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Southern Right Whale Eubalaena australis in the Golfo San Matías (Patagonia, Argentina): an update of recolonization process

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ABSTRACT

1. Southern Right Whales is thought to be experiencing a density-dependent process while expanding its distribution range in Patagonia.
2. The recovery of the species and the increase in the number of SRW sightings in GSM created a new opportunity to develop the whale-watching activity in Bahía San Antonio Marine Protected Area.
3. This paper reports an update of the population growth trend and changes in the age and sex classes of the right whale in the Golfo San Matias estimated from a data set collected through both aerial censuses and on-board whale-watching surveys.
4. Aerial counts show showed a high variability between years, and consequently no significant change in abundance was recorded over the years.
5. For the first time in the last 9 years of monitoring the whale-watching activity, mother calf pairs were the predominant group sighted during all months of the season.
6. The increase in sightings of mother calf pairs in in Bahía San Antonio Marine Protected Area indicates the beginning of a new stage in the recolonization process.
7. The differences observed between the aerial and on-board surveys underlining the significance of monitoring both the coastal zone and the offshore area.

INTRODUCTION

Southern Right Whale (SRW) *Eubalaena australis* has been driven almost to the border of extinction after three centuries of exploitation in the Southern Hemisphere (Romero et al., 2022). Consequently, SRW has been internationally protected since 1935 by the International Convention for the Regulation of Whaling. Since no whaling occurred after 1973 several stocks of SRW off Argentina-Brazil, South Africa, New Zealand and Australia have shown signs of recovery (Bannister, 2001; Best, Brandão & Butterworth, 2001; Cooke, Rowntree & Payne, 2001; Carroll et al., 2011, 2014; Danilewicz, Moreno & Sucunza, 2016) and it is projected that the population will continue to grow for the next decade (Romero et al., 2022). This positive global growth trend is consistent with the recent findings reported in Peninsula Valdes (PV). In this breeding ground a density-dependence process was reported in which the preferred areas located surrounding PV seem to be close to the carrying capacity, "exporting" individuals to other less dense regions such as Golfo San Matías (GSM) located northward of PV (Crespo et al., 2018; Sueyro et al., 2018) (Figure 1). In addition, recent studies using satellite transmitters implanted on SRW in PV and GSM, have shown that some individuals makes trips between these areas in the same season (Zerbini et al., 2016, 2018). Moreover, the population growth rate was estimated at 10% for GSM that suggested that these growth rates were not only the result of overall population growth, but also reflect immigration and seasonal movement between different wintering grounds (Arias et al., 2018a).

