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Working plan for assessing movement rates between breeding grounds of southwest Atlantic southern right whales applying multi-state analysis

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INTRODUCTION

Southern right whales (SRW, *Eubalaena australis*) of the SW Atlantic Ocean gather every winter along the coasts of Argentina, Brazil and Uruguay (Costa et al., 2005; Groch et al., 2005; Simões-Lopes et al., 1992; Whitehead and Payne, 1981). Based on the analyses of mtDNA and microsatellite loci, the SW Atlantic SRW are part of a single population stock that uses different calving grounds (Carroll et al., 2020; Oliveira et al., 2011; Ott et al., 2011), where Península Valdés (PV) in Argentina and the southern Brazilian coast have the largest concentrations. SRW have been studied since 1971 at PV and since 1987 in southern Brazil. Since then, aerial surveys were conducted for photo-identification, and the photographic records were used to identify individuals based on the distinctive callosity patterns on their heads (Payne et al., 1983).

Despite SRW that calve off Argentina and Brazil being part of the same population, assessments on population dynamics have been conducted separately for each region. Several population parameters were estimated for SRW off PV in earlier years using mark-recapture methods (Payne et al., 1990; Whitehead et al., 1986), and then, theoretical models were developed specifically for the PV population (Cooke et al., 2015, 2003, 2001). Studies over the past five decades have provided information on whale population and trends. Estimations derived from theoretical models and using mark-recapture data of adult females, indicated a population growth rate of 6.5 $\pm$ 0.2 % from 1970 to 2012 (Cooke et al., 2015). Population growth at PV was estimated of 3.15% annually between 1999-2015 (95% IC 0.53% – 5.75%) using Generalized Linear Models

framework and aerial censuses (Crespo et al., 2019). For SRW in southern Brazil, a rate of increase of 14% per year (95% IC 7.1% – 20.9%) was estimated between 1987 and 2003 using a linear regression of the natural log of the number of identified females (Groch et al., 2005). Later, a rate of increase of 12.0% (CI 8.5- 14.2%) was estimated by applying theoretical models developed by Cooke et al. (2003) and analysing the data over the period 1987-2010 (IWC, 2012). Recents studies applying mark-recapture methods to female sightings were performed for both regions (Renault-Braga et al. 2021 and Agrelo et al. under review). A rate of increase of 4.2% (CI 95%, 3.9-4.5) was reported by using the data from PV and considering the effects of climate change on female survival (Agrelo et al. under review). An updated population size using POPAN and Pradel models resulted in 569 (±38) mature females and a rate of increase of 4.8% (CI 95%, 3.6-6) was reported recentely for southern Brazil (Renault-Braga et al. 2021, SC/68c/SH/XX). Future population growth and abundance assessments will be addresed by Justin Cooke including the data from both regions.

Events of high mortality were observed in both regions. Between 2007 and 2015, an increase in calf mortality was observed in PV (Rowntree et al., 2013; Sironi et al., 2018). The Southern Right Whale Health Monitoring Program has been monitoring this population by post-mortem examinations since 2003. From 2003 to 2019, 810 dead whales were found at PV and surrounding areas (an average of 50 whales per year) (Di Martino et al., 2019) with a peak of 116 strandings in 2012 (Sironi et al., 2018). Biotoxins, infectious diseases, malnutrition, the physiological and behavioral effects of Kelp Gull (*Larus dominicanus*) attacks on newborn calves, and density-dependent processes are some of the hypotheses that have been proposed to explain high calf mortality (Fernández Ajó et al., 2020, 2018; Marón et al., 2018, 2015; McAloose et al., 2016; Wilson et al., 2016). Recently, new results suggested that the stress from injuries (predominantly due to Kelp Gull harassment) could be a contributing factor to calf deaths of SRW at PV (Fernández Ajó et al., 2020, 2018; Sironi et al., 2018). A recent analysis using mark-recapture models showed that gull harassment decreases calf survival (Agrelo et al., in prep). In Santa Catarina, Brazil, strandings have been recorded since 2002, and monitored systematically since 2015. From 2002 to 2020 there were 42 right whale strandings, with the highest number recorded

in 2018 (n=11). From the total, 33 (78.6%) were calves of the year, 2 (4.8%) were juveniles and 7 (16.7%) were adults. The high number of strandings in 2018 was coincident with the highest number of right whales sighted in the aerial survey conducted in September 2018 in Brazil. Pathologic findings and causes of death were investigated in eight individuals (out of 27) in which necropsy was possible, between 2010 and 2017 (Groch et al., 2019a). The animals were mostly calves (7 newborns/calves, 1 adult) and males (5 males, 3 females). The main causes of stranding and/or death were neonatal respiratory distress syndrome and trauma of unknown origin. An important finding was that three animals were PCR-positive for cetacean morbillivirus (Groch et al., 2019b), which has been cause of death in other cetacean species (Van Bressem et al., 2014).

