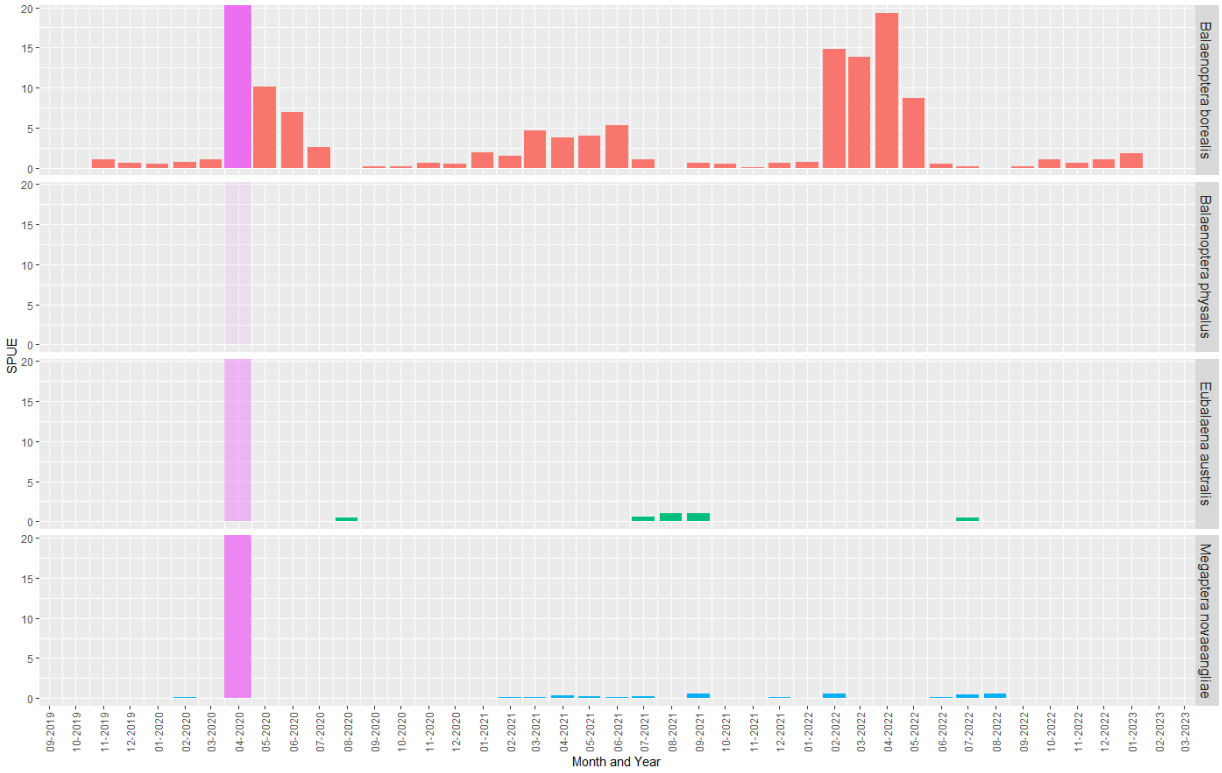

Figure 3. Sighting per Unit Effort from scans performed at Punta del Marqués, Chubut for the most common Mysticety species. The line in pink is the month of the shut down because of the pandemic COVID 19, when no scans were performed.

Regarding dolphin's species, they are common throughout the year. Commerson's and Risson's dolphins are present in the area more frequently during the summer months, conforming groups of 3.18 (SD= 1.77) and 7.66 (SD= 4.61) individuals respectively. The third most common specie is the dusky dolphin, that is not seen in the area as frequently as the former ones, and two out of the three times they were spotted was during summer. Nevertheless, the group size is much larger, with an average of 14.25 (SD=11.99) individuals per group. Many groups of dolphins were sighted from the vantage point, but their species identity could not be recorded, and hence they are shown as "Unknown dolphin" in Figure 4. Our records indicate that dolphins are present in the area, and they also include Peale's dolphins and large pods of bottlenose dolphins with calves (with several positive identifications aided by Unmanned Aerial Vehicles, data not shown).

