Abundance estimates of southern right whales (*Eubalaena australis*) in Bahía San Antonio, Patagonia, Argentina

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ABSTRACT

The abundance of southern right whales (*Eubalaena australis*) was estimated by the means of aerial line-transect surveys for the area of Bahía San Antonio, a bay located in the north-western region of the San Matías Gulf (40°50'S 64°50'W), Rio Negro, Patagonia Argentina. In total, seven aerial surveys were conducted in the first week of August and September 2009, September, October and November 2010, and August, September 2011. Survey effort equalled a total flight time of 12.4h, during which 200 whales were counted in 119 whale groups. Half of the encounters were solitary animals and 17% were mating groups. Corrected abundance estimates showed the highest amount of whales present in the bay during the month of September, with 85±71, 207±108 and 117±55 animals in 2009, 2010 and 2011 respectively. In adjacent months, less than half the amount of whales seemed to be present. The correction factor $g(0)_{availability}$ resulted 0.392±0.456. Perception bias was not accounted for. These aerial surveys resulted in the first estimates of southern right whale abundance in this north Patagonian bay and indicated a rather abrupt peak during the month of September. This being the peak month for right whale presence is consistent with data from other regions in the Southwest Atlantic, but data obtained in the other months remained scarce and thus results should be interpreted carefully. The complete absence of whales in the area during November 2010 and August 2011 raises further questions on the predictability of the whale's presence in the area. Overall, more consistent aerial surveys should be conducted to accurately determine the annual and interannual evolution of southern right whale abundance in the study area.

KEYWORDS: SOUTHERN RIGHT WHALES; ABUNDANCE ESTIMATE; SURVEY- AERIAL; SOUTHERN HEMISPHERE; SOUTH AMERICA; BREEDING GROUNDS; FEEDING GROUNDS; SITE FIDELITY; DISTRIBUTION

INTRODUCTION

The distribution of southern right whales (*Eubalaena australis*) ranges between 18°S and 50°S (de Oliveira Santos *et al.*, 2001) with the most important known calving areas in the Southwest Atlantic located off Argentina (Península Valdés) and Brazil (Santa Catarina) (Flores *et al.*, 2000; Payne, 1986; Payne *et al.*, 1990; Rowntree *et al.*, 2001). Due to commercial whaling during the 18th and 19th centuries, the population of southern right whales was severely depleted (IWC, 2001), leading to their near extinction. Today, due to the international protection of the species, the worldwide population is growing annually (Best, 1990; Cooke *et al.*, 2001; Payne *et al.*, 1990) including Argentinean waters, with estimated growth of 6.9% (Cooke *et al.*, 2003). This increase has raised various hypotheses about the re-occupation of historical wintering grounds along the Southwest Atlantic coastline (Belgrano *et al.*, 2007; de Oliveira Santos *et al.*, 2001; Failla *et al.*, 2008; Flores *et al.*, 2000; Iñíguez *et al.*, 2003; Piedra *et al.*, 2006).

In Northeast Patagonia, possibly as a result of this apparent increase in occurrence, southern right whales are increasingly being targeted by commercial whale-based tourism activities (Vermeulen *et al.*, 2012). It is important to monitor the presence of this species in this region and obtain accurate information on local tendencies of abundance and group compositions (annually and interannually). Therefore, aerial surveys were conducted in Bahía San Antonio, the foremost touristic area in Northeast Patagonia. In this report, the results of these surveys are presented.

MATERIAL AND METHODS

Data were collected in Bahía San Antonio, a bay located in the north-western region of the San Matías Gulf (40°50'S 64°50'W), Rio Negro, Patagonia Argentina (Fig. 1).

Aerial surveys

Aerial surveys were conducted in the first week of the following months: August–September 2009; September; October–November 2010; and August–September 2011. Both financial resources and climatological conditions were the factors determining the timing and frequency of the surveys. The transects for the aerial surveys were designed using the standard distance sampling methods applied to clusters of animals (Buckland *et al.*, 1993) and the program *DISTANCE* 6.0 (Thomas *et al.*, 2006). The design consisted of 14 North–South (up to 40.9°S) parallel transect lines with a 2.5km separation, covering a total area of 418km^2 (mean CP = 0.78; Fig. 1). Transect length was chosen according to the safety restrictions of the pilot.

