SC/68C/SH/04

Sub-committees/working group name: SH

Report of the southern right whale aerial surveys 2020

Els Vermeulen, Chris Wilkinson, Gideon van den Berg, Sanne Paarman

Report of the southern right whale aerial surveys 2020

Els Vermeulen, Chris Wilkinson, Gideon van den Berg, Sanne Paarman

Mammal Research Institute Whale Unit
Department of Zoology and Entomology
University of Pretoria, South Africa

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Natural and Agricultural Sciences

Acknowledgements

These surveys were carried out under the auspices of ExxonMobil and Total, for which we are very grateful. We further wish to thank all those who supported this fieldwork, including Silvercross Helicopters, De Hoop Collection, Denel Overberg Test Range and private citizens along the route. Special thanks are given to Jean Tresfon for his contribution and support to conduct the aerial count survey.

All research was carried out under a permit from the Department of Environment, Forestry and Fisheries to approach whales and under specific Marine Protected Area permits from the relevant conservation authorities.

Content

Acknowledgements 2
Content 3
Abstract 4
Introduction 6
Methods and Procedures 7
Annual photo-identification aerial survey 7
Aerial count survey 8
Photo-identification analysis 9
Results 10
Annual photo-identification aerial survey 10
Aerial count survey 16
Photo-identification analysis 17
Discussion 18
Shift in peak presence 18
Observed calving intervals 19
Foraging ecology 19
Recommendations 20
Acknowledgements 21
Literature cited 22

Abstract

Annual aerial surveys have been carried out since 1969 to monitor the South African population of southern right whales (*Eubalaena australis*). From 1979, these annual surveys incorporated identification using photography of natural markings, resulting in an uninterrupted 41-year survey series of photo-identification history. Although these surveys have revealed the steady population increase since the protection of the species from commercial whaling, recent results of these surveys have indicated substantial changes in the prevalence of southern right whales on the South African breeding ground. These changes include 1) a marked decline of unaccompanied adults since 2010, 2) an increase in the reproductive cycle from the normal 3-year cycle to 4- and 5- year calving intervals since 2010, and 3) an enormous fluctuation in the number of cow-calf pairs along the South African shore since 2015.

The 2020 annual photo-identification aerial survey was flown between the area of Nature's Valley and Muizenberg in late September (27 to 29 September 2020) in a general westward direction, with the aim to count all southern right whales and photograph all females with calves as well as individuals with a brindle or grey blaze colouration. For this survey, an Airbus EC120B helicopter was used, chartered by Silvercross Helicopters. A total of 12 hours and 53 minutes of flight operations were required to complete the survey, of which 9 hours and 27 minutes were flown as search effort, and 3 hours 26 minutes were flown in transit to and from the survey start and end-points. In total, 67 cow-calf pairs of southern right whales (134 animals) and 31 unaccompanied adults were observed, leading to a total of 165 southern right whales. This the second-lowest number of cow-calf pairs along the South African coastline since 1986 (after the extreme low numbers of 2016 (55 pairs)). For unaccompanied adults, this marks the fourth-lowest count since the commencement of the aerial surveys.

In total, 67 cow-calf pairs and 19 unaccompanied adults were photo-identified during the survey. Subsequent data analysis indicated the presence of 4 duplicates in the dataset, leading to the identification of 82 unique individual southern right whales, including 64 cows. Of these, 30 could be matched to previously known females, giving results on 28 new inter-calving intervals (2 females were previously identified without a calf). The observed calving intervals indicated the majority of cows had a normal 3-year (68%), 6-year (11%) or 9-year (7%) calving interval. Considering a 6- and 9-year interval is assumed to be a combination of two and three normal 3-year calving intervals respectively, this result is remarkably different from the recently observed shift to a 4- and 5-year calving cycle since 2010. Photo-identification analysis further showed that 84% of the identified have been added to the catalogue post-2010 and thus presumably under the age of 20. Only 4 cows re-identified in 2020 were known to the catalogue since prior the year 2000.