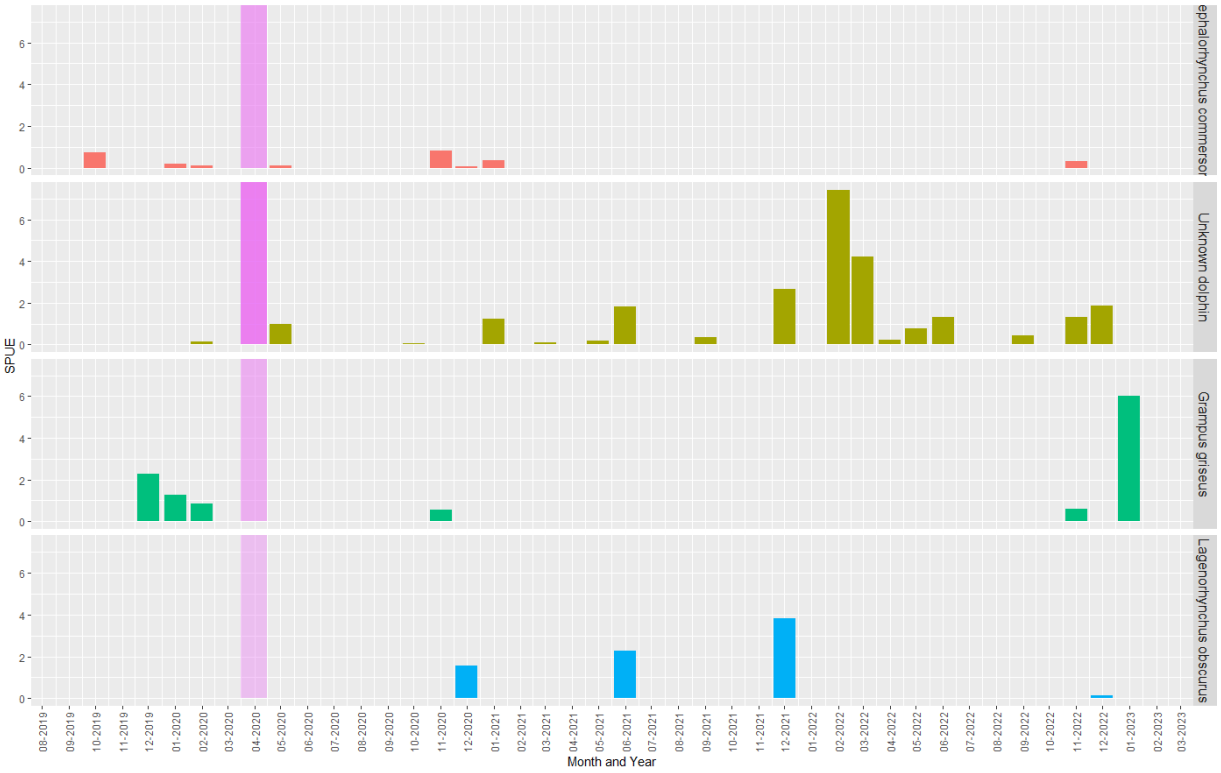

Figure 4. Sighting per Unit Effort from scans performed at Punta del Marqués, Chubut for the most common odontocetes species. The line in pink is the month of the shut down because of the pandemic COVID 19, when no scans were performed.

Behavior

The behaviour of the baleen whales is shown in Figure 4. For every species, Travelling refers more to the fact that whales or dolphins were moving from one point to the other in the survey area, rather than travelling and just passing though. Both the humpback and the sei whale are in the area feeding or searching for food. Also, the humpback whale shows social behaviours in the area, mainly recording tail and fin slaps and jumps. Contrary, sei whales are less prone to socialize and almost 25% of the recorded behaviours are related to different feeding techniques. In the case of the southern right whale the recorded behaviours are related socialization, mainly associated to reproductive activity. Southern right whales were socializing in mating groups or just travelling; no feeding events were recorded. The only fin whale spotted was travelling.