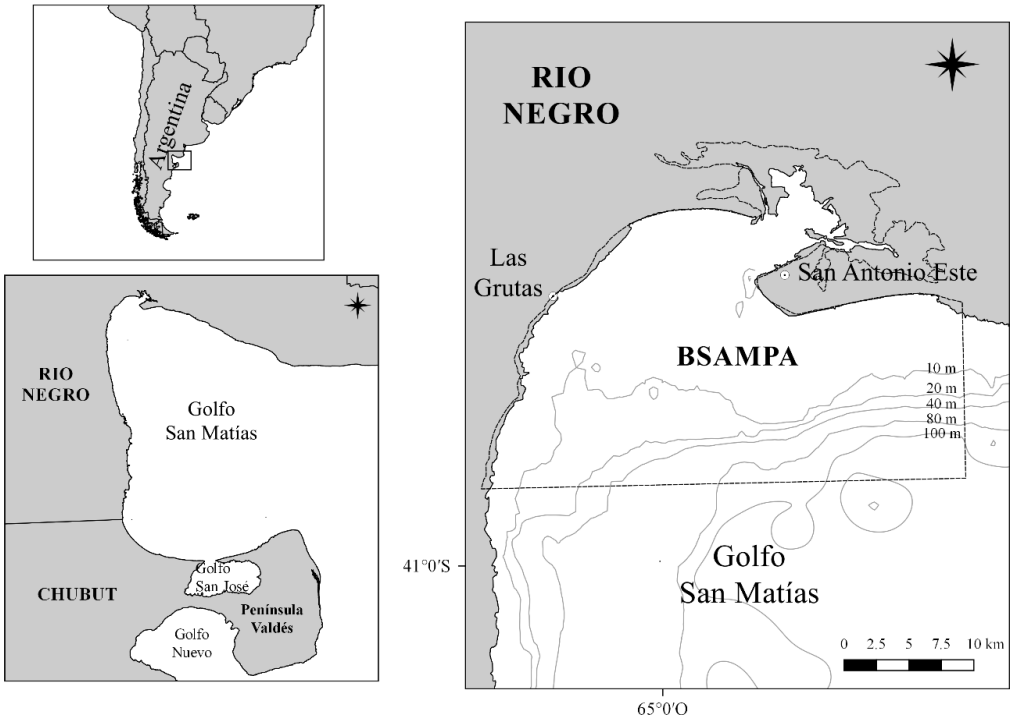

Figure 1. Location and detailed map of the study area in Bahía San Antonio Marine Protected Area (BSAMPA), Río Negro, Argentina.

The recovery of the species and the increase in the number of SRW sightings in GSM created a new opportunity for sport fishing and diving operators of Bahía San Antonio Marine Protected Area (BSAMPA) located in the northwest coast of the gulf. This area is a summer tourism destination; therefore the commercial actors have been considering the whale-watching (WW) as one alternative to break the seasonality and diversify their activities to generate incomes throughout the year. In this context, WW in BSAMPA was authorized by the government since 2012 with its legal framework enforced by the Secretaría de Ambiente y Desarrollo Sustentable of the Río Negro province. Given the scientific uncertainty of the potential impact of this incipient WW activity in its early stage, specific regulations directed to order the WW operations in BSAMPA were initially adopted, based on the experience accumulated during more than 40 years in PV. In addition, a research program has been implemented to acquire scientific knowledge for adapting and updating the regulation to this specific site (Arias et al., 2018b). Thus, the studies to gather information on population trend and ecological aspects of the species in the GSM started in 2006 (Crespo & Dans, 2008; Crespo et al., 2011; Vermeulen & Cammareri, 2012; Svendsen, 2013; Arias et al., 2018a), while the impact studies began in 2012 at the same time of the WW activity started to develop in BSAMPA (Arias et al., 2018b; Arias, 2019).

As a result of these investigations, it was observed that the GSM is dominated by unaccompanied whales (whales without claves) (Arias et al., 2018a), and consequently during commercial trips most of the sightings are made on these groups (Arias et al., 2018b). The low number of mother-calf pairs observed in the GSM could indicate that this is not a core area for rearing the calves. However, considering the records of navigators and explorers who traveled along the coast of GSM during whale season at the beginning of the 19th century the GSM and particularly the BSAMPA could have been an important breeding area at that time (Arias et al., 2018a). In the same sense, Svendsen (2013) using habitat models found that some places in the northwest area of the GSM would constitute suitable habitats for mother-calf pairs of right whales. In the last years, there have been records of mothers with very young calves, sometimes with fetal folds, an indication that these calves were born in GSM, particularly in the area around BSAMPA (M.A. pers. obs.).

Therefore, the objectives of this work were to estimate the rate of increase in the area and evaluate changes in the age and sex classes recorded in the GSM throughout time in a recolonization context.

MATERIALS AND METHODS

Study area

The study area encompasses 345 km of GSM coast and adjacent waters from Puerto Lobos (42° 00´S/ 65° 04´W) to the mouth of the Río Negro river (41° 02´S / 62° 47´W) (Fig 1), in Río Negro province, Argentina. The study area is adjacent to the main SRW nursery ground in South America, Península Valdés (Payne 1986, Payne *et al.* 1990, Rowntree *et al.* 2001).