Due to COVID-19 limitations, only one aerial count survey could be flown prior to the photo-identification survey, with the sole purpose to count cow-calf pairs in the area of Hermanus New Harbour and Witsand (covering the main nursery grounds). This survey was flown in an eastward direction on 21st August 2020 using an autogyro. Results of this survey indicated the presence of 71 cow-calf pairs and 11 unaccompanied adults in this limited stretch of coastline.

The decrease in whale numbers from the August count survey to the October photo-identification survey re-confirms a shift in peak presence from early October (when the annual photo-identification survey is flown) to earlier in the year. This is the 4th consecutive year in which an apparent shift in peak presence was shown, with hypothesis formulated on a reduced residency time of cow-calf pairs on their South African breeding ground. Whether or not the observed age and calving interval of the females photo-identified on the annual aerial survey this year is a result of a non-random component of the population being captured, remains to be determined.

The incessant low number of unaccompanied adults remains a concern in regards to the country's whale-watching industry (legislation prohibits the approach of cow-calf pairs < 300m), as accumulative effects of approaching vessels on cow-calf pairs could have energetic consequences for both cow and calf. However, considering the COVID-19 limitations on the South African whale-watching industry, these effects would have been negligible in 2020.

The observed demographic fluctuations in the South African southern right whale population reiterates the extreme value of this long-term dataset. An uninterrupted continuation of these survey series is therefore crucial, not only to monitor southern right whales in their breeding ground off South Africa, but also to improve our understanding of the changing state of the larger marine ecosystem these whales inhabit.

Introduction

Since their international protection in 1935, southern right whale (*Eubalaena australis*) populations have increased substantially from a mere 60 reproductive females in 1920 to some 13,600 individuals in 2009 (IWC, 2013). The South African population is believed to be the largest breeding stock of the global population, comprising some 6,116 individuals (Brandão et al., 2018) or > 30% of the total (IWC, 2013). This population, which occupies seasonal calving and nursery grounds in the nearshore and protected waters of the southern Cape coast, has been monitored through annual aerial surveys since 1969. From 1979 onwards, these annual aerial surveys have incorporated photo-identification (Best, 1981; Best, 1990; Best et al., 2001; Best 2011), a method by which individual whales are identified through overhead photographs of the callosity pattern on the head and/or skin pigmentation patterns found on the back (brindle colouration, grey blaze and white patches) (Payne et al. 1983). To reduce the length (and costs) of the surveys, since 1979 special focus is given to all nursing females and their calves (cow-calf pairs), as well as individuals with a brindle, white blaze or partial grey colouration (since 2005). This currently 40-year long database provides the necessary information for vital demographic parameters of the population to be modelled and estimated (including, for example, calving intervals, female survival rates and age at first parturition) (Best et al., 2001; Best et al., 2005).

However, recent results of this long-term database show abrupt changes in the population since 2010 including (a) an abrupt decrease in sightings along the South African coast of unaccompanied adults (i.e. adult whales without a calf incl. males and females without a calf), (b) extreme fluctuations in the number of cow-calf pairs since 2015 (Findlay et al., 2017), (c) an increase in calving intervals from 3-year calving intervals to 4- and 5-year intervals, suggesting calving failure (Vermeulen et al., 2018; Brandão et al., 2018), (c) an apparent shift in peak presence of cow-calf pairs in the South African breeding ground from early October to late August/early September (Vermeulen et al., 2018), and (d) a continued decrease in the population increase rate from 7.1% per annum in 2001 (Best et al., 2001), to 6.8% in 2011, 6.6% in 2012 and to 6.5% per annum in 2017 (Brandão et al., 2018). Together, these changes suggest that a fundamental demographic shift in the population may be in progress. Such data warrant further in-depth analyses and indicate that the continuation of the long-term monitoring of southern right whales within the calving grounds of the southern Cape is more vital than ever before.