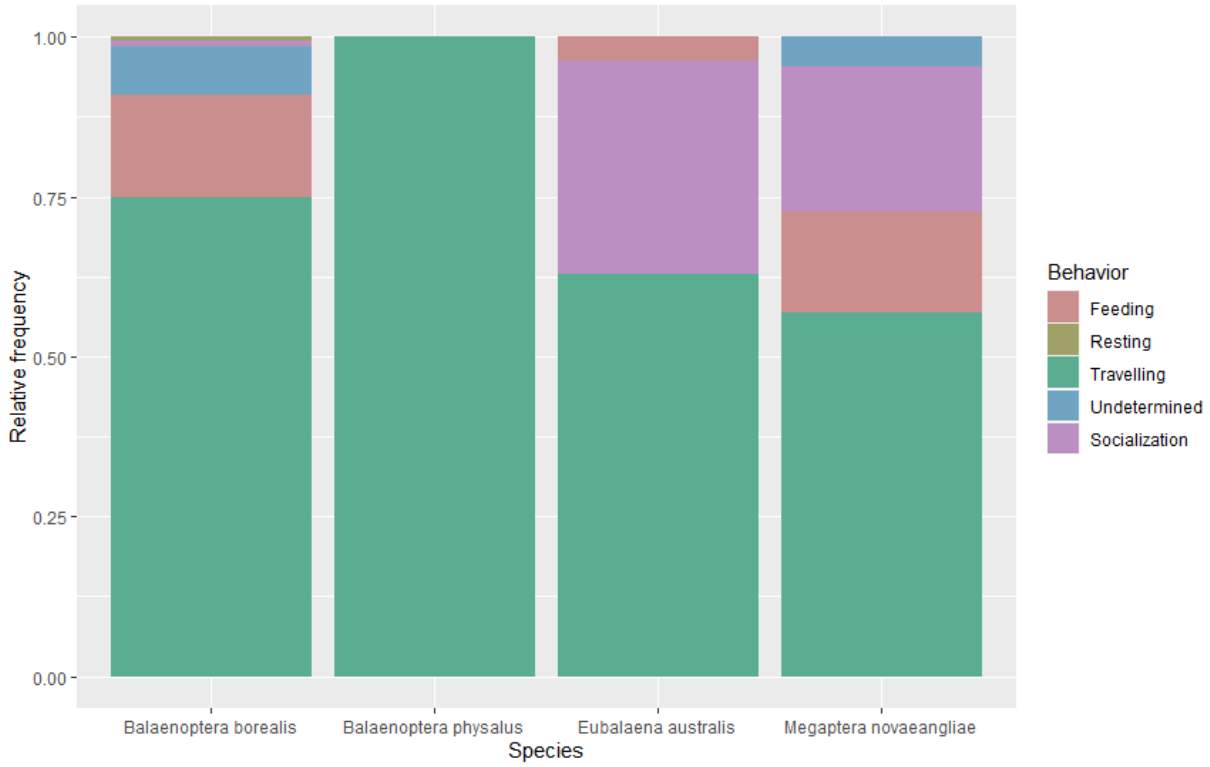

Figure 4. Behaviours performed by Mysticety at Punta Marqués, Chubut.

The recorded behavioural states were *Travelling* and *Feeding* for the sei whales. In the case of the sei whales this can reflect the importance of the area as a not previously reported feeding ground in this Patagonian coastal area. It is quite common to observe this species feeding on squat lobster swarms (*Munida grereria*) or (probably) copepods (Figure. 5).

