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Intersessional working group report: Multi-ocean assessment of southern right whale demographic parameters and environmental correlates

Doug Butterworth, Justin Cooke, Claire Charlton, Els Vermeulen, Andrea Ross-Gillespie, Anabela Brandão, et al.

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Multi-ocean assessment of southern right whale demographic parameters and environmental correlates

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Primary Investigators of the IWC-SORP funded project

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1. Executive summary

The work of the Intersessional Working Group (WG) "Multi-ocean assessment of southern right whale (SRW) demographic parameters and environmental correlates'" aims to compare SRW population demographics across the main southern hemisphere (SH) wintering grounds. This is to be achieved by applying a common demographic model to the populations in each region: Southwest (SW) Atlantic (Argentina/Brazil), Southeast (SE) Atlantic (South Africa), Australia and New Zealand, in order eventually to test hypotheses for the relationships between reproductive success and environmental variables. The project is an integral component of the International Whaling Commission Southern Ocean Research Program (IWC-SORP) Theme 6, "The right sentinel for climate change: linking foraging ground variability to population recovery in the SRW". The IWC-SORP funding proposal related to this WG, submitted in January 2020 (SC/68b/O01), was successful.

Key progress made between April 2021 and March 2022 includes:

- The Southern Right Whale Consortium was established to facilitate multi-ocean collaboration and to develop data quality control standards – the related Memorandum of Understanding has initially been signed by 11 southern right whale researchers, and remains open to all those interested.

- At the time of the last report, the version of the common model applied to the SW Atlantic data incorporated an additional “unsuccessful mother” component. This explicitly modelled the number of females experiencing late abortions or early calf deaths, as this was found to be important for fitting to the data for the region. This component was not present in the version of the model applied to the South African data. Since then, this component has been included in the formal specification of the common model. The coding for this inclusion is almost complete, with model-fitting to commence soon. The model will first be fit to the South African data, then to the other available data sets.
- A global desk-top assessment of southern right whale sightings South of 40°S was completed by honours student Cuyler van Jaarsveld (University of Pretoria). Data were collected from multiple sources and used to produce maps in order to visualize where and when SRWs were sighted. A total of 357 sightings data points were collected from 13 separate sources, including SOWER cruises, CCAMLR, Happywhale, PROANTAR, ObsInt, IWC reports and the South Georgia Heritage Trust Database. A full report can be seen at SC/68d/SHxx

2. Introduction

The International Whaling Commission (IWC) Scientific Committee (SC) Southern Hemisphere (SH) intersessional working group (WG) for ‘Multi-ocean assessment of southern right whale (SRW) demographic parameters and environmental correlates’ (SC/67b/SHWP12 and SC/68a/SHWP19) was formed and endorsed during SC67b (2018). This work forms an integral part of IWC-SORP Theme 6, “The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale (SRW)”. An IWC-SORP funding proposal to advance the work of this WG, submitted in January 2020 (SC/68b/O01), was successful.

This multi-ocean collaborative project aims to compare population demographics across the main SH wintering grounds, by applying a common demographic model to the populations in each region in order eventually to test hypotheses for the relationships between demographic parameters (reproductive success, survival and population increase) and environmental variables. It involves 22 researchers from 7 countries and utilises 50+ years of data from SH wintering grounds to inform IWC-SH subcommittee priority species assessment for SRWs, and to address priority areas for IWC-SORP. The regional populations with available long-term photo identification (ID) databases which are available to be included are: (1) SE Atlantic (South Africa), (2) SW Atlantic (Argentina/Brazil), (3) Australia and (4) New Zealand.

3. Objectives

Specific objectives include:

1. To establish a SRW Consortium to develop data quality control standards, identify analytical biases, and facilitate multi-ocean collaboration.
2. To specify of a common demographic model to estimate life history parameters for the main breeding populations, which is to include: calving interval, age of first parturition, mortality (of calves and non-calves) and population growth.
3. To obtain comparable estimates of the key parameters of the demographic model and of population growth rates for the populations from each of the major wintering grounds.

4. To collate published and available information in a desktop review of contemporary feeding grounds to inform the selection of environmental variables for further investigation of links between demographic parameters (especially reproductive success) and climate.

