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INTERNATIONAL WHALING COMMISSION

Satellite tracking of Southern right whales (*Eubalaena australis*) from Golfo San Matías, Rio Negro Province, Argentina

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ABSTRACT

Satellite transmitters were deployed on nine southern right whales (*Eubalaena australis*) in Golfo San Matías, Province of Rio Negro, Argentina in October 2016 (n=1) and September 2017 (n=8). This region is located nearly 200 km north of Peninsula Valdés (PV), the main breeding and calving ground for this species in the western South Atlantic Ocean. Tag duration varied between 46 and 204 days (average of 117 days). Movement patterns showed marked individual variation. Five individuals moved southwards towards Golfo San José and Golfo Nuevo, in PV shortly after tagging. Four other whales moved north along the coast of the Buenos Aires Province in Argentina and of Uruguay. Movement patterns in coastal areas suggest that whales in the northern Golfo San Matías regularly visit areas further to the south in PV, but interestingly only whales tagged in the former migrated northward along the coast. All whales eventually moved east towards offshore waters of the outer continental shelf and shelf break along the coast of Argentina (from the La Plata River to the Falkland/Malvinas Islands). Most whales tracked until later in the season (after January) migrated east/southeast towards South Georgia/Islas Georgia del Sur and the Scotia Sea/Mar de Escocia, where they remained for the duration of their tags. One individual was migrating east past 22°W of longitude when the tag stopped transmitting. Behavioral states estimated by a hierarchical space-state model indicate areas of potential foraging importance in the outer continental shelf off southern South America, the South Atlantic Basin, the Eastern Scotia Sea/Mar de Escocia and the northern Weddell Sea/Mar de Weddell. These findings complements others from an ongoing long-term study to understand the migratory routes and destinations of southern right whales wintering off the coast of Argentina and, overall, reveals that this species inhabits vast extensions of the South Atlantic Ocean and visits multiple potential feeding areas each season.

KEYWORDS: SATELLITE TELEMETRY, SOUTHERN RIGHT WHALES, WESTERN SOUTH ATLANTIC, MIGRATION, FEEDING GROUNDS

INTRODUCTION

Southern right whales (SRWs) were depleted to near extinction by whaling in the late 1800s (IWC, 2001; 2013). After full protection in 1935, this species has been recovering (Best et al., 1993; Cooke et al., 2001; IWC, 2001; 2013). The coast of Argentina houses one of the largest SRW breeding aggregation in the Southern Hemisphere. Abundance in this region was estimated at nearly 4,200 individuals in 2009 with an annual growth rate of 6-7% over the past 40 years (Cooke et al., 2001; Crespo et al., 2011; Cooke, 2013; IWC, 2013). Whales typically congregate in two protected gulfs around Peninsula Valdés (PV), Golfo Nuevo and Golfo San José, in the Province of Chubut. However, in recent years, aggregations of whales have been observed in other areas along the coast such as the northern Golfo San Matías, near San Antonio Oeste, in the Province of Río Negro (Arias et al., 2017).

Whales in PV have died in unprecedented numbers over the past decade, primarily impacting calves under 3 months of age and with a significant variation in number from year to year (IWC, 2011; Rowntree et al., 2013; Sironi et al., 2016). Causes for this high mortality are unknown but there is concern that it is affecting population growth rates (Marón et al., 2015). The IWC Scientific Committee recommended satellite tagging studies to determine the

migratory routes and destinations of SRWs in the western South Atlantic because knowledge of these areas could help explain the causes for mortality observed in PV (IWC, 2011; 2013) and because it contributes to further develop management actions in the recently-created Conservation Management Plan (CMP) for this population. In fact, the IWC's CMP highlights that determining local movements, migratory routes and the location of feeding ground(s) for SRWs in the South Atlantic Ocean is a top priority.

Several feeding grounds have been suggested for SRWs in the Southwest Atlantic based on historical catch records (Tormosov et al., 1998), with different prey species consumed at different latitudes and regions. But the precise information on the location(s) and utilization of the main feeding grounds for this whale population is still poorly known. As these locations are determined, the scientific community can then focus on characterizing such habitats from an environmental and ecological perspective, providing information on the availability and seasonality of resources, and exposure to toxins, pollution and infectious agents along the entire migratory habitats of SRWs wintering off southeastern South America.