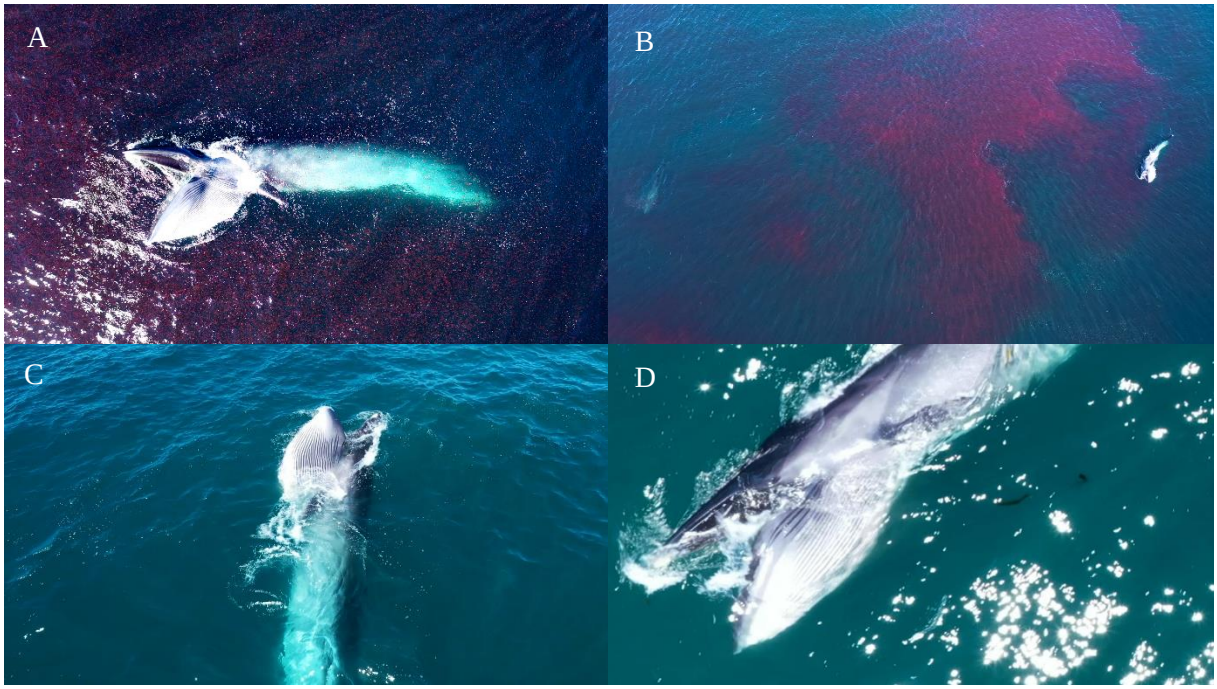

Figure 5: A-B. Sei whale feeding on squat lobster swarms (*Munida gregaria*). C-D. Feeding on copepods.

In the case of dolphins also the Commerson's and dusky dolphins spend a fair amount of time feeding, while Risso's also spend time socializating. Socialization is related to jumping and breaching, and that is the reason why the dolphins that were sighted briefly during the scan or that were far from the observation point that preclude to identify the species (Figure 6).