Progress towards achieving the specific objectives is summarised below.

4. Results

Objective 1: *Southern Right Whale Photo ID consortium*

A Memorandum of Understanding (MoU) was finalized for the formation of a SRW consortium, in which partners agree to collaborate with an ultimate goal to generate scientific data on the species on a circumpolar scale, which could not be achieved by individual research groups alone. The first, and most urgent, project undertaken by this consortium relates to the collation of long-term photo-identification and sightings datasets to allow for a comprehensive assessment of the global population status of southern right whales under a common statistical and biological model - the fundamental goal of this project. For more information, see SC/68c/SH07.

The initial signatories to the SRWC MoU are listed below. They relate to IP holders of long-term sighting history data of individually identified southern right whales, data needed to be shared for the successful completion of this project. Obviously, the consortium remains open to include further interested partners who wish to collaborate towards a better understanding and conservation of the species. The number of projects that can be conducted under the consortium's umbrella is unlimited. The MoU is non-binding, and project-specific data sharing agreements will be established underneath the umbrella provided by the consortium.

- Mandy Watson - Department of Environment, land, water and planning, AU
- Mariano Sironi – ICB, ARG
- Karina Groch – Instituto Australis, BR
- Will Rayment – University of Otago, NZ
- Kris Carlyon – Department of Primary Industries, Parks, Water and Environment, AU
- Emma Carroll – University of Auckland, NZ
- Alexandre Zerbini – University of Washington and NOAA, USA
- Jennifer Jackson – British Antarctic Survey, UK
- Victoria Rowntree – University of Utah, USA
- Els Vermeulen – University of Pretoria, SA

A first virtual meeting of the SRWC is planned to be held just prior to the SC68d meetings to discuss ways forward, after which meetings may be held (bi-)annually.

Objective 2: *Development of common SRW demographic model*

2.1. Model structure

Specification of the common SRW biological model (common model) is now complete, with a new feature added of explicitly modelling an "unsuccessful mother" component for females experiencing late abortions or early calf deaths. The model will allow various demographic parameters (e.g., true calving intervals and their changes over time, population growth rates) to be estimated for the different SRW populations. Major datasets have been provided for model input from Argentina/Brazil, Australia and South Africa. A New Zealand dataset will be requested once model runs are complete for datasets from the regions listed above.

This common model which accommodates the various aspects of the different SRW populations is shown schematically in Figure 1. Reproductive females are divided into (newly) Pregnant, Calving (lactating) (i.e., successful mothers), Unsuccessful mothers (females experiencing late abortions or early calf deaths) and Resting stages. The "normal" reproductive cycle is three years, consisting of one Austral winter season in each of the pregnant, calving and resting phases, with the calving phase disaggregated into successful mothers and unsuccessful mothers (Figure 1). However, there are various alternative paths that are each associated with a probability parameter which is to be estimated from each dataset (where possible). Some or all of these probability parameters may vary with time. It is these variations which this project hopes to relate to environmental factors (i.e., prey availability and climate variates) in future modelling (not covered under the IWC-SORP funded work scope SC/68b/O01). The probability parameters correspond to the following events:

α: a female becomes pregnant again after weaning its calf and skips the usual resting year (resulting in a 2-year calving interval if that pregnancy proceeds to term)

β: a resting female chooses to rest for a further year (resulting in a 4-year calving interval if followed by a normal cycle)

γ: a pregnant female loses its foetus too late to become pregnant again the same year, and reverts to the resting phase without having given birth (resulting in a 5-year calving interval if followed by a normal cycle)

δ: a pregnant female loses it foetus early and becomes pregnant again, thus spending a consecutive year in the pregnant phase (resulting in a 4-year calving interval if followed by a normal cycle).

$\boldsymbol{\lambda}$**: a** pregnant female is an "unsuccessful mother", i.e., experiences a late abortion or an early calf death and rests the following year.

$\boldsymbol{\beta}^*$: an unsuccessful mother (that rested a year after losing its calf in a late abortion or in an early calf death before it could be observed) rests an additional year.

(The probabilities of the paths are determined by the requirement that the transition and remaining probabilities for each state sum to the survival rate.)