Aerial and on-board surveys

From 2007 to 2022 coastal aerial surveys were carried out in GSM. However, due to lack of funding, there was no continuity of sampling throughout these years. A total of seventeen coastal aerial surveys were conducted over nine years. The timing of these surveys was planned for the period in which it is most likely to find right whales on the GSM coast (Arias *et al*. 2018, Failla *et al.* 2008). These surveys had as their principal objective the recording of the position (lat, long), the number of animals and the type of group of the SRW. Four categories of SRW groups type were identified: a) solitary individuals (SI), adult or

subadult males or females; b) social active groups (SAG), usually comprising one adult female and one or severals males; and c) non-social active groups (NonSAG), composed by adults or sub-adults whales not showing courtship behaviour (Best et al., 2003) and within a distance of two body lengths from one another. The flights were performed on a Cessna 182-B aircraft and the crew was composed by two observers, one on each side of the plane and a third person recording the information. The flights were carried out when sighting conditions were good, without fog and with a sea state between 0 and 3 in the Beaufort scale.

To estimate the trend of the number of whales that come to the GSM we built a generalized linear model and select as response variable the number of whales recorded in each flight (Arias et al., 2018a). The structure of the model was the same that Crespo *et al.* (2018) used to estimate the growth rate of this species in Península Valdés. Therefore, the Year, the Julian day (considered as the number of days accumulated since January 1) and the Julian day^2 were chosen as explanatory variables. In addition, considering that the sea state changed among flights, the Beaufort was added as an explanatory variable. The Beaufort was recorded in each of the 5 km coast segments mentioned above, and the median was estimated as a proxy for the conditions in each flight.

The models were constructed with the negative binomial error structure and were fitted using package *MASS* with the software R 3.3.1 (R Development Core Team 2013). We ranked the models according to the Akaike Information Criterion adjusted for small samples (AICc) (Burnham and Anderson, 2002). Model comparisons were made with ΔAICc that indicate the magnitude of the difference in AICc values between each model and the best fitting model. Models with ΔAICc < 10 were considered as candidate models for this data set (Burnham and Anderson, 2002). Also, we estimated the AICc weight value that is considered as the weight of evidence in favor of the model i, given the models considered (Burnham and Anderson, 2002). The objective of this model building was to test if there is an effect of the year on the number of whales recorded; hence we tested the subset of models that included the explanatory variable Year plus the null model.

Since 1999 the number of whales recorded in the coastal aerial surveys in PV has been used as a measure of relative abundance (Crespo et al., 2018). This survey method assumes that around 95% of the whales are found within a coastal strip known as the “whale road” (Payne, 1986). In GSM the sighting per unit effort index was eight times higher in the coastal strip than outside of the coastal strip (Arias et al., 2018a). Although this result supports the assumption, many whales were recorded outside the coastal zone, particularly in BSAMPA (Arias et al.,

2018a). Consequently, to complement the data collected through coastal aerial surveys sampling on board opportunity platforms (WW vessels) was carried out.

On board data were collected systematically from the beginning of the whale watching activity during nine WW seasons (2012-2022) between August and October each year. Due to the lack of funding 2017 WW season could not be monitored. In addition, due to the COVID-19 restriction, the 2020 WW seasons was canceled. Onboard data were recorded by a trained observer on board of some of the four vessels (8-10 m length) authorized to operate. Each day between 1 and 6 commercial trips were monitored depending on the number of tourists and weather conditions. Several sightings were performed during the same trip and each sighting was independent (that is, the same group was not re-sighted in one trip). A 'sighting' was considered when the vessel approached a group of SRW and remained at least for 1 min at a distance of at least 100 m from the focal whale. The distance was estimated 'by eye' using vessel length to calibrate distance (Dawson et al., 2008). Date, hour, trip duration, track recorded by a handheld GPS and weather conditions for each trip were recorded. Data collected in each sighting included: position (lat, long), sighting duration, group size and group type.