This report provides the results of the 2020 southern right whale aerial surveys

Methods and Procedures

Annual photo-identification aerial survey

The annual helicopter-based photo-identification survey of southern right whales is conducted along the southern Cape coast of South Africa from Nature's Valley to Muizenberg (for locations see Figure 3) at the end of September - early October, a time when it is believed most calves are present along the coast (i.e. most calves have been born and have not yet left on their annual migration south). Operating procedures have been largely standardised over this 40-year survey-series (although technological advances have been incorporated where necessary). The survey is flown coastwise and generally westwards at an altitude of 330 m and a ground speed of 80-100 kts under adequate sighting and photographic conditions. The survey is generally conducted between 08h00 to 16h00 each day as glare compromises photography earlier and later in the day. The survey continues the following day from the point reached at the end of the previous day. In the past years, the surveys have been flown with an Airbus EC120B helicopter some 500-800 m offshore, with one observer searching inshore from the starboard forward seat, while a second observer searches offshore from the rear port seat (with assistance from the pilot on the port forward seat). If deemed advantageous, the observer in the rear seat could shift over to the starboard side of the helicopter and assist with spotting in a shoreward direction at times. Should glare interfere with sighting conditions, then the flight path would shift temporarily over the shore, with the pilot and rear observer searching seawards so as to increase sightability. The use of the Airbus helicopter has allowed for safer hovering capabilities, and the configuration within the helicopter has allowed for photographing in a southerly and easterly direction (by the observer in the rear port seat) limiting the exposure to glare from midday onwards and thus decreasing hovering times (see Figure 1).

All observed cetacean groups are recorded, including group size and composition, as well as time and position. If photography of southern right whales is required, the helicopter descends to an altitude of 150 m. The callosity patterns and pigmentation features of all cow and calf pairs and animals with a distinct colouration pattern are photographed by the rear observer using a Canon 7D EOS camera with a 100-400 mm lens. Once photography is complete the aircraft returns to an altitude of 330 m and resumes searching or moves directly to the next sighted group at an altitude of 150 m.

Figure 1. Picture of the Airbus EC120B helicopter in Cape Town International Airport, and in flight.

A support vehicle accompanies the aerial survey, allowing for daily provisioning of the survey team, transport of equipment and luggage, and, most importantly, rotation of observers during each day's survey if needed.

Aerial count survey

In order to examine the general increase of cow-calf pairs along the southern Cape coast during whale season (June to December), an additional aerial survey was carried out between Hermanus New Harbour and Witsand (for locations see Figure 3) using a light-weight autogyro (or gyrocopter; Figure 2) prior to the annual photo-identification survey. This year, only one such survey could be conducted due to COVID-19 limitations.

An autogyro is a small type of aircraft that uses an unpowered rotor in autorotation to develop lift, and an engine-powered propeller, similar to that of a fixed-wing aircraft, to provide thrust. It is a very fuel-efficient aircraft which allows for cost-effective monitoring of an extended coastal strip compared to an aeroplane or helicopter. However, an autogyro only allows for two passengers; the pilot who sits in the front and an observer in the rear. Additionally, due to the engine-powered propeller and an unpowered rotor, the autogyro has no hovering capabilities, and is often an open configuration. All these aspects make it difficult to collect photo-identification data while making notes and observations. Therefore, the sole purpose of these surveys is to count southern right whale females associated with calves as accurately as possible.

Figure 2. Image of the autogyro used for the count survey

The extent of coastline between Hermanus New Harbour and Witsand was chosen as it is believed to cover two of the main nursery grounds of the southern Cape coast; i.e. De Hoop Nature Reserve and Walker Bay (Elwen and Best, 2004). Although Saint Sebastian Bay (from Witsand to the East; Figure 3) is also known as a main nursery ground, this bay cannot be covered due to the fuel restrictions of the aircraft and financial limitations.