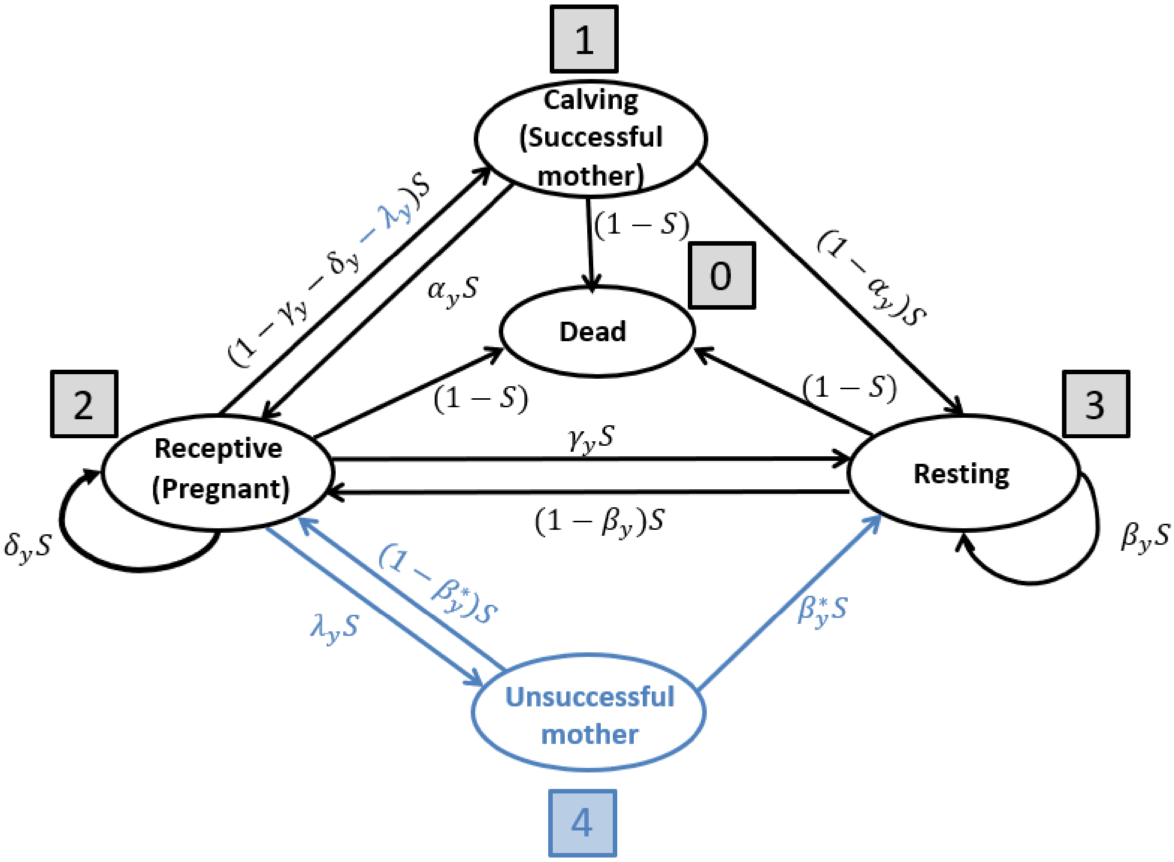

Figure 1. Schematic outline of the common biological model. Text and arrows in black correspond to the Brandão *et al.* (2021) model and blue text and arrows to the additional component explicitly modelling the number of females experiencing late abortions or early calf deaths. This component has been added under the guidance of J. Cooke (*pers. comm.*) in accordance with the model previously applied to the SW Atlantic data.

The coding for the final common model is nearly complete. Runs to be undertaken will include the South African and the Argentina/Brazil SRW photo-ID sightings data because these data are familiar and available to the modelling team. The next steps after that are to include other datasets, including Australia and New Zealand, and to compare demographic parameters.

