Aquatic Mammals 2024, *50*(5), 402-408, DOI https://doi.org/10.1578/AM.50.5.2024.402

Short Note

Seasonal Occurrence of Southern Right Whales (*Eubalaena australis)* in Miramar, Buenos Aires Province, Argentina, Between 2016 and 2019

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Southern right whales (*Eubalaena australis*; SRWs) were heavily exploited by commercial whaling and were driven close to extinction during the 19th and 20th centuries (International Whaling Commission [IWC], 2001). With their numbers still low (an estimated circumpolar population of 13,000 in 2010; IWC, 2013b) relative to the estimated pre-whaling abundance of between 60,000 and 100,000 whales in the Southern Hemisphere (IWC, 2001), this species is now showing signs of recovery. The estimated population size for the species in 1997 was 7,500 animals, with an estimated average growth rate for all populations in the Southern Hemisphere of 7.5% (IWC, 2013b). The most recent population growth rate estimates suggest this species is increasing at 6 to 7%/y on both sides of the Atlantic Ocean, as well as in Australia (Crespo et al., 2011; IWC, 2013b; Cooke et al., 2015). However, some subpopulations (e.g., southeast Pacific) appear still to be severely depleted (IWC, 2013a) and are considered critically endangered (Cooke, 2018).

Península Valdés, Argentina, is an important nursery ground for SRWs in the southwest Atlantic Ocean. Every year, whales can be observed in relatively large aggregations (up to 1,700 individuals; Crespo et al., 2019) during the austral winter/spring season. The abundance of SRWs from Península Valdés was estimated at 4,245 (95% CI = 3,765 to 4,725) individuals in 2010 (IWC, 2013b).

In recent years, SRWs have increasingly been observed close to Miramar (38° 16' 34" S, 57° 50' 3" W), in the southeast of the Buenos Aires Province of Argentina. It is possible that these sightings represent SRWs expanding their distribution in wintering habitats and/or movement along the coast through historical or new migratory routes as a result of their recovery. Similar occurrences have been confirmed along Argentina's coast outside their primary nursery grounds near Península Valdés, including Río Negro and Santa Cruz Provinces (Belgrano et al., 2008, 2012a, 2012b; Failla et al., 2008; Arias et al., 2016, 2018), Brazil (Groch et al., 2005), and Uruguay (Jorge et al., 2011; Riet-Sapriza et al., 2011). Miramar is located between Península Valdés, Argentina (700 km to the south), and Santa Catarina, Brazil (1,400 km to the north), another known calving ground for SRWs in the southwest Atlantic. Satellite tracking of SRWs near Península Valdés connects the study area with movement of individuals out of calving grounds in the northern Patagonian Gulfs (Zerbini et al., 2015, 2016, 2018). Likewise, a whale tagged in Islas Georgias del Sur/South Georgia Island (IGS/SGI) migrated towards Brazil having passed along the coast of Miramar (Kennedy et al., 2020). Sueyro et al. (2022) conducted a study using species distribution models (SDMs) to predict the SRW distribution off Argentina, which indicated that besides the current known coastal habitats, areas in the south

of the Buenos Aires Province and coastal areas off Golfo San Jorge constitute suitable habitats.

Despite observations of SRWs off the coast of Buenos Aires Province, systematic surveys have not been conducted to assess seasonal distribution and abundance for this species. The steady increase of SRW sightings in Miramar attracted the attention of citizens and the city government because the consistent presence of whales could encourage the development of whale-watching activities in the region. Proper implementation and regulation of such activities requires a better understanding of SRWs' occurrence, seasonal patterns, and habitat use.

From 2016 to 2019, visual surveys were carried out to test the hypothesis that SRW numbers were increasing and to assess the seasonal presence and relative abundance near Miramar (Figure 1). Further, this study was conducted to generate baseline knowledge to potentially contribute to the implementation and regulation of commercial activities (e.g., whale watching) in the region. Also,