Surveys were conducted in good weather conditions and a calm sea state (Beaufort ≤ 3) using a high-wing Cessna 152 with a flat window. Due to the small size of the aircraft, only one researcher could travel on each flight. Observations where therefore made from one side only. Average speed and height of the aircraft was kept constant over the surveys at 90kn (166kmh^{-1}) and 700ft (213m) respectively. All surveys aimed to take place during the period of high tide to minimise the variation in area submerged caused by the large tidal fluctuations characteristic of the study area (up to 9m; Servicio de Hidrografía Naval Argentina).

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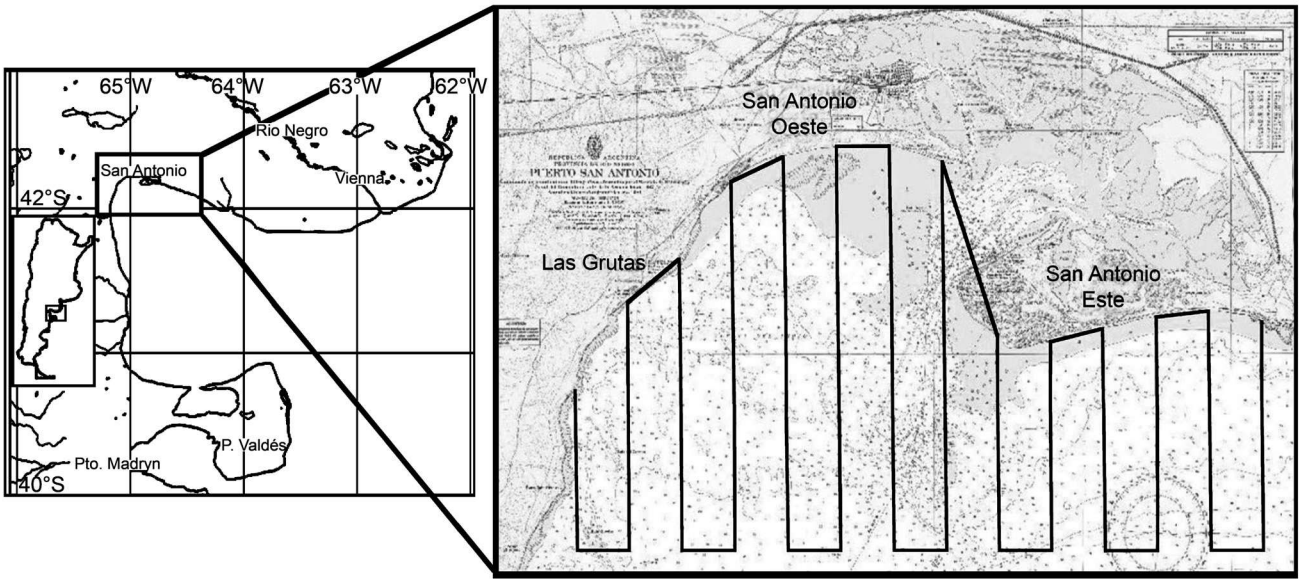

Fig. 1. Study area and transect design for the aerial surveys.

At the start of each survey, weather conditions (wind speed and direction) were noted. When a group of whales was sighted, data were written down on species, location (using a Garmin GPSmap 60csx), time, group size and composition. The downward angle to the group perpendicular to the aircraft's track was then measured using a hand-held clinometer (Suunto PM5/360PC). When possible, the total time the whale was visible to the observer was measured using a chronometer to later aid in the calculation of $g(0)$.

When whales were close enough, the transect line was abandoned to take photo-ID pictures. Afterwards the aircraft returned to the transect line to continue the survey.