Exploratory fits will be required to determine which parameters can be reliably estimated for each data set. For example, the additional parameters required to fit the SW Atlantic situation (λ and β^*) may not be well estimated from the South African data. For its part, the SW Atlantic data set may lack sufficient inter-annual contrast to estimate the δ parameter, which was originally introduced to accommodate the South African data. If it is found that not all parameters are separately estimable for all data sets, then discussion will be required to determine suitable values or priors for the remaining parameters. The Australian dataset will be ready for exploratory fitting once the coding is finalised; this will be undertaken to identify any further issues that may not be apparent in the SW Atlantic and SE Atlantic (South African) datasets.

2.2. Application to South African data

Previous results reported here (and in Brandão *et al.* 2021) were based an application of an earlier draft of the common model which did not include the "unsuccessful mother" component. This model was an extension of the model of Brandão *et al.* (2019) to include the parameter, δ, to allow for a four-year calving cycle resulting from early abortions, so as to be able to account for recent increases in calving intervals indicated by the data.

The results obtained previously indicated that inclusion of the "delta-loop" alone was not sufficient to eliminate the possibility of unrealistically low sighting probability estimates for some recent surveys. This necessitated the inclusion of a penalty term in the model fitting procedure to obtain results more consistent with the annual survey effort which has been quite stable over time. However, a coding error was recently discovered, and the corrected results now show that the "delta-loop" is able to account for nearly all of the very low number of sightings of cow-calf pairs (see Figure 2). The correction to the code has changed the estimates for other parameters only slightly

Further work is ongoing to assist in drawing inferences about which environmental conditions may link to the delays in whale calving for this population of southern right whales (SC/68A/SH/12).

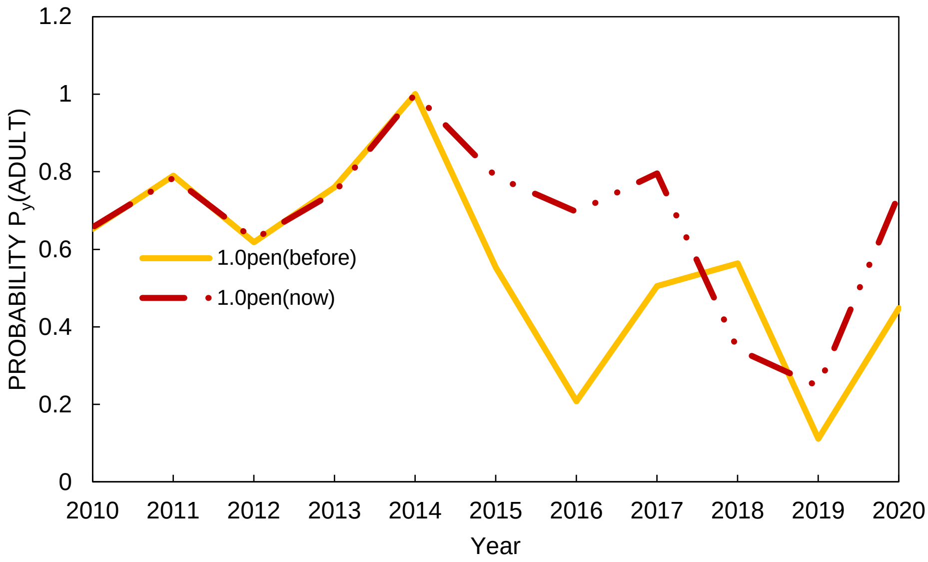

Figure 2. Estimated probabilities of observing a cow-calf pair on South African aerial surveys for recent years under the draft common model before and after the coding correction.

2.3. Application to the Argentina/Brazil data

The collection of Photo-ID for this region was summarised in the previous report.

Demographic Model

The biological model for reproductive females, which is close to the current proposed common model, except that γ is set to zero, is embedded into the demographic model for the entire population based on that developed by Cooke *et al.* (2015). This model is designed to be fit to the entire data set including whales without calves. However, for comparison with earlier implementations of the model for Argentina (e.g., SC/55/O23) and with the implementation used for South Africa (see above), the model will also be fit to cow-calf data only.

A further feature of the SW Atlantic data sets is a high degree of heterogeneity, and the exploratory fits found that large number of nuisance parameters were required to account for different sighting probabilities between the whales in various states and between individuals, where the relative probabilities also seem to vary over time. These additional parameters are required to fit the data, but do not require changes to the common biological model.