RESULTS

Whales have been recorded on every flight made between August and October since 2007. The highest number of whales was recorded in late August and early September, with a maximum of 252 individuals recorded in the coastal strip in a single census in early September of 2021. The solitary individuals and the non-social active groups were predominant group type during all the season (Fig. 2).

Unlike aerial surveys, changes in the proportion of group types sighted during whale watching operations in BSAMPA were recorded. Until 2022 WW season, during a commercial trip most of the sightings were performed on solitary individuals and non-reproductive social groups (Fig. 3), agreeing with what was observed in coastal aerial surveys. However, during the last WW season, for the first time in the last 9 years of monitoring the activity, mother calf pairs were the predominant group sighted during all months of the season (Fig. 3). This change was not gradual, since in recent years only a few sightings were made on mother calf pairs.

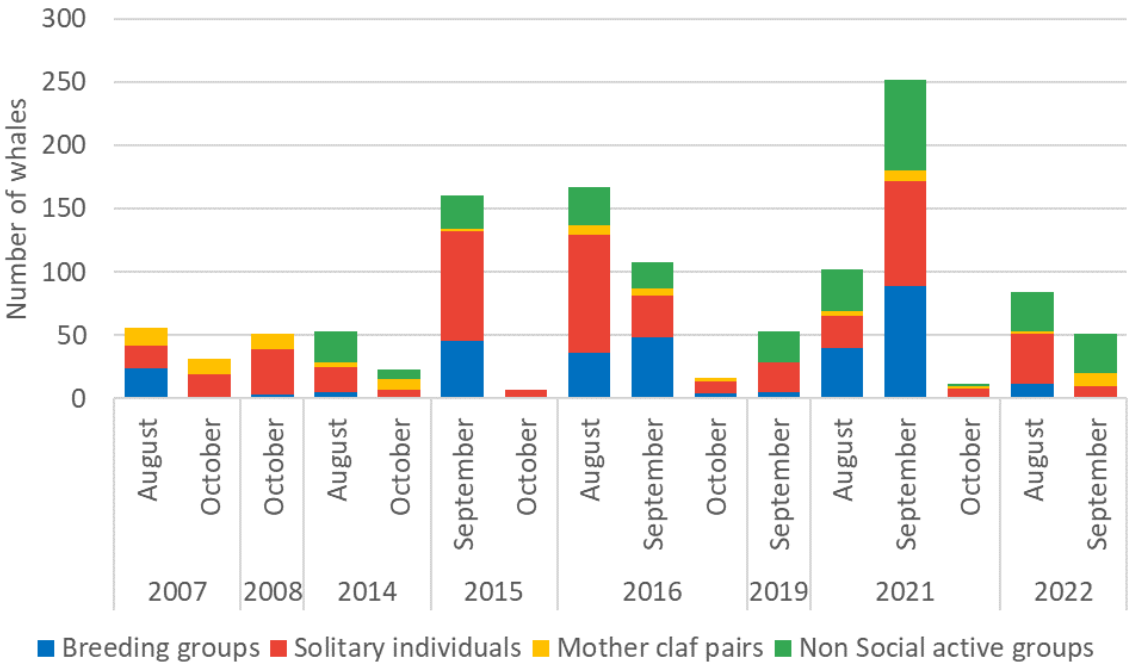

Figure 2. Proportion of group types registered during all the aerial surveys performed each season.