Due to the high calf mortality events observed at PV and the link with gull harassment, a Conservation Management Plan (CMP) was implemented in 2012 for the SW Atlantic SRW population (Iñíguez Bassega et al., 2012). The CMP aims to protect SRW by monitoring attributes of the population, minimizing anthropogenic threats and maximizing the likelihood of recovering to healthy levels and recolonize their historical range (Iñíguez Bassega, 2018). The CMP suggested to compare reference catalogues from all areas used by this population with the aim of providing key information for future population assessments.

Mark-recapture models can be used to estimate population parameters from live-encounter data, such as apparent survival and other demographic parameters for wildlife populations (Lebreton et al., 1992). During the last decade, several studies applied mark-recapture likelihood-based methods to estimate population parameters of large cetaceans, mainly for humpback whales (*Megaptera novaengliae*) and fin whales (*Balaenoptera physalus*) (Ashe et al., 2013; Galletti Vernazzani et al., 2017; Orgeret et al., 2014; Ramp et al., 2014; Schleimer et al., 2019; Teerlink et al., 2015; Wedekin et al., 2017). For North Atlantic right whales, this methodology was used to estimate the survival probability in a study that identified an abrupt decline in the population size (Caswell et al., 1999). For SRW of New Zealand, population size was estimated by mark-recapture methods with photo-identification data combined with microsatellite genotyping (Carroll et al., 2011, 2013), and for SRW in southeastern Australia a rate of increase and population

size were estimated applying POPAN superpopulation models (Stamation et al., 2020). However, these methodologies have not yet been applied to estimate movement rates in large cetaceans.

PROPOSED WORKING PLAN

During IWC SC 2020, the SH sub-committee highlighted the need to have a "multi-state mark-recapture and population dynamic analysis of Brazil-Argentina photo-ID data to assess movement rates between regions" in the SW Atlantic (Scientific Committee Report SC/68B IWC, 2020). Combining Argentina and Brazil datasets and the matches between calving grounds (Rowntree et al., 2020, SC/68b/CMP/20) we will apply mark-recapture multi-state models for assessing movement rates between calving grounds and region-specific survival. In adittion, we aim to address biological hypotheses about the influence of micropredation by Kelp Gulls, high calf mortality and density-dependence processes at PV on movement probabilities. We expect to complete these analyses and present them at the Scientific Committee meeting in 2022.

Available data from Argentina and Brazil catalogues

Península Valdés in Argentina (42° 30′ S, 63° 56′ W) is the largest calving ground for SW Atlantic SRW population. Aerial photoidentification surveys were conducted from 1971 to 2019. Analyses have been completed through 2018 and the catalogue currently includes 3,921 individuals. In the coast of Southern Brazil (28°29´ S, 48°45' W), aerials surveys have been conducted irregularly from 1987 to 1994 and annually since 1997 to present. Data analysed up to 2020 include 1,024 identified individuals.

By comparing both catalogues, 124 matches were found (Rowntree et al., 2020, SC/68b/CMP/20). Most of the whales sighted in both calving grounds were first identified at PV and later in Brazil (n=65), followed by individuals first identified in Brazil and later seen at PV (n=37). The remaining individuals (n=22) switched between calving grounds in more than one occasion.

Region-specific survival and movement rates between regions

Multi-state analysis (Nichols and Kendall, 1995) will be applied to the combined Argentina-Brazil database to estimate the transition probability between regions, and to estimate region-specific survival and recapture probability. Sightings will be collapsed by year and each year will be considered as one capture occasion. The database will be organized into individual encounter histories within a presence-absence matrix of sightings for each occasion, and a photo-identification-based recapture history will be created for each individual. For individuals identified and recorded only in Argentina and only in Brazil, the presence in the encounter history will be represented as A and B, respectively. Whales seen in both calving grounds in different years will have a sequence of "A" or "B" in their encounter histories. We aim to address movement probabilities between regions in both direction (ψ^{AB}, ψ^{BA}), region-specific survival (ϕ^{A}, ϕ^{B}) and region-specific recapture probabilities (p^{A}, p^{B}). Models will include the effect of transients, heterogeneity in recapture probability and the influence of time on these parameters.

Influence of covariates on movement probabilities

After modelling region-specific survival and movement rates between regions, the selected model will be used to address the influence of external covariates on movement probabilities. The probability that a whale moves from a calving ground to another, may vary over time. Also, population increase was likely to be influenced by biological processes at PV during the study period. Therefore, we will investigate the influence of Kelp Gull micropredation, calving failure and density-dependent processes (through the number of whales observed each year) on movement rates between Argentina and Brazil.

Participants

The analysis will be done by Macarena Agrelo as part of her postdoctoral research with the collaboration of Justin Cooke. The Right Whale Program in Argentina (Instituto de Conservación de Ballenas and Ocean Alliance), co-directed by Victoria Rowntree and Mariano Sironi, will provide the data from PV. Victoria Rowntree processed the photos, analysed the data and prepared the database from PV, with the collaboration of Carina Marón and Florencia Vilches (Instituto de

Conservación de Ballenas). Karina Groch (Instituto Australis) processed the photos and provided the database from southern Brazil and Eduardo P. Renault-Braga (Instituto Australis) will organise the data from Southern Brazil and contribute with the statistical analyses.

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