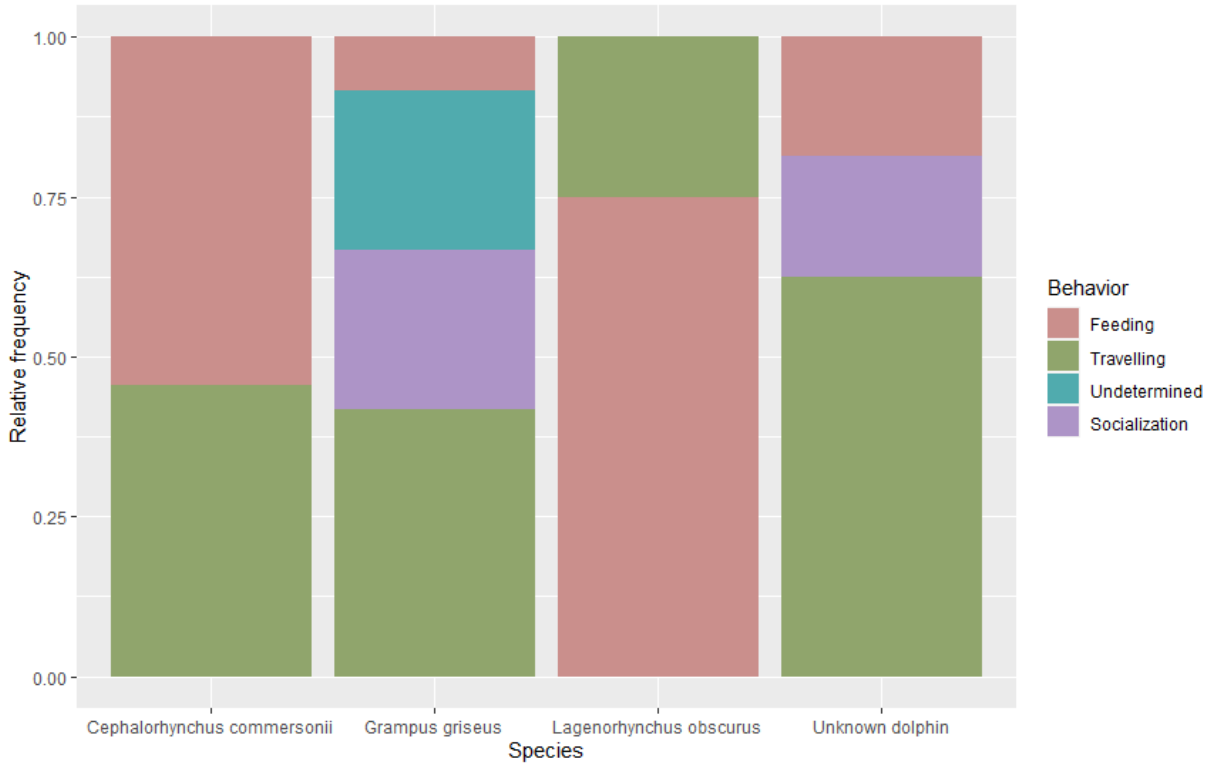

Figure 6. Behaviours performed by Odontocete at Punta Marqués, Chubut.

Abundance estimates for sei whales.

Considering the seasonal abundance of sei whales in the area recorded from the cliff-top and its SPUE, two flights were performed, one on November 26th and a second one on May 16th. These flights were regarded as low and high season respectively. Both flights were made along the coast of the Golfo San Jorge, in Chubut Province, in weather conditions that allowed the sighting of several species of cetaceans. On November 9th, 8 sightings of sei whales were made, totalling 10 individuals. For the May census, 82 sightings comprising 116 sei whales were made (Figures 5 and 6).

In addition, pods of Commerson's dolphins, Risso's dolphins, Southern Right Whales, Humpback and Minke whales (*Balaenoptera acutorrostrata/bonaerensis*) were observed in November. In May, only Dusky and Commerson's dolphins and Southern Right Whales were spotted (Figures 6 and 7).