In 2014, a long-term satellite tagging study was initiated off the coast of Argentina in order to address recommendations by the IWC SC and identify movement patterns of SRWs in the western South Atlantic (Zerbini et al., 2015; 2016). A whale tagged in 2015 revealed a connection between whales in PV and those found further to the north, near San Antonio Oeste. In 2016 and 2017, tags were deployed in this locality to investigate movements of animals visiting the northern Golfo San Matías. Results of tagging in these years are presented here.

MATERIALS AND METHODS

Integrated transdermal configurations of location-only SPOT5 and SPOT6 satellite tags were deployed on nine SRWs in Golfo San Matías, one in October 2016 and eight in September 2017 (Table 1, Fig. 1). One tag did not transmit properly and just provided 149 locations for a period of 56 sequential days of transmissions. This tag was not used in the statistical movement analysis reported here, but its transmission period was used to calculate transmission duration statistics. Instrumentation was performed from a tagging platform mounted on the bow of a fiberglass speedboat following the methods described in Zerbini et al. (2016). Tags were deployed with a custom-modified pneumatic line thrower (Heide-Jørgensen et al., 2001; Gales et al., 2009) and biopsy skin samples were collected concurrently to tag deployment for genetic characterization and sex determination. Whenever possible, sex of tagged individuals was determined by their role in a social group (e.g. mother with a calf) or by examination of photographs of the genital area of a tagged whale.

Table 1 – Southern Right Whales tagged in Golfo San Matías in 2016 and 2017.

Whale ID	Whale Name	Date/Time of Tagging	Tag Duration	Number of locations received	Social Class/Role	Sex
81123.16	Villarina	10/14/2016 13:35	73.43	1633	Mother	F
87627.17	Mandarina	9/15/2017 13:15	166.45	3387	Adult	TBD
87762.17	Segunda	9/16/2017 17:32	189.27	4217	Adult	TBD
81125.17	Lolita	9/18/2017 16:47	204.30	4614	Adult	F
84498.17	Traviata	9/19/2017 12:05	100.50	3854	Adult	TBD
87634.17	Gaucha	9/19/2017 13:23	46.44	1115	Adult	F
87766.17	Mariposa	9/20/2017 15:09	95.37	2067	Adult	TBD
87636.17	Saltimbanqui	9/21/2017 12:34	56.48	139	Adult	TBD
87637.17	Cherubino	9/22/2017 18:03	123.25	4074	Adult	TBD

Argos data processing and analysis followed the methods described in Zerbini et al. (2015, 2016). Briefly, Argos locations were filtered using the R package 'argosfilter' (Freitas et al., 2008; R Development Team, 2013) and modeled using a hierarchical Bayesian switching state-space model (hSSSM) (Jonsen et al., 2005, 2007; Jonsen, 2016; Bailey et al., 2009) as implemented in the R package 'bsam'. This package fits the hSSSM using Markov Chain Monte Carlo (MCMC) simulations via software JAGS (Plummer, 2003) and the model allows for location estimates to be inferred from the observed Argos locations by accounting for measurement errors and from the dynamics of the movement process (Patterson *et al.*, 2008). Two behavioral modes were estimated and were assumed to represent transiting (mode 1) and 'area restricted search' (ARS) behavior (mode 2). Predicted locations

for each whale were estimated at six hour intervals. Two MCMC chains were run in parallel, each for a total of 20,000 samples. The first 10,000 were discarded as burn-in. The posterior distribution of behavioral modes was approximated by retaining every 20th sample in the remaining chain to reduce auto-correlation (thus keeping 500 samples from each chain, for a total of 1000 samples). While two behavioral modes were estimated for each MCMC simulation, the means of the MCMC samples provided a continuous value from 1 to 2 for each location predicted by the model. We assumed the behavioral state to correspond to ARS if the posterior mean at each location was >1.75, as transiting if the mean was <1.25, and as uncertain otherwise (Jonsen et al., 2007; Bailey et al., 2009). Locations estimated as ARS behavior were used to estimate high-use habitats by SRWs.