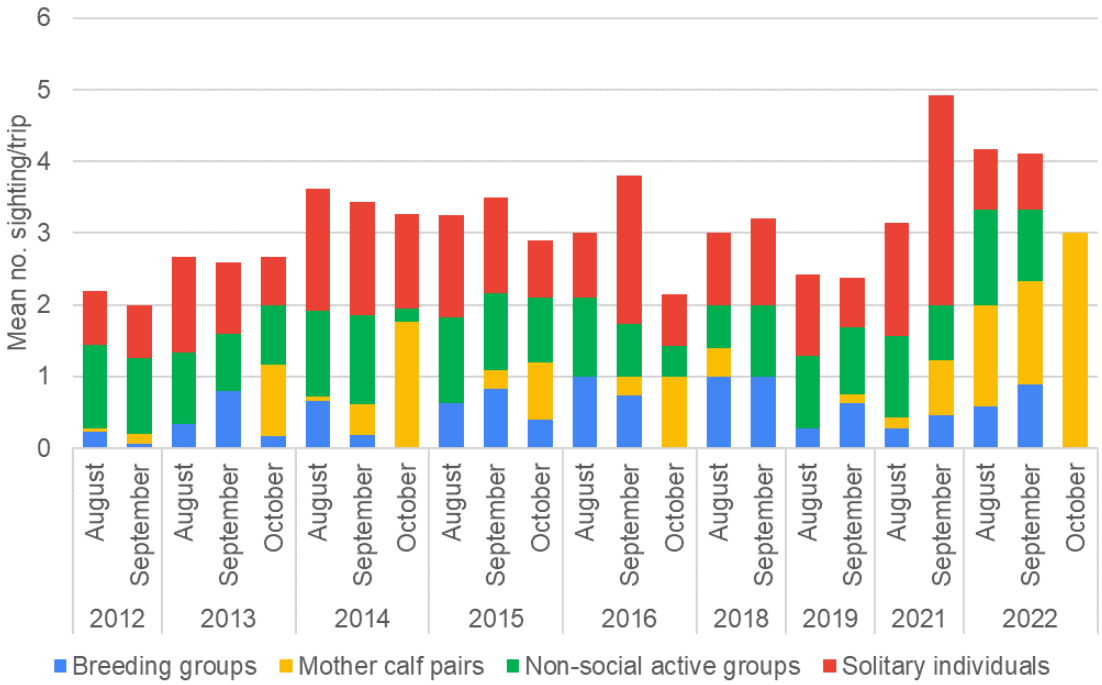

Figure 3. Mean number of sightings of each group type per commercial trip during the whale-watching seasons.

The best model supported by our data to account for the number of whales recorded in each aerial survey was the one that included the Year, the Julian day and the Julian day^2. The ΔAICc between all models that included the year as an explanatory variable was less than 10, therefore all these models were considered as candidate models. The growth rate estimated in each model was always negative with values that ranged between -2.18% and -0.71% and

confidence intervals that ranged between -8.80% and 7.23%. However, the effect of the Year was not significant in all models (Table 1).

Table 1. Models for SRW censuses, using Year (Y), Julian day (JD), Julian day^2 (JD^2) and Beaufort (BF) as predictor variables. For each model, the effect of the variable Year is expressed as an annual increase rate and its associated 95% confidence interval (CI). The models are ordered according to the support given by the data assessed by the AICc.

Model	Predictors	Effect of the Year	95 % CI	AICc	ΔAICc	AICw
1	Y+ JD+JD^2	-0.71%	-6.49; 0.05	169.9	0	0.776
2	Y + JD +JD^2+BF	-2.18 %	-7.75; 0.03	172.6	2.7	0.206
3	Y + JD^2	- 1.12 %	-8.80; 6.55	178.3	8.4	0.012
4	Y + JD	-0.71 %	-8.65; 7.23	179.6	9.7	0.006

DISCUSSION

This study presents evidence that the SRW is recolonizing areas in north Patagonia. The increase in the number of mother calf pairs recorded in the SABMPA is associated with the immigration from other wintering grounds as Península Valdés and support the proposed expansion of the Península Valdés population towards other areas due to a density-dependence process (Arias et al., 2018a; Crespo et al., 2018; Sueyro et al., 2018). In addition, recent studies using satellite transmitters implanted on SRW in PV and GSM, have shown that some individuals make trips between these areas in the same season (Zerbini et al., 2016, 2018).