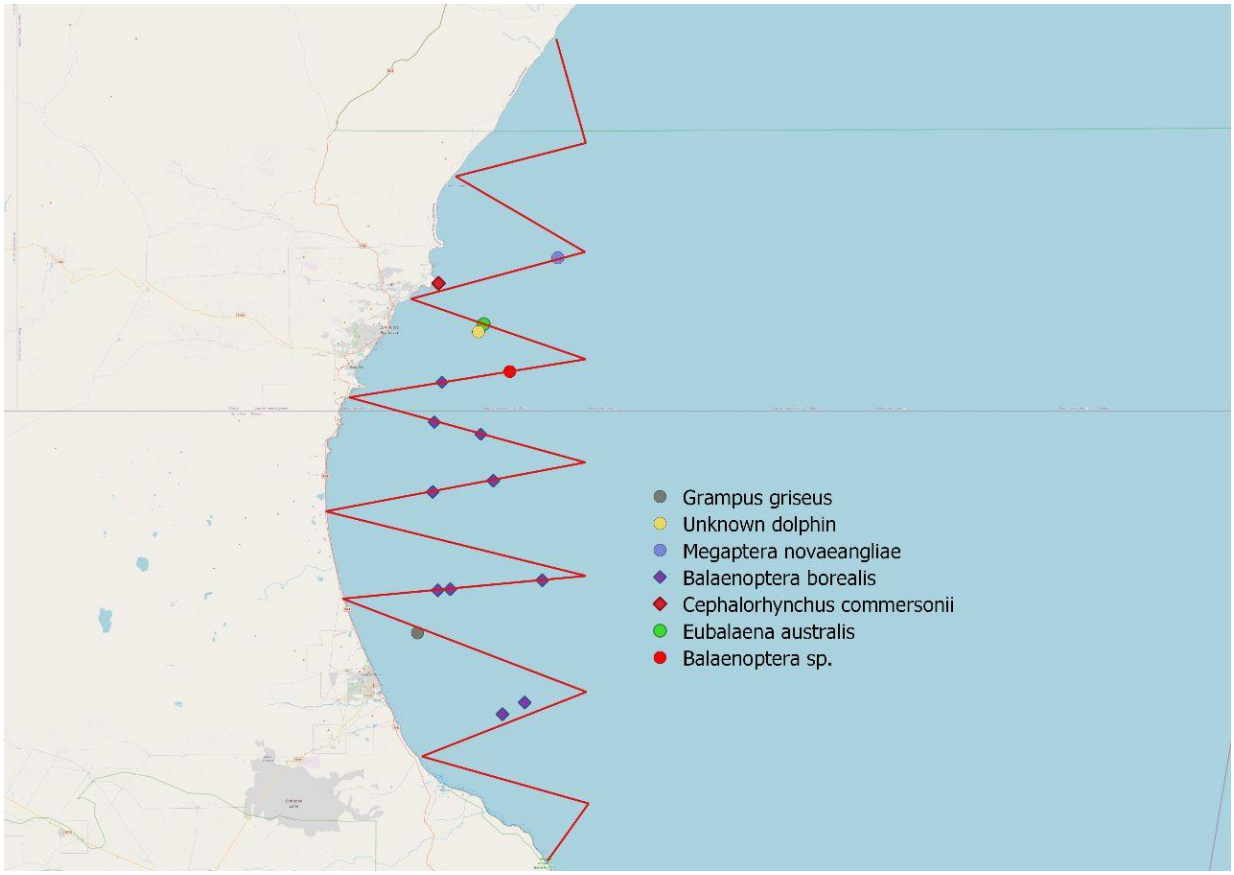

Figure 6: Tracks and sighting of whales and dolphins during the flight performed in November 2021.

The distance of x = 0 from the transect line was considered to occur at a perpendicular distance of 80 m, and all other distances were rescaled accordingly. The detection function was then extrapolated and fitted to these truncated data back to the track line. Data were also right truncated at w = 500 m. The area used for extrapolating the estimates were set considering logistic restrictions, flying as far as 20km from the coast, was 4890 km2.