Exploratory model fitting

Some progress has been made in fitting the model to the SW Atlantic data, but as a result of unforeseen circumstances, updated results are not yet available.

2.3. Application to the Australian data

The Australian data have been made available to analysts, and have been pre-processed for input to the common model. Once the model coding has been completed and the model has been fit to the South African data, it will be fit to these Australian data. The Australian dataset is somewhat smaller than the South African dataset, so difficulties in estimating certain parameters may be experienced, but the extent of this will only be known once the fitting process commences.

Objective 3*: Obtain comparable estimates of the key parameters of the demographic model and of population growth rates for the populations from each of the major wintering grounds*

This will be addressed after the final development of the common model.

Objective 4: *Identification of foraging grounds to inform selection of environmental correlates*

A desktop study was conducted by Cuyler van Jaarsveld in the scope of his BSc Hons project at the University of Pretoria, under supervision of Drs Vermeulen and Carroll. The aim was to collate all published and unpublished data, grey literature, and other readily available information on the global occurrence SRWs, offshore and south of 40°S into a comprehensive review over the period 1980-2020. The goal is to use these data to advance understanding on the location of offshore SRW foraging grounds, likely leading to the ability to select environmental variables which may be relevant for the future investigation of links to reproductive success, pertinent to objective 2 and 4 of the IWC-SORP Theme 6.

Sighting data points were gathered from various sources including published and unpublished data and other readily available sources. Data from published literature and other databases were collected by searching for relevant journal articles, maps, books and encyclopaedias via Google Scholar as well as recognized databases including Encyclopaedia Britannica, JSTOR, PANGEA, South Georgia Heritage Trust (SGHT) and Scopus. Data from unpublished data and other available sources were collected by searching through Google Scholar and most importantly by obtaining a letter endorsed by SORP (Appendix 1) which allowed for the sending of data requests to various organisations and research vessels including the SC-IWC, Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), Polarstern (research icebreaker from Alfred Wegener Institute for Polar and Marine Research), Brazilian Antarctic Program (PROANTAR), Southern Ocean Whale and Ecosystem Research Program (SOWER), Happywhale, Marine Mammals Research and Conservation Discussion

(MARMAM), and Observation International (ObsInt). Furthermore, a data request was also posted on the IWC-SORP website to increase exposure for the study with the purpose of maximizing data collection.

A total of 357 sightings data points were collected from 13 separate sources, with the majority of the sightings data, 91.3%, collected from organisations and databases (n=326), while 8.7% was collected from published literature (n=31). The largest collections of data came from the South Georgia Heritage Trust database (n=109) comprising 30.5% of all data, and SOWER (n=95) contributing 26.6% of all data. Sightings data from CCAMLR (n=50) made up 14% of the data collected, with Happywhale data (n=32) comprising 9%. PROANTAR data (n=10) comprised 2.8%, while data from PANGEA (n=5) and Nijs and Rowntree (2017) (n=6) made up 1.4% and 1.7%, respectively. Furthermore, both ObsInt data (n=13) and data from IWC reports (n=13), comprised 3.6%, while data contributed by Moore et al. (1997) (n=11) and data provided by Dr. Marc Eléaume from the National Museum of Natural History in France (n=11) , made up 3%. Polarstern data (n=1) and data from Moore et al. (1999) (n=1) both contributed 0.3%.

A full report can be seen in SC/68d/SHxx

Progress was also made towards improving understanding of foraging grounds through satellite tagging, stable isotopes and historical catch data, which are outlined further in the IWC-SORP Theme 6 report (SC/68d/SHXX).

5. Conclusions

Objectives 1 and 4 were finalised, and substantial progress was made towards fulfilling objective 2.

- A Southern Right Whale Consortium was established, and the related MoU has already signed by 11 researchers.
- A common demographic model has been agreed upon and the coding is almost complete. Application of this model to the South African data will commence shortly, followed by the other available data sets (SW Atlantic and Australia). Exploratory fits will be required to determine which parameters can be reliably estimated for each data set. If it is found that not all parameters are separately estimable for all data sets, then discussion will be required to determine suitable values or priors for the remaining parameters.
- A desktop review was completed to assess SRW offshore sightings South of 40°S, ultimately to inform the selection of environmental variables for further investigation of links between demographic parameters (i.e., reproductive success) and climate.