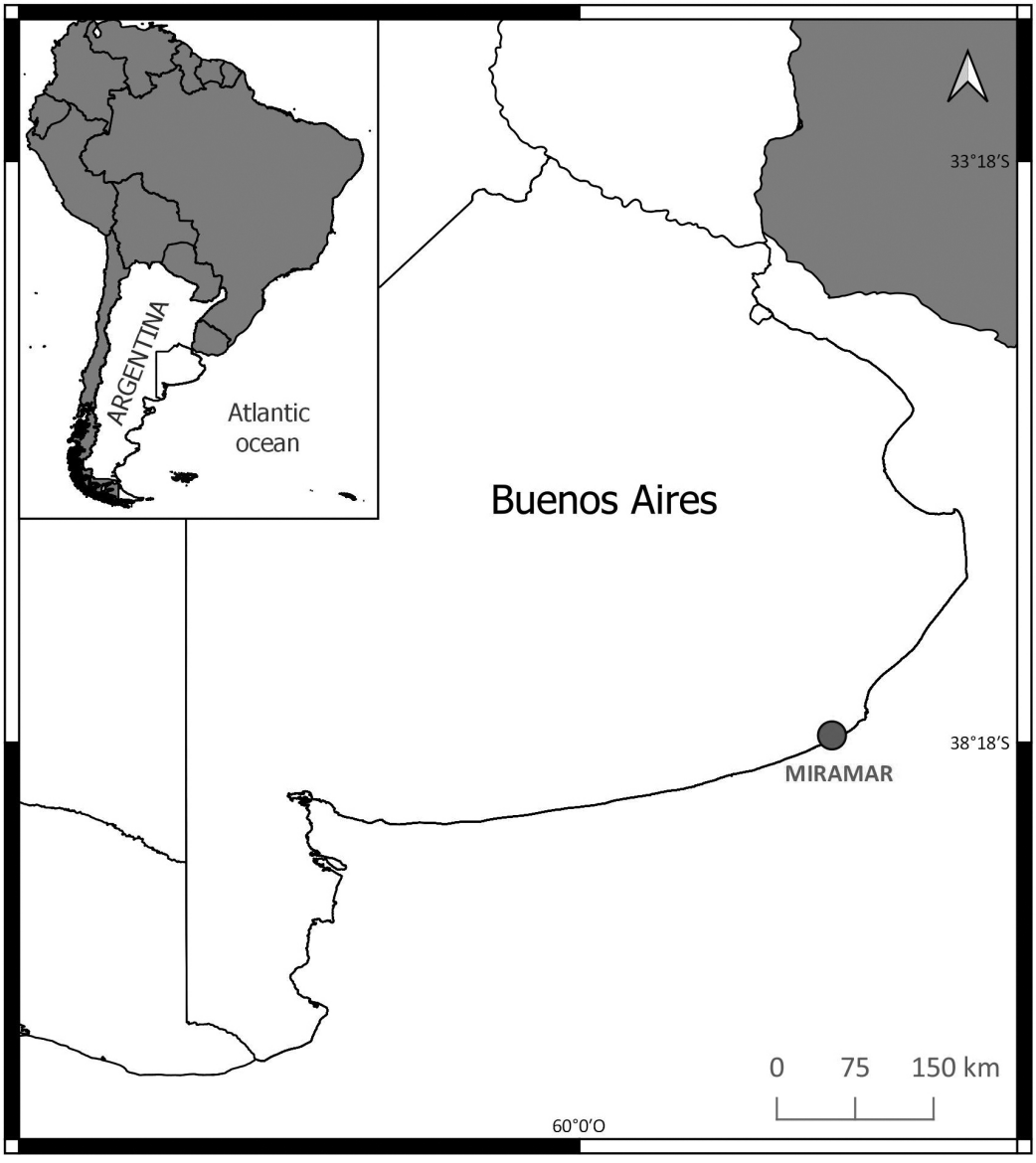

Figure 1. Study area location of southern right whales (*Eubalaena australis*)—Miramar, Buenos Aires Province

results from this study might assist in developing additional management actions that would contribute to potential regional protection of SRWs in the southwest Atlantic.