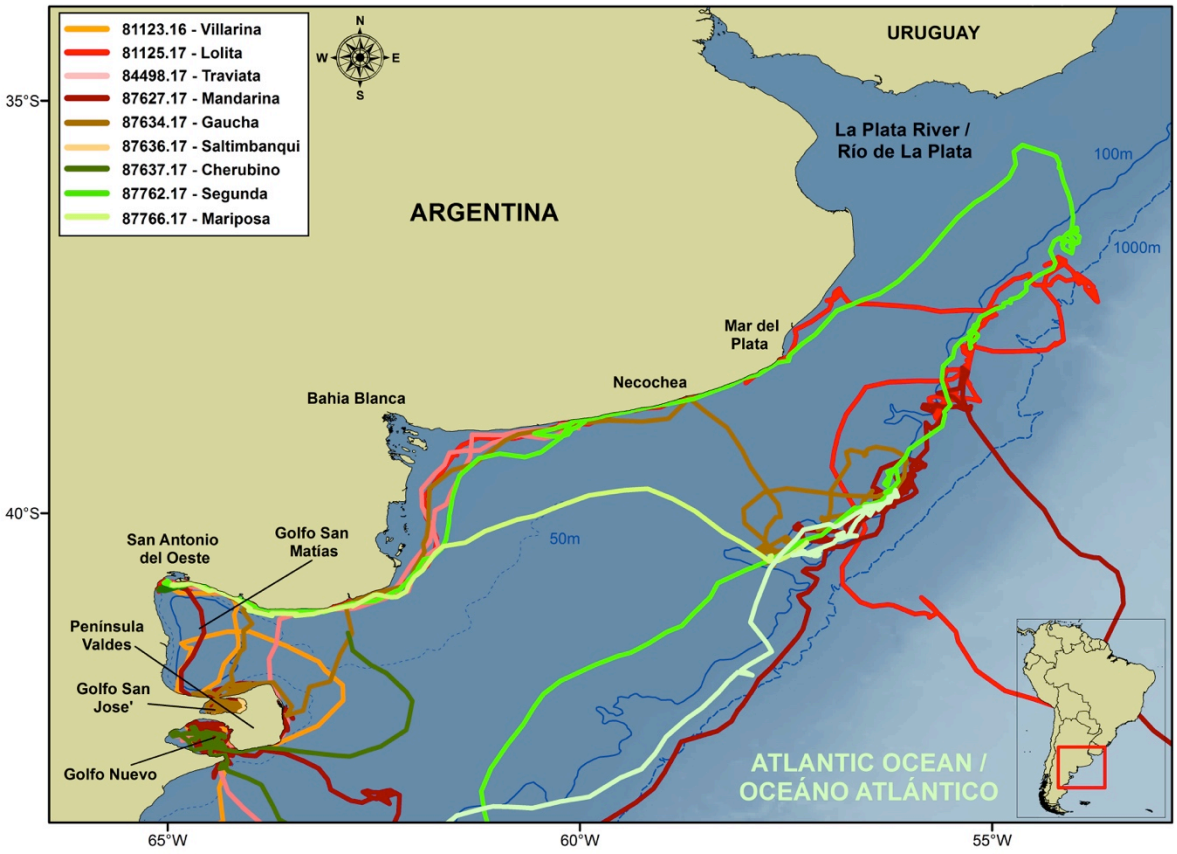

Fig. 1 – Tracks in coastal areas of Southern right whales tagged in Golfo San Matías in 2016 and 2017.

RESULTS AND DISCUSSION

Tag duration ranged from 46 to 204 days, with average and median durations of, respectively, 117 and 101 days. These constitute the longest mean and median duration across all published satellite tracking studies of any right whale species.

Coastal Movements

Telemetry data revealed that whales tagged in the northern Golfo San Matías moved to various locations along the South American coast (Fig. 1). Four individuals (Whale IDs 81125.17, 84498.17, 87762.17, 87766.17) moved north along the coast of the Rio Negro and Buenos Aires Provinces, migrating past Bahia Blanca, Necochea, Mar del Plata as far north as the La Plata River, off of the Uruguayan coast (Fig. 1). These individuals typically moved close to shore following the coastline, with only occasional 'stops' at certain locations (e.g. areas where the hSMMM predicted behavioral models classified as ARS, Fig. 2). Examples, of regions were whales changed behavior

correspond the northeastern Golfo San Matías and an area south of Mar del Plata (Fig. 2). One of the whales that moved north along the coast of Argentina (Whale ID 84498.17) subsequently turned back and visited PV/Golfo Nuevo.