Perpendicular distances were trigonometrically calculated using the aircraft's altitude and the declination angle to the sighting. The flat windows of the aircraft did not allow observers to see animals at declination angle between 60°–90°. Therefore a limit was set at 55°, corresponding to a left truncation distance of 150m. Perpendicular distances were also right-truncated at 10% of the observations, as recommended by Buckland *et al.* (1993).

Various models were tested to fit the detection function, including the uniform function, half-normal function and the hazard rate function with cosine, Hermite or simple polynomial adjustments. The model that best fitted the data was selected according to the Akaike Information Criterion (AIC; Akaike, 1973).

Finally, since the detection probability on the trackline, $g(0)_{availability}$, is not equal to 1 in aerial surveys of whales (availability bias), the probability of detecting a southern right whale was estimated following the approach of Barlow *et al.* (1988):

$$g(0)_{availability} = (s + t)/(s + d)$$

where s is the average time a southern right whale is at the surface, d is the time the whale is submerged and t is the time the whale is within the visual range of an observer when in the aircraft. The values for s and d were measured from boat-based surveys, whereas the value for t was measured directly from the aircraft when possible. Final abundance estimates were then corrected with this factor.

RESULTS

Effort, group size and composition

Over the study period, seven aerial surveys were conducted, resulting in a total flight time effort of 12.4h. In total, 200 whales were seen in 119 whale groups (2009: n = 36 whale groups; 2010: n = 46 whale groups; 2011: n = 37 whale groups), equally distributed over the study area. Group sizes ranged between 1–5 animals with a mean group size of 1.7 animals (SD = 0.83; median = 1.5). Overall, half of the encounters were solitary animals (50%) whereas 17% were mating groups (SAG) with a mean group size of 2.5 individuals (SD = 0.7). Less than 1% of the encounters were mothers with their calves. For up to 32% of the encounters, the group composition could not accurately be classified. However, the number of whale groups and number of whales seemed to increase from September 2009 to September 2011 as shown in Table 1. The proportions of the different group compositions varied with it. As such, the proportion of solitary animals decreased from 60% (n = 15) of the encounters in 2009 to 37% (n = 14) in 2011, and the proportion of mating groups (SAG) encountered increased from 4% (n = 1) in 2009 to 22% (n = 8) in 2011 (Fig. 2). Nevertheless, this variation tested as insignificant ($\chi^2 = 7.73$; df = 2; $p = 0.2$).

Table 1

Summary of the amount of whales (no. whales) and whale groups (no. WG) observed during the aerial surveys of September 2009, 2010 and 2011.

	September	
	No. whales	No. WG
2009	38	25
2010	50	28
2011	69	37
Total	157	90

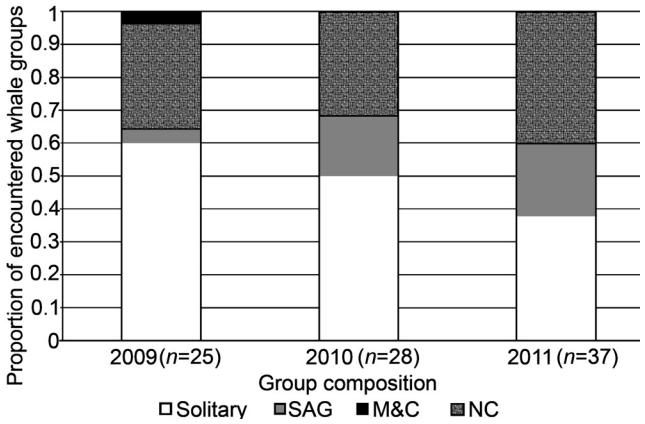

Fig. 2. Proportion of the different group compositions of southern right whales in Bahía San Antonio during the month September of 2009, 2010 and 2011. Solitary = solitary animal; SAG = Surface Active Group (mating group); NC = Not Classified; M&C = Mother and calf.