While many factors may influence dispersal, increased access to mates and avoidance of inbreeding are important contributors in promoting sex differences in dispersal (Greenwood 1980). It is argued that there is a direction of the sex bias in mammals' dispersal because of the type of mating system. In the case of polygynous and promiscuous species of mammals, as the SRW, juvenile males are the predominant dispersers (Greenwood 1980, Dobson 1982, Pusey 1987, Danchin *et al.* 2008). In the case of mother-calf pairs, the mother has an additional energetic cost because it faces a great energy demand because they are gestating or lactating (Constantine 2014). Therefore, the familiarity with a given area is beneficial for them while

whales without calves can move without experience an additional cost. The dominance of solitary individuals in the hotspots of the GSM and mother calf pairs and in the Península Valdés hotspot (Arias et al., 2018a) support the hypothesis mentioned above. Thus, at least at present, the GSM is not a core area for rearing the calves. However, the increase in sightings of mother calf pairs in SABMPA indicates the beginning of a new stage in the recolonization process. Recently, through the development of predictive models of future occupation, it has been proposed that mother calf pairs will select the SABMPA as a calving area in the coming years (Sueyro, 2023). In addition, it was suggested that the expansion towards the GSM will be determined by pulses in the moment the threshold of 3 whales per square kilometer is reached in the hotspot of Península Valdés (Sueyro et al., 2018). Consequently, an increase in the presence of mother calf pairs is expected in the next years in the GSM, and particularly in the SABMPA that could have been an important breeding area during the 19th century (Arias et al., 2018a).

The dispersal proposed for the northern Patagonian gulfs population seems to be happening in other SRW stocks, like in Brazil (Groch *et al.* 2005, Danilewicz *et al.* 2016), South Africa (Barendse and Best 2014) and New Zealand (Carroll *et al.* 2011, 2014), accompanying the population growth. Whales expanded their range and showed evidence of recolonization of ancient areas around the main nursery area. As has been observed in the GSM, these areas are dominate by unaccompanied whales and appears to be important for feeding and socializing but not as a nursery area (Barendse and Best 2014, Groch *et al.* 2005). Also, both in New Zealand and South Africa, movements between the main wintering ground and secondary wintering ground were recorded and suggest that there is a considerable exchange between them (Mate *et al.* 2011, Barendse and Best 2014, Carroll *et al.* 2011, 2014, Childerhouse *et al.* 2010), as it was reported for the northern Patagonian gulfs (Zerbini *et al.* 2016, 2018). In addition, the expansion to new areas next to the focal dense area associated with density-dependent processes has already been reported in other marine mammals of Patagonia such as South American sea lions (*Otaria flavescens*) (Grandi *et al.* 2008).

The result of this study indicated that during the study period there were no changes in the abundance of whales in GSM. This is inconsistent with the positive growth rate reported for the GSM during the period 2007 – 2016 (Arias et al., 2018a). The inclusion of the aerial surveys carried out in the following years added noise to the model due to the great variability observed in the system. Although this variability is to be expected during the recolonization process of an area, it should also be considered that the proposed models are not able to cope with the interannual variation in the arrival of the whales to GSM area. In addition, it should

be noted that the analysis of generalized linear models only consider the total number of whales counted in the coastal strip. Although this method has been validated for the GSM (Arias et al., 2018a), it should be considered that a large number of whales may be outside the coastline at the time of the aerial survey, especially in SABMPA due to the geographic characteristics that allow whales to find shallow areas in offshore areas (Arias et al., 2018a). These differences became evident during the present study underlining the significance of monitoring both the coastal zone and the offshore area. In addition, the results obtained highlight the importance of long-term monitoring, especially in the case of long-lived species such as SRW. However, a critical aspect for researchers is the lack of the necessary budget to conduct elemental long-term studies. In this sense, a formal management plan, with specification of actors, responsibilities, schedule, budget and financial sources, could make the research task easier. In GSM, the lack of budget has led to scientists and WW operators to work in a collaborative way to get the essential data and information. This allowed the creation of a partnership between scientists and WW operators that generated a flow of information in both directions and promoted good sighting practices (Arias, 2019).

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