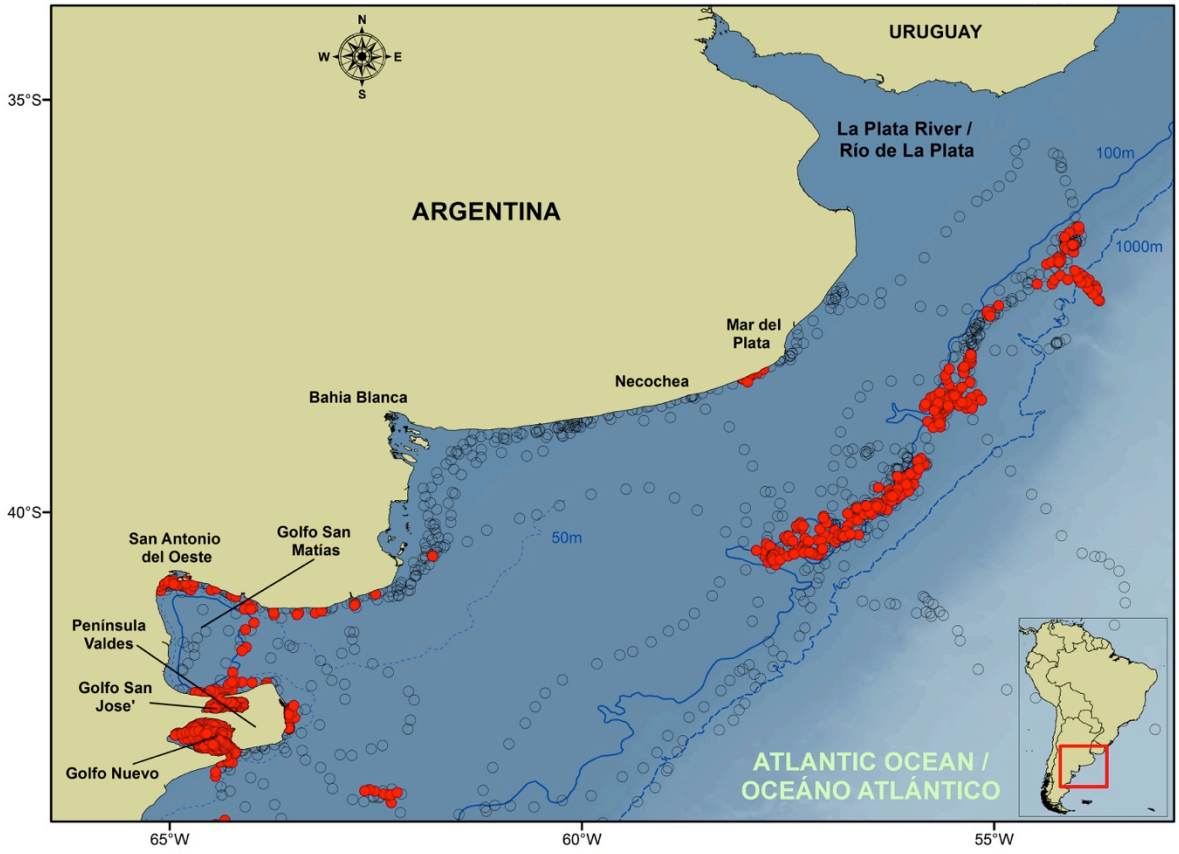

Fig. 2 – Behavioral modes (red dots) estimated as area restricted search (ARS) near coastal habitats off the coast of Argentina for SRWs tagged in Golfo San Matías in 2016 and 2017. Open circles represent estimated locations not classified as ARS.

Five other whales (Whale IDs 81123.16, 87627.17, 87634.17, 87636.17, 87637.17) visited PV, including the east coast of the Peninsula or one or both of the gulfs in this region (Golfo San José and Golfo Nuevo) (Fig.1). The high proportion of behavioral states estimated as ARS (Fig. 2) is consistent with previous studies demonstrating that the waters around PV constitute important (mating and calving) habitats for SRWs (Payne et al., 1990; Cooke et al., 2001, Rowntree et al., 2001). One individual (Whale ID 87634.17) moved from Golfo San Matías towards Golfo San José and the east coast of PV before turning back and migrating north along the northeast coast of Argentina.

SRW movements in coastal waters off Argentina suggest that a relatively large proportion of whales (>50% in this study) in Golfo San Matías regularly visit PV. The connection between these two relatively close regions was expected given that some animals tagged in PV in previous years made trips towards the northern areas of Golfo San Matías (Zerbini et al., 2015; 2016). Interestingly, only animals tagged in Golfo San Matías migrated north of the Río Negro Province along the northern coast of Argentina.