Observations were made from the 20th and 21st floors (69.5 and 72.5 m above average sea level, respectively) of a building located at Miramar's promenade (38° 16' 34" S, 57° 50' 3" W). At the study's beginning, monthly land-based observations were conducted from April to November 2016 and between April 2017 and March 2018. This relatively long sampling season was needed to establish the months when whales were most frequently observed. Once this exploratory phase was completed, searching effort was focused on the period of higher whale occurrence (July through October) for subsequent study years (2018 and 2019). Observations were conducted only when environmental conditions were appropriate for visual surveys (e.g., low wind intensity ≤ 25 km/h, Beaufort sea scale ≤ 3, air visibility). The area was scanned for SRWs by one observer (EZ) using sampling methods described by Altmann (1974) and Mann (1999) with the aid of 7 × 50 Fujinon reticulated binoculars. Each 3-min scan was followed by 2 min of rest. Each sighting was defined as a unique and independent event whenever an individual or a group of whales remained visible in the study area. A new sighting was only logged if a group had not been seen previously for longer than 30 min. Groups were defined as individuals swimming in a coordinated manner within 100 m of each other and performing similar behavior.

The sighting per unit of effort (SPUE) was calculated for each month of study, and sighting data were analyzed using a General Linear Models (GLM) framework. Both the Poisson and Negative Binomial GLM were applied to SRW sighting data. Covariates considered as predictor variables of SRW sightings included year and month; both were considered as continuous variables and factors. To determine whether there was evidence for a non-linear relationship between sightings and temporal variables, possible quadratic dependence was also explored for month. Given the relatively short period time series, there were insufficient data to assess possible year-to-year variation in encounter rates. Effort was included in all models as an offset. For model selection, Akaike Information Criterion (AIC) was used to indicate the most appropriate model (Franklin et al., 2001). Addressing model selection in a statistical framework allowed the evaluation of which data best supported our hypotheses about predictor variables and error structures.

The presence of SRWs was confirmed between May and October, with a peak period of most sightings from July to October. SPUEs were similar in their distribution for all years, with a peak in August or September and a maximum value recorded in September 2019 (4.75 SPUE; Table 1; Figure 2).

The most supported GLM based on the lowest AIC score treated year as a linear predictor, assumed a negative quadratic dependence on month, and had a negative binomial error distribution. This model suggested that SRW sightings off Miramar increased 30%/y (SE = 0.097; 95% CI = 11 to 50%/y) from 2016 to 2019.

Table 1. Summarized sightings and sighting per unit of effort (SPUE) of southern right whales (*Eubalaena australis*; SRWs), 2016 to 2019 (the symbol "--" means no effort in that month)

	2016			2017			2018			2019		
	No. of sightings	Effort (h)	SPUE	No. of sightings	Effort (h)	SPUE	No. of sightings	Effort (h)	SPUE	No. of sightings	Effort (h)	SPUE
January	--	--	--	--	--	--	0	25.95	0.00	--	--	--
February	--	--	--	--	--	--	0	23.45	0.00	--	--	--
March	--	--	--	--	--	--	0	35.05	0.00	--	--	--
April	0	19.35	0.00	0	33.30	0.00	--	--	--	--	--	--
May	3	25.20	0.12	2	38.20	0.05	--	--	--	--	--	--
June	2	20.80	0.10	1	19.95	0.05	--	--	--	--	--	--
July	15	30.95	0.48	14	31.35	0.45	30	32.5	0.92	40	27.40	1.46
August	145	32.85	4.41	70	27.25	2.57	152	34.65	4.39	89	27.50	3.24
September	10	16.65	0.60	72	19.15	3.76	79	24.45	3.23	138	29.05	4.75
October	1	22.95	0.04	7	10.10	0.69	13	24.10	0.54	18	19.00	0.95
November	0	10.80	0.00	0	17.50	0.00	--	--	--	--	--	--
December	--	--	--	0	22.90	0.00	--	--	--	--	--	--