Abundance

The uniform cosine model was chosen in the view of the minimum AIC to model the detection function of southern right whales in the study area. Pooling all the sighting data together and using the mean group size, this model led to an estimate of the effective strip width (ESW) of 1,587m (%CV = 11.6). The uncorrected density estimates resulted in 0.05 (%CV = 15.1) and 0.08 whales km^{-2} (%CV = 27.8) for August and September 2009 respectively, 0.19 whales km^{-2} (%CV = 44.7) and 0.05 whales km^{-2} (%CV = 43.2) for September and October 2010, and 0.11 whales km^{-2} (%CV = 21.5) for September 2011. During the aerial survey in November 2010 and August 2011 no southern right whales could be observed.

Based on observations from boat-based surveys, the time whales spent at the surface (s) was averaged at 6.13sec ± 3.04sec, while the average time whales were submerged (d) was calculated as 180.4sec ± 84.3sec (n = 42). During aerial surveys the time a whale was within the visual range of an observer (t) was measured (n = 46), averaging 66.9sec ± 37.5sec. Therefore, the estimates of $g(0)_{availability} = (s + t)/(s + d)$ resulted in a correction factor of 0.392 ± 0.456. The corrected estimates of whale abundance in the study area over the different surveys are summarised in Table 2.

DISCUSSION

Group size and composition

Data on group composition were similar to previous information obtained from land and boat based surveys (Cammareri and Vermeulen, 2008; 2010; Vermeulen *et al.*, 2012), with the majority of the whales being solitary. The variation in group composition seen over the subsequent September months was insignificant. Continuous research should determine if this tendency remains insignificant over the years, or if this insignificance is a result of, for example, too few data. If the increasing presence of mating groups in Bahía San Antonio is in fact a trend, this could mean that the area is becoming increasingly important for southern right whale mating, which would be important information to be monitored. Continuous research should furthermore investigate a possible shift in the presence of different group compositions within one year. In any case, the overall small group size of the observed mating groups raises doubts on the role of the study area as an important breeding ground at the moment.

The data presented confirm that the study area is neither a calving nor a nursing ground. This is valuable information when considering the local increasing touristic pressure (Vermeulen *et al.*, 2012). Similar data were found for the coastal region of Uruguay (Costa *et al.*, 2007; Jorge *et al.*, 2011), with the two main calving grounds of the species in the Southwest Atlantic located both North (Santa Catarina, Brazil) and South (Peninsula Valdés, Argentina) of the larger area including North Patagonia and Uruguay. As was reported by Jorge *et al.* (2011), southern right whales have a differential habitat use along the Southwest Atlantic Ocean, where only some areas are preferred calving and nursing grounds. Environmental variables such as sea surface temperature, bathymetry and slope have been shown to be significant in determining the southern right whale distribution (Elwen and Best, 2004; Keller *et al.*, 2006; Murison and Gaskin, 1989). As such, southern right whales, and specifically mothers and calves show a clear preference for shallow waters, sheltered from wind and swell (Elwen and Best, 2004; Patenaude and Baker, 2001; Payne, 1986), currents (Rowntree *et al.*, 2001), fronts (Patenaude and Baker, 2001) and possible predators. Although the study area is a shallow enclosed bay (unlike the Uruguayan coast; Riet-Sapriza *et al.*, 2011), preferred by resident bottlenose

Table 2

Abundance estimates for aerial surveys conducted in 2009, 2010 and 2011. *D* uncorrected=uncorrected density of whales in the study area (whales/km^{-2}); *N* uncorrected=estimate of uncorrected number of whales in the study area (no. whales); *N* corrected=estimate of number of whales in study area corrected for detection probability $g(0)_{availability}$ (no. whales).

		August		September		October		November	
		Estimate	%CV	Estimate	%CV	Estimate	%CV	Estimate	%CV
2009	*D* uncorrected	0.05	15.1	0.08	27.8	–	–	–	–
	N uncorrected	21.6	15.1	33.4	27.8	–	–	–	–
	N corrected	55.2	38.4	85.3	70.9	–	–	–	–
2010	*D* uncorrected	–	–	0.19	42.2	0.05	43.2	0	0
	N uncorrected	–	–	79.4	42.2	20.9	43.2	0	0
	N corrected	–	–	207.4	107.5	53.3	110.2	0	0
2011	*D* uncorrected	0	0	0.11	21.5	–	–	–	–
	N uncorrected	0	0	45.9	21.5	–	–	–	–
	N corrected	0	0	117.1	54.9	–	–	–	–