Migration/Offshore Movements

All whales tagged in Golfo San Matías in 2016 and 2017 moved towards the outer continental shelf and shelf break of the South American coast. These individuals typically remained between the 100 and 1000m isobaths from the La Plata River/Rio de La Plata (~35^{o}S) and an area to the west and around the Falklands/Malvinas at approximately 52^{o}S (Fig. 3). Four whales migrated from the outer shelf break toward offshore habitats in the southern South

Atlantic Ocean. Whale ID 81123.16 stopped transmitting within days of moving into the South Atlantic basin. Whale ID 87762.17 departed from the Argentinian continental shelf west of the Falklands/Malvinas towards an area to the west/southwest of the South Orkney Islands/Islas Orcadas del Sur in the southern Scotia Sea (Fig. 3). Two other individuals (Whale IDs 81125.17 and 87762.17) left the continental shelf off Argentina from middle latitudes (~38-40°S) and migrated southwest towards South Georgia/Georgia del Sur. The former made multiple trips between these islands and the eastern Scotia Sea/Mar de Escocia, and stopped transmitting southwest of the South Orkneys/Orcadas del Sur in an area close to where individual ID 87762.17 had been. These two whales explored this habitat at similar times, later in the summer and in the fall seasons (March and April 2018). Whale ID 87627 migrated across the Scotia Sea/Mar de Escocia and continued moving east by the time the tag stopped transmitting.

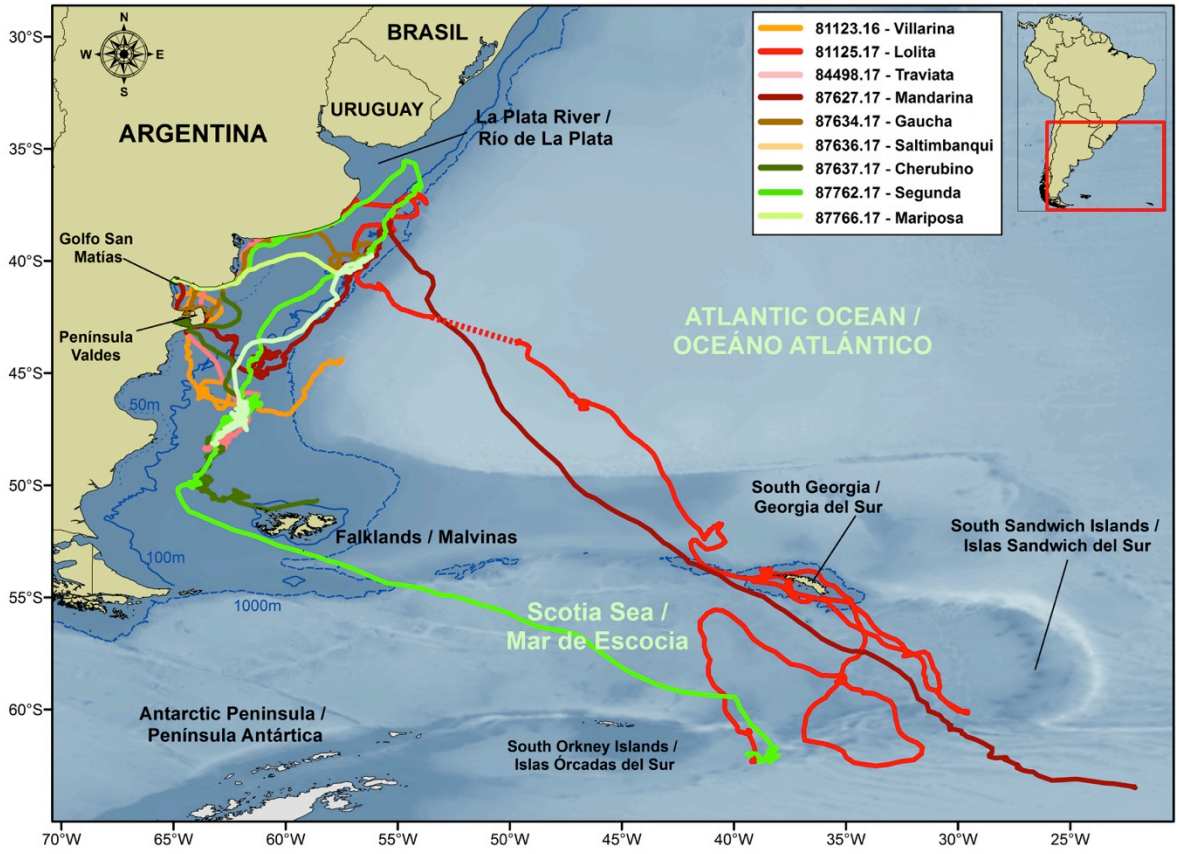

Fig. 3 – Tracks of SRWs tagged off the coast of Argentina in 2016 and 2017 showing migratory destinations in offshore habitats.