The collaborators of this IWC-SORP funded project would like to acknowledge the contribution of the long-term photo-ID sightings datasets and the considerable far-sighted efforts of key researchers from each region. In particular, Peter Best and John Bannister are acknowledged for establishing the South African and Australian programs and the long time series of data from these regions are critical for the investigation of the important issues which this project plans to address.

6. Challenges

Given the complexity and intricacies of the common model, the implementation of the changes to the code to incorporate the new aspects of the common model have not been straightforward. Further challenges are envisioned with the application of the common model to the various datasets. Each dataset has characteristics that are particular to that population, and therefore, as mentioned before, exploratory fits will be required to determine which parameters can be estimated reliably for each and some iterative process will probably be necessary before final results can be obtained. From previous experience in fitting models with fewer estimable parameters that took several hours to run, this exercise will likely prove very time-consuming.

7. Outlook for the future

Outline of how you see the project progressing and the resources that might be required

The project workplan outlines that the next steps to fulfil project objectives (1-4) include:

- Continue collaborative efforts under the SRWC to develop data quality control standards and identify analytical biases
- Complete the coding of the common model and apply to the various data sets available;
- Determine which parameters are estimable for which data set and determine suitable values for priors for the remaining parameters.
- Compare demographic parameters across the different SRW wintering grounds
- Investigate suitable environmental variables for further assess the links between demographic parameters (i.e., reproductive success) and climate.

Resources are available and work scheduled to hopefully deliver outputs by October 2022 as specified in IWC-SORP contracts.

8. Project outputs e.g. (Please follow style examples below)

a. IWC/SC papers

SC/68d/SHXX: Vermeulen E, Germishuizen M, Wilkinson C (2022) Report of the 2021 South African southern right whale aerial surveys. Report presented to the 68D IWC scientific committee (Southern Hemisphere Subcommittee), Cambridge, UK.

SC/68D/SHXX: *Charlton C, Vermeulen E, Carroll EL, Butterworth D, Justin C, Ross-Gillespie A, Brandao A, Groch K, Leaper R, Rayment W, Rowntree V, Sironi M, Watson M, Double M, Jackson J (2022) Progress Report on the intersessional working group "Multi-ocean assessment of southern right whale demographic parameters and links to environmental correlates", June 2021 to March 2022. Report presented to the 68D IWC scientific committee (Southern Hemisphere Subcommittee), Cambridge, UK*

9. Scientific references cited in report (Please follow style examples)

Brandão A, Vermeulen E, Butterworth DS (2019). Updated application of a photo-identification based assessment model to southern right whales in South African waters to include data up to 2018. Report presented to the 68Ath IWC scientific committee (Southern Hemisphere Subcommittee), Nairobi, Kenya. SC/68A/SH/14.

Brandão A, Ross-Gillespie, A, Vermeulen E, Butterworth DS (2021). Updated extension of a photo-identification based assessment model to southern right whales in South African waters to allow for the possibility of an early abortion of the calf in the model. Report presented to the 68Cth IWC scientific committee (Southern Hemisphere Subcommittee), held virtually. SC/68C/SH/05.

Cooke J.G, Rowntree V, Sironi M (2015) Southwest Atlantic right whales: interim updated population assessment from photo-id collected at Península Valdéz, Argentina. Paper SC/66a/BRG/23 presented to the IWC Scientific Committee.

Moore M J *et al.* (1999) 'Relative abundance of large whales around South Georgia (1979-1998)', *Marine Mammal Science*, 15(4), pp. 1287–1302. doi: 10.1111/j.1748-7692.1999.tb00891.x.

Nijs, G. and Rowntree, V. J. (2017) 'Rare sightings of southern right whales (Eubalaena australis) on a feeding ground off the South Sandwich Islands, including a known individual from Península Valdés, Argentina', *Marine Mammal Science*, 33(1), pp. 342–349. doi: 10.1111/mms.12354.