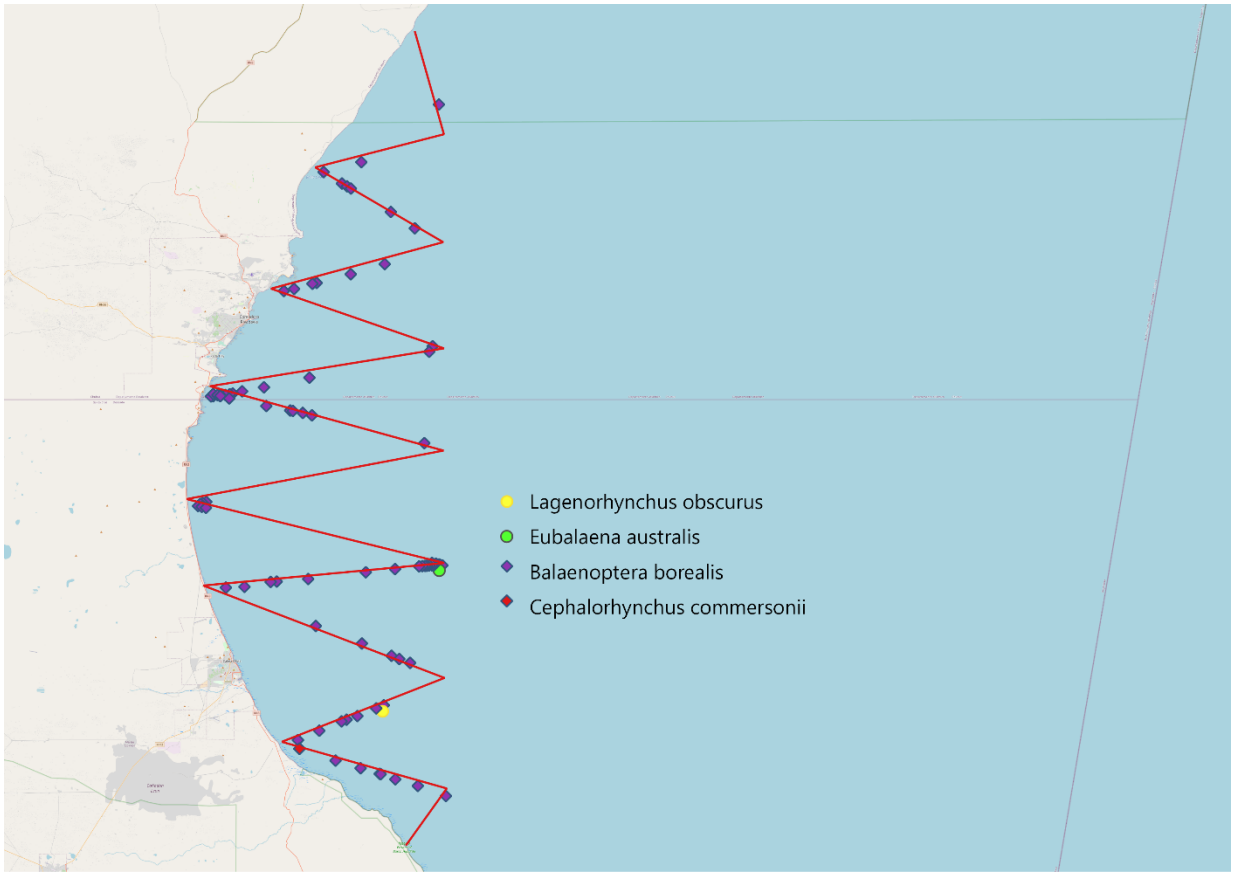

Figure 7: Tracks and sighting of whales and dolphins during the flight performed in May 2022

Table 1. Density and abundance estimations for coastal area of Golfo San Jorge in surveys performed in November 2021 and May 2022.

Survey	Extrapol Area (km2)	Dens	Dens L limit	Dens U limit	N	N L Limit	N U Limit
November 2021	4980	0.1331	0.03883	0.4559	796	232	2727
May 2022	4980	0.3919	0.2576	0.5963	2777	1809.0	4262.0

Ref: Dens: density; Extrapol Area: Extrapolation Area; L Limit: Lower limit 95% CI; U Limit: Upper limit 95% CI. Density is expressed in individuals/km2; the extrapolation area is expressed in km^2 and abundance is expressed in number of individuals.

With respect to parameter estimation, the expected cluster encounter rate, size, and density were analysed for each flight. The best-fitted model was always a Halfnormal/Cosine series without expansion. Total effort for the designed survey was 498,37km for each flight. The estimates obtained are shown in Table 1. The estimated number of sei whales in the area is of

2777 individuals for the autumn (May) and a much lesser number on spring (November) reaching around 800 whales.

DISCUSSION

The results presented in this paper indicate that the coastal area of Golfo San Jorge is a high diversity spot for cetaceans. A total of 5 mysticety species were recorded during systematic scans from the cliff-top, but additional information also reports the presence of blue whales (*Balaenoptera musculus*) on two occasions and several minke whales (data not shown). Also, 6 species of odontoces have been recorded during the scan, but bottlenose dolphins (*Tursiops truncatus*) were also spotted during non-systematic observations. This has been reported before, considering the Argentinean coast as a cetacean diversity hotspot (Moudrý & Devillers, 2020).