When tracks of whales tagged in Golfo Nuevo, PV in 2014 and 2015 (Zerbini et al., 2016) are compared to those from whales tagged in Golfo San Matías (Fig. 4), similar patterns emerge. For example, whales tagged in the two regions made extensive use of the outer continental shelf of Argentina, including waters around the Falklands/Malvinas. For the individuals that migrated away from the shelf, the general migration direction is to the SE towards the Scotia Sea/Mar de Escocia. However some differences in the movement patterns were noted. First, none of the whales tagged in Golfo Nuevo in 2014/2015 moved north along the coast of the South American continent (as seen in Figs 1 and 4 for the individuals tagged in 2017). Also, whales tagged in Golfo San Matías explored habitats in higher latitudes. Notably, three individuals migrated to the southern Scotia Sea/Mar de Escocia and areas immediately to the north of the Weddell Sea/Mar de Weddell. None of the whales tagged in 2014 and 2015 had occupied these habitats. Because of the relatively close proximity of tagging locations of whales instrumented in 2014/15 (Golfo Nuevo, PV) and 2016/17 (Golfo San Matías) and because of the connectivity (demonstrated by movement of tagged animals) between both regions, it is not surprising that whales tagged in the two different locations would behave similarly. The differences in movement patterns reported above likely

correspond to individual variation or inter-annual variability leading, for example, to differences in habitat suitability across years. However, further studies are required to provide additional data to better understand variation in habitat use by SRWs in the western South Atlantic.