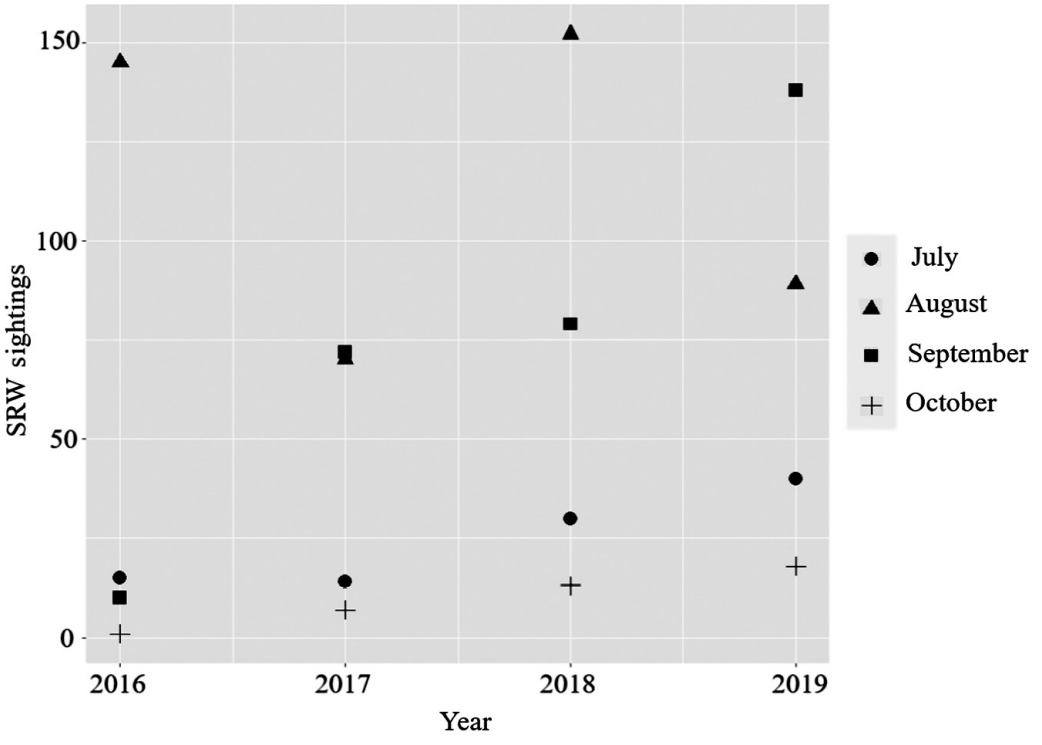

Figure 2. Number of SRW sightings by month per year

Table 2. Models of SRW sighting using year, month, and quadratic month as predictor variables and their AIC value

GLM	Variables	Error	AIC
0	0	Poisson	664.28
1	Year	Poisson	631.10
2	Year + month	Poisson	633.05
3	Year + month + month^2	Poisson	203.59
4	0	Binomial	161.21
5	Year	Binomial	162.23
6	Year + month	Binomial	163.84
7	Year + month + month^2	Binomial	142.10

With 4 y of systematic studies off Miramar (2016 to 2019), we were able to determine that SRWs were seasonally present in the area, and sightings occurred between May and October with a peak in August and September. The negative quadratic dependence of sightings with month presented in the GLM supports this finding. The peak in SRWs' seasonal occurrence near Miramar is consistent with seasonal abundance peaks in Golfo San Matías in north Patagonia (Arias et al., 2018); on the nursery ground of Santa Catarina, Brazil (IWC, 2012); and along Península Valdés, Argentina, where the greatest abundance of the species is typically documented at the end of August or in mid-September (Crespo et al., 2019).

The greatest occurrence of SRWs in Miramar in August and September could be related to a higher abundance of copepods (Oithonidae), particularly *Oithona nana*, in waters close to the study area. From 2000 to 2017, Viñas et al. (2021) showed an

increase in the abundance of Oithonidae throughout our study period with elevated concentrations for winter and even higher levels in spring at an EPEA station (Estación Permanente de Estudios Ambientales/Permanent Station of Environmental Studies) of the INIDEP (Instituto Nacional de Investigación y Desarrollo Pesquero), located approximately 25 km offshore Miramar. These findings coincide with an increase in the concentration of chorophyll-a (total fraction Chl_{total} and that contributed by the phytoplankton fraction less than 5 μm in diameter $Chl_{<5}$) for the same period and area (Silva, 2011; Ruiz et al., 2020). Furthermore, whaling records show that SRWs killed south of 50° S had stomachs filled with krill; those captured north of 40°S had their stomachs filled with copepods; and those in between these latitudes fed on a mix of krill and copepods (Tormosov et al., 1998). Recent studies showed that SRWs use three primary feeding grounds (Patagonian Shelf, IGS/SGI) and the Polar Front (Rowntree et al., 2008; Valenzuela et al., 2009, 2018; Jackson et al., 2020), but more recent satellite tracking studies indicate that feeding areas span much of the Scotia Arc and that some of these various feeding grounds can be visited within the same season (Zerbini et al., 2016, 2018). Observations of foraging SRWs were recorded in Miramar waters (Fundación Cethus, unpub. data, 2020). Although SRWs feed on copepods of the genera *Calanus* and *Pleuromamma* (Tormosov et al., 1998), we cannot rule out that they do not utilize high concentrations of Oithonidae in the study area. Changes in diets to take advantage of other prey availability have been observed in gray whales (*Eschrichtius robustus*; Moore, 2016; Hildebrand et al., 2021; Moore et al., 2022). Further studies of fatty acids and compound-specific isotopes of whales and their candidate zooplankton prey could help to better distinguish the species of prey being consumed off Miramar.