dolphins (Vermeulen and Cammareri, 2009), the low inclination of the slope, large tidal fluctuations (up to 9m) and overall lack of high cliffs could make the waters of the bay more sensitive for adverse weather conditions and currents, and thus less preferred by mothers with their calves. The study area might, however, be sheltered enough for unaccompanied whales to form groups and engage in social and/or mating behaviour, in which energy saving could also be an advantage (Riet-Sapriza *et al.*, 2011). Overall, no preferred areas within the bay could be observed over the years as all sightings were evenly distributed over the entire study area.

Abundance

The aerial surveys resulted in the first specific estimates of southern right whale abundance in Bahía San Antonio. These results indicated the marked presence of southern right whales in this North Patagonian bay, but the densities remained low when compared to the area around Peninsula Valdés (Crespo *et al.*, 2011).

The estimation of $g(0)_{availability}$ presented in this article appears to be lower than most of the values found for other large whales (e.g. Andriolo *et al.*, 2006; Barlow and Forney, 2007; Okamura *et al.*, 2010; Skaug *et al.*, 2004). This low value could be caused by the turbidity of the water (Els Vermeulen, pers. comm.), as it has been known to be one of the major sources of availability bias in aquatic surveys (Marsh and Sinclair, 1989) due to the lower amount of time a whale is within the visual range of an observer. However, estimation of $g(0)_{availability}$ is based on a limited amount of data and should be taken into account prudently. If indeed the estimate of $g(0)_{availability}$ presented here is an underestimate, the abundance of southern right whales in the study area could be overestimated.

Conversely, the estimation of g(0) from aerial surveys should also include the perception bias (Marsh and Sinclair, 1989), which is a bias due to a proportion of the whales at the surface being missed by the observer. In this study, only one observer was able to travel with the pilot due to limited resources and therefore this bias will be present but could not be taken into account. The inclusion of this bias would most likely result in an increased abundance estimate of southern right whales in the study area. It can thus be concluded that, although these first abundance estimates give a general impression, the specific values should be treated with care as they may be biased due to the failure to meet correctly all the assumptions inherent to line-transect surveying of an aquatic environment.

The results further indicate the occurrence of a sharp peak in whale abundance in the bay in September, with less than half the number of individuals in adjacent months. A peak in September for southern right whale presence has been reported previously for other coastal regions in Argentina (Province Rio Negro: Failla *et al.*, 2008; Province Chubut: Payne, 1986), and other regions in the Southwest Atlantic (de Oliveira Santos *et al.*, 2001; Flores *et al.*, 2000; Parmejane and Groch, 2006; Uruguay: Piedra *et al.*, 2006), but data obtained over the other months remain very scarce and thus results should be interpreted carefully.

The complete absence of whales during the aerial surveys in November 2010 and August 2011 raises questions on the predictability of the occurrence of whales in the area. Furthermore, previous data have also indicated that whales could be seen in the study area as early as April (Cammareri and Vermeulen, 2008). This apparent irregular evolution in whale occurrence over the different months has been reported previously (Cammareri and Vermeulen, 2008), and could be the result of the predominant presence of solitary animals, known to show shorter residence times and to behave in a less predictable way (Jorge *et al.*, 2011). Also, due to several limitations, the area surveyed is relatively small and there is no information available on the presence of southern right whales in the near adjacent regions. Therefore a small change in the distribution pattern of these whales might greatly affect the data gathered in the study area at a particular point in time.

As data are limited, no indication can be given towards the suggested increasing presence of southern right whales in the study area over the years. Once again, aerial surveys should be continued over consecutive years to compare relative abundances and should preferably be more consistent over the different months within one year and covering a larger area of Northeast Patagonia.

Photo-ID

During these first aerial surveys, identification pictures were taken and allowed the identification of seven individual southern right whales. None of these individuals could be re-identified between surveys. These pictures will further be compared with other catalogues of the southwest Atlantic.

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