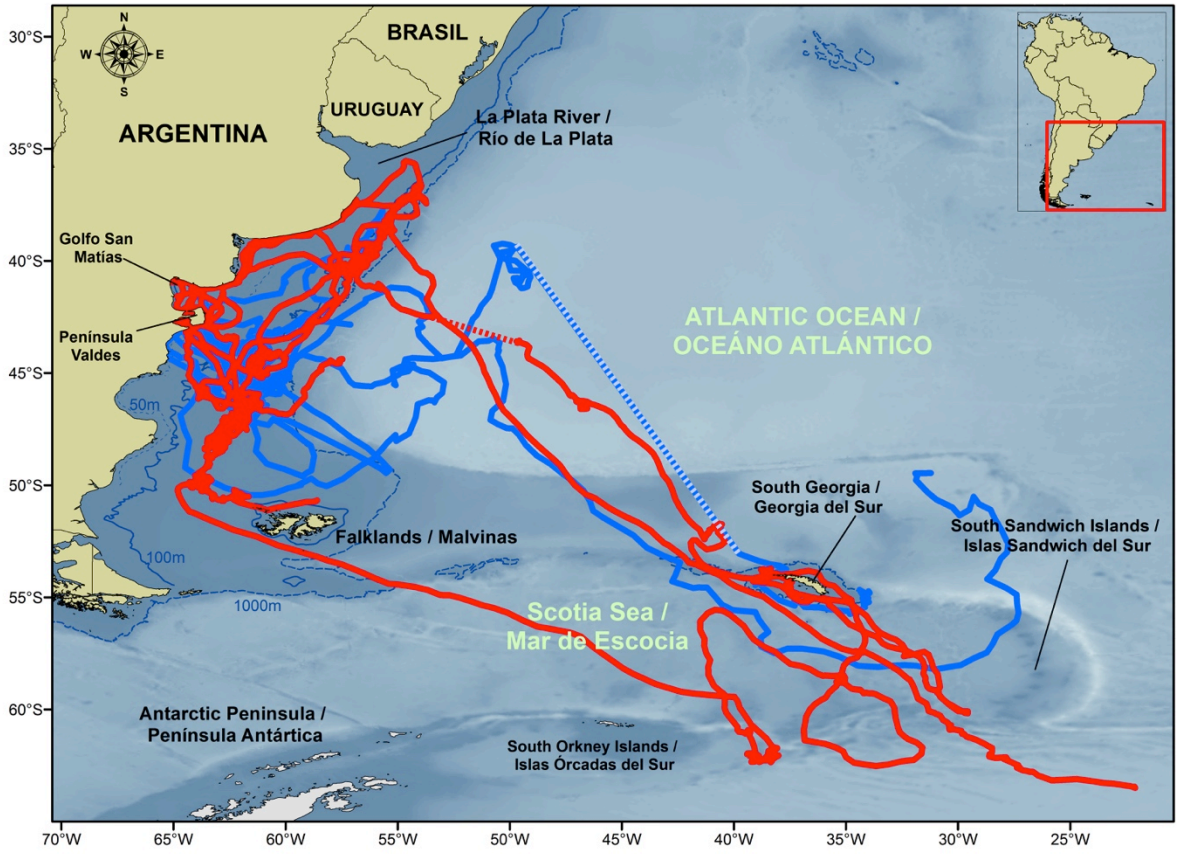

Fig. 4 – Tracks of SRWs tagged off the coast of Argentina in 2014/15 (in Golfo Nuevo, Peninsula Valdés, blue) 2016/17 (in Golfo San Matías, red lines) showing movement patterns and migratory destinations. Dotted lines connect tracks of individual whales in periods without transmission.

Results of the hSSSM indicated high densities of ARS locations (areas of high use) in the outer shelf and slope from approximately 35° to 53°S, which is expected given the amount of time all whales spend in the region (typically between October and December) (Fig. 5). Areas with ARS were also observed in the South Atlantic Basin (~45°S), to the northeast of South Georgia/Georgia del Sur and within and to the south of the Scotia Sea/Mar de Escocia (Fig. 5). Behavioral states estimated by the hSSSM for whales tagged in 2014/15 (from Zerbini et al., 2016) and those reported above indicated the predominance of ARS locations in four main areas (Fig. 5):

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 35°S and 52°S and the 100m and the 200m isobaths,
3) The South Atlantic Basin between 40°S and 50°S and 25°W and 60°W.
4) Areas around South Georgia/Georgia del Sur and the Scotia Sea/Mar de Escocia.

The relatively high use of waters near PV by right whales has been known for at least 40 years (Payne et al., 1990; Cooke et al., 2001, Rowntree et al., 2001) as the species uses the relatively calm waters of Golfo Nuevo and Golfo

San José as a breeding and calving ground. It is likely that Golfo San Matías is also an important habitat and a potential extension of the breeding/calving grounds near PV.