In years in which observations occurred between November and April (2016, 2017, 2018; see Table 1), no SRWs were recorded near Miramar. This seasonal pattern is consistent with that population off Península Valdés (where whales typically arrive in late April or early May and remain in the area until November or even late December; Crespo et al., 2019), and off southern Brazil (where the whale season spans from July to November; Rowntree et al., 2020). During the austral summer and fall, sightings of SRWs have been recorded far from shore, along the outer continental shelf and shelf-break of Argentina, and in circumpolar latitudes (e.g., Orcadas Islands, IGS/SGI) by both historical whaling notes and recent studies (Rossi-Santos et al., 2007; Valenzuela et al., 2009, 2018; Zerbini et al., 2015, 2016, 2018; González Carman et al., 2019). Four main locations have been described where the whales spend most of their time between October and December (Zerbini et al., 2018): (1) the coast of Argentina near Península Valdés and Golfo San Matías; (2) the outer continental shelf and slope off the South American coast between 35º and 52º S, and the 100 and 200 m isobaths; (3) the South Atlantic Basin between 40º and 50º S and 25° and 60° W; and (4) areas around IGS/SGI and the Mar del Scotia (Scotia Sea).

The 30%/y increase in sighting rate in the study area may be related to the population growth within these two main nursery grounds: 6 to 7%/y for Península Valdés (Crespo et al., 2011; IWC, 2013b; Cooke et al., 2015) and 12% in Brazil (IWC, 2012) coupled with an expansion in the SRWs' use of the South American coast. Sueyro et al. (2018) postulated that in the breeding ground of Península Valdés, the recorded expansion to new areas by some group types and a change in coastal habitat use patterns are consequences of population growth. Considering the geographical location and the observed seasonality, it is possible that the Buenos Aires Province coastline may represent an important SRW coastal habitat. In 2012, the IWC established a Conservation Management Plan (CMP) for southwest Atlantic SRWs (IWC, 2012). The CMP's research actions include an evaluation of the species' migratory connections within wintering grounds and between its feeding and nursery areas. The continuation of this study (e.g., land-based surveys with theodolites to assess distribution and behavior and collecting photo-identification data to distinguish individuals) is relevant to better understand habitat use and other potential factors (such as an El Niño event and change in the sea surface temperature) that might influence seasonal patterns of SRW occurrence off the coast of the Buenos Aires Province. At the local scale, understanding the distribution and behavior of SRWs near the coast of the Buenos Aires Province will be important for the community and authorities to implement regulations in compliance with whale conservation and responsible whale-watching activities. In addition, it is important that research and conservation efforts to promote recovery continue and that the population remains protected.

Acknowledgments

The authors thank the following people and institutions for their support during fieldwork: M. Hevia, V. Reyes Reyes, A. Marino, J. I. Lamas, M. Mercatante, K. Españadero, the Iñíguez family, the Lamas family, Fundación Cethus, Prefectura Naval Argentina, Miramar's Secretary of Tourism, Culture and Sport, Inmobiliaria Perata, Playa Club building employees, and Montecarlo Hotel. This study was financially supported by Whale and Dolphin Conservation (WDC), IBM Argentina,

The Rufford Foundation, and Kilverstone Wildlife Charitable Trust. Research was conducted through permits issued by the Dirección Provincial de Recursos Naturales de la Provincia de Buenos Aires – Organismo Provincial para el Desarrollo Sostenible (OPDS).

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