The analysis of the SPUE revealed that the sei whale is by far the most common cetacean in the area. Their number increased every year in early autumn. During 2021 there is a peak of 20 sei whales/scan, which is extremely high. In general, between 2 to 10 sei whales are sighted on each scan, with counts as high as 54 individuals, and naked eye counts reaching up to 70. These figures are an order of magnitude higher than any other baleen whale in the area. As a result of this first systematic study, data suggest that the seasonality of the species in the area would have its peak during the second trimester of each year, namely April-June. Nevertheless, sei whales are sighted year-round, in lesser numbers. Although these data are preliminary this loosely coincides with the previous works in the area (Iñíguez et al., 2010; Páez et al., 2017; Páez et al., 2018; Retana & Lewis, 2017; Reyes, 2006).

Humpback whales are less abundant but during 2021 they were present from February until September. There is no obvious reason why humpback whales were not detected during 2020 and 2022. The information on the humpback whales is much scarce in this study but they are frequently sighted, at a very close range from the shore. Most individuals seems to be juveniles, and probably are sighted during their migration from and to the southern Brazilian waters (Riera, Luccchetti, & Coscarella, 2022). In the case of the fin whales, their sightings are anecdotical, and only one opportunity they were registered during a scan, although several other individuals were spotted during biopsy sampling surveys that are being undertaken as part of the same project. Southern right whales are spotted during a shorter period than the reproductive season that takes place at Península Valdés (Crespo et al., 2019), and most were mating groups.

In the case of dolphins, they are easier to see during the summer, albeit they are present throughout the year. Unluckily, in many of the sighting there was no species identification. New techniques are being explored to assess the species identity, including the use of Unmanned Aerial Vehicles. From the footage recorded until now, it seems plausible that the large pods of dolphins sighted, especially during the summer, are both Dusky dolphins and bottlenose dolphins. The former is a species that is distributed in the area is often common during the

summer (Garaffo et al., 2010). In the case of bottlenose dolphins, pods of 50 individuals were spotted, leading us to think these pods are comprised of the oceanic form of *T. truncatus*, instead of the Lahile's dolphin (*T. truncates lahile*), the coastal form registered for the Argentinean coast (Loizaga, Grandi, Cunha, & Crespo, 2020; Vermeulen & Bräger, 2015; Vermeulen & Cammareri, 2009).

The Golfo San Jorge is an extremely productive coastal area (Dans et al., 2021), and hence it is not surprising that cetaceans use this area as a feeding ground. Most species spend a fair share of their time feeding. In the case of sei whales, a feeding ground was reported recently near Malvinas/Falkland island (Baines & Weir, 2020). In this area, sei whales also feed on squat lobsters during the austral summer months (Jan-Mar). In the case of Golfo San Jorge squat lobster increased exponentially since the 2010s (Ravalli, De La Garza, & Greco, 2013), and the records of sei whale started by the same time (Páez et al., 2018). Also, by the time, the sighting of this species has increased in other areas of the Argentine coast (Iñíguez et al., 2010). For humpback whales *Socialization* (Figure 4), related to surface behaviours such as tail or pectoral fin slapping, breaching and jumps. Also humpback whales were spotted feeding in the area, mainly on silversides (*Odonthestes* sp.) using a recently described technique named *Natural Barrier Feeding* (Riera et al., 2022).

The results achieved indicated the existence of a high seasonal abundance of sei whale in the coastal area of Golfo San Jorge. The density changes abruptly from November to May, increasing approximately three fold, and during May is higher than the reported for Falkald/Malvinas Islands (Weir et al., 2021). Considering the distribution of whales in Golfo San Jorge (Figures 6 and 7) and the lack of information on the actual distribution of the species within the gulf (Retana & Lewis, 2017) it is probably that the abundance of this species in the area is actually higher than in Falkland/ Malvinas. Wier et al. (2021) estimated (depending on the used method) between 707 and 916 animals, while for the surveyed area in this study a peak of 2777 individuals were estimated.

The continuation of this study is important to better understand the habitat use and the factors that influence seasonal patterns of rorquals occurrence in Golfo San Jorge. It will also provide behavioural information on the presence of this species near the coast.

Such data will be important to develop the guidelines, and will aid the local authorities to implement and regulate whale watching activities. At the moment, four local entrepreneurs have requested and have been granted with permits to perform nautical trips. Although these companies are not allowed to perform whale watching, our research team, along with regional and local authorities are working together to develop these activities based on the information gathered with the current project.

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