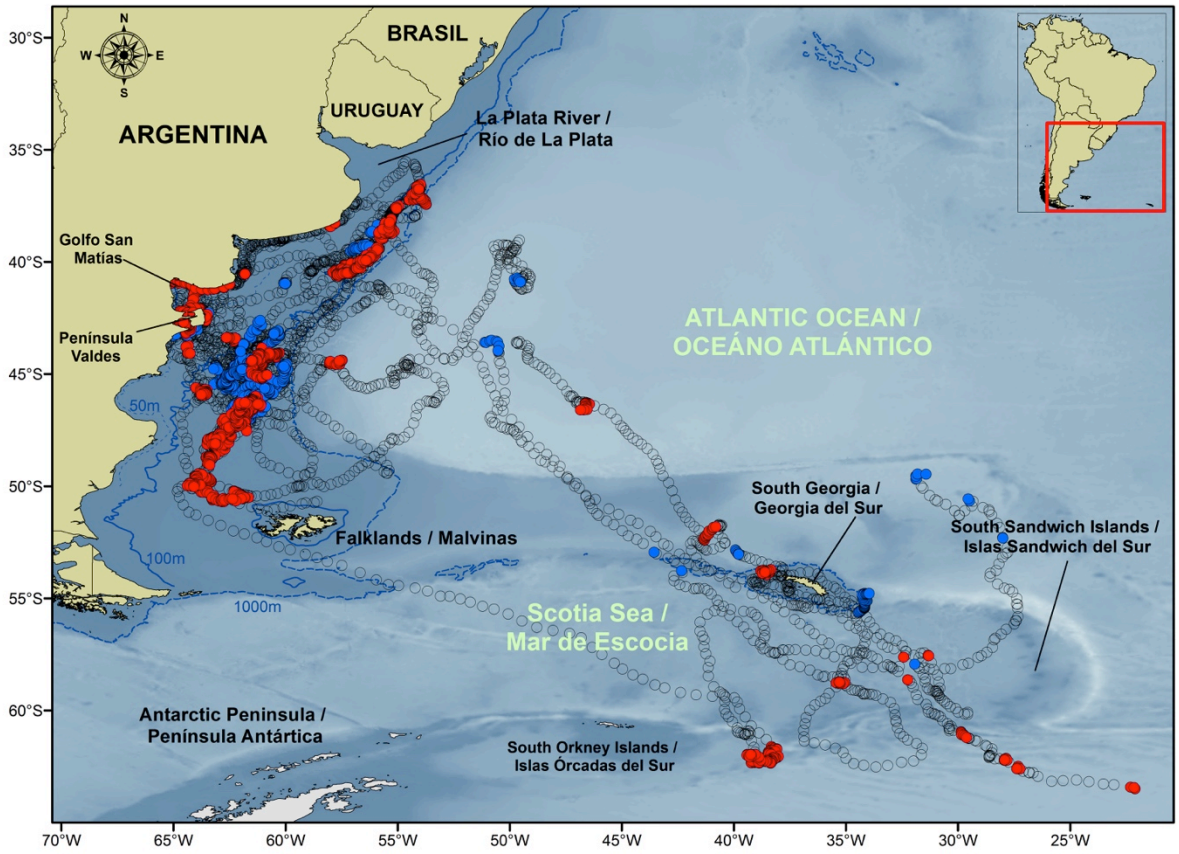

Fig. 5 - Areas of high use (behavioral modes estimated as Area Restricted Search – ARS) of SRWs tagged off the coast of Argentina in 2014/15 (blue circles) and 2016/17 (blue circles). Open circles represent estimated locations not classified as ARS.

Assuming that behavioral states estimated as ARS represent feeding once animals move away from their mating/calving grounds, it is clear that the outer shelf and slope along the southern coast of South America represent important habitats for SRWs after the breeding season. Almost all whales inhabited this region for periods of time that ranged from a few weeks to several months. In at least one case, a whale tagged in 2014 spent the entire feeding season in this area before returning to PV the following year (Zerbini et al., 2015). The shelf and shelf break off southeastern South America have been historically used by right whales (Townsend, 1935). More than 1,000 whales were illegally killed by the Soviets in the 1960s (Tormosov et al., 1998) in this region, emphasizing the importance of these habitats for SRWs. Interestingly, a gap in the distribution of ARS locations was consistently seen over the shelf between 40 and 44°S (Fig. 5) over the four tagging years. While whales regularly moved within this area, they did not engage in searching behavior and this perhaps suggests an area of lower habitat suitability. Future examination of the oceanographic conditions and perhaps other data types (e.g. zooplankton biomass) may assist in explaining the reasons for this gap.

The occurrence of SRWs in South Georgia/Georgia del Sur has also been relatively well documented in the early 20th century and also during the 1960s whaling (Tormosov et al., 1998; IWC, 2001) and more recent sighting data (Moore et al., 1999; Richardson et al., 2012). This region has been regarded as a feeding destination of some SRWs wintering off PV (Best et al., 1993; Rowntree et al., 2001). While whales do occur near South Georgia/Georgia del

Sur, it is clear that the animals move around the Scotia Sea/Mar de Escocia and adjacent areas suggesting the feeding habitats in these regions cover an extensive area.

Telemetry data shows that SRWs moved between different habitats in the western South Atlantic during their feeding season, notably areas #2, 3 and 4. In many cases, the same whale visited the three regions, clearly indicating the potential for foraging in multiple regions (and on potentially different types of prey) within the same season. Nonetheless, the movements of these individuals to different foraging areas provides specific evidence that may be consistent with different isotopic signatures of prey/SRW tissues samples analyzed from this population (Valenzuela et al. 2009; 2011) and with the movement patterns of SRWs in other regions (Childerhouse et al., 2009; Mate et al., 2011).

Conclusions

While our sample size from these years of tagging may be considered small, the dedicated effort over the last 4 years has resulted in 23 tags being deployed on SARW in this region. This study has provided new insights into current feeding areas and the first direct assessment of inter-annual variability for habitat-use outside of PV. Clearly, additional satellite tagging is needed to better understand how representative and consistent are the seasonal movements towards feeding destinations. This will be important to examine, particularly if different cohorts of animals (especially females and mothers) exhibit some fidelity or inter-annual variation, while taking into account animals of different age, sex and reproductive classes. In this case, more consistent patterns in movements and habitat-use will likely emerge. Provided some additional funding can be secured to complement existing resources, we intend to continue and hopefully increase tagging efforts in the upcoming years.

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