The survey was flown in an eastward direction between 08h00 and 14h00 at an altitude of approximately 300m, a speed of approximately 60kts and a distance of 500m offshore. During the survey, the pilot would mainly search ahead and coastwise, while the observer in the back would search offshore. Intercom communication between the pilot and the observer allows for the observer to make notes of the cow-calf pairs counted both inshore and offshore. When whales were too far offshore to determine group composition, they would be approached after which the aircraft would return to a distance of approximately 500m offshore. If the presence of a calf could not be determined with certainty, the observed whale would be recorded as unaccompanied, and the survey would continue. Each survey would take no longer than approximately 3 hours in a continuous flight, limiting the likelihood of duplicates within the count.

Photo-identification analysis

Photographs of the 2020 annual photo-identification aerial surveys were processed as follows: Firstly, the best images of each encounter were selected and those for same-day duplicates amalgamated. Secondly, photographs were visually inspected to eliminate within-year duplicates for the photo-identification matching process. Finally, matching of individuals was conducted using the Hiby-Lovell automated computer-based image recognition (Hiby and Lovell, 2001) and associated database system, which utilises digitised extracts of the callosity patterns (automatically adjusted for tilt and inclination) to make inter-individual comparisons. Automated comparisons of callosity patterns are rated for similarity using digital algorithm indices of similarity from 1.00 to zero, with the most similar candidate presented first. Matching by eye starts with the highest index and continues until a match is made or until the index has fallen to 0.50, although the performance of the system is such that the actual match is found in the first 3 candidates in over 90% of the cases. The dorsal pigmentation features are used in confirmation of a match and can be directly matched by eye with calves from earlier years (even in the absence of suitable photographs showing callosity patterns) to provide known-age individuals. When an individual was matched with a previously known individual, the sighting was recorded in the catalogue. When no match could be found, the individual was assigned a unique identification number and incorporated into the catalogue as a new individual. Once all the matching was complete, capture-recapture histories and associated calving intervals were extracted from the dataset. Further analysis of population parameters and distribution will be conducted according to Best (1990), Best et al. (2001; 2005) and Brandõ et al. (2018) among others.

Results

Annual photo-identification aerial survey

The 2020 annual photo-identification aerials survey was flown along the coast between the 27th and 29th of September 2020 in a westwards direction between Nature's Valley and Muizenberg. The helicopter and survey team were positioned at Witsand on the 26th of September. The region between Nature's Valley and Infanta Point was surveyed on the 27th of September. Infanta Point to Ryspunt was surveyed on the 28th of September and the remaining coast from Ryspunt to Muizenberg on the 29th of September.

A total of 12 hours and 53 minutes of flight operations were required to complete the survey, of which 9 hours and 27 minutes were flown as search effort, and 3 hours 26 minutes were flown in transit to and from the survey start and end-points. Table 1 shows the general progress of the survey. Figure 3 shows the flight path including the distribution of the different sightings. Figures 4, 5 and 6 provide additional detail to the sightings.

Table 1: Flight schedule of the 2020 annual southern right whale aerial survey flown between Nature's Valley and Muizenberg.

Flight	Date	Flight Start	Flight End	Total Time	Survey start	Survey end	Search Time	Transit Time	CC SRW	Un Ad SRW
1	26-09-2020	Cape Town International Airport	Witsand	1:12	Transit			1:12		
2	27-09-2020	Witsand	George	0:42	Transit			0:42		
3	27-09-2020	George	George	1:33	Natures Valley	George coast	0:57	0:36	0	1
4	27-09-2020	George	Witsand	2:34	George coast	Uiterstepunt	2:23	0:11	12	6
5	28-09-2020	Witsand	De Hoop	2:55	Uiterstepunt	Rhyspunt	2:41	0:14	34	9
6	29-09-2020	De Hoop	Grootbos	2:47	Rhyspunt	Hermanus New Harbour	2:32	0:15	20	13
7	29-09-2020	Grootbos	Cape Town International Airport	1:10	Hermanus New Harbour	Muizenberg	0:54	0:16	1	2
Total				**12:53**			**9:27**	**3:26**	**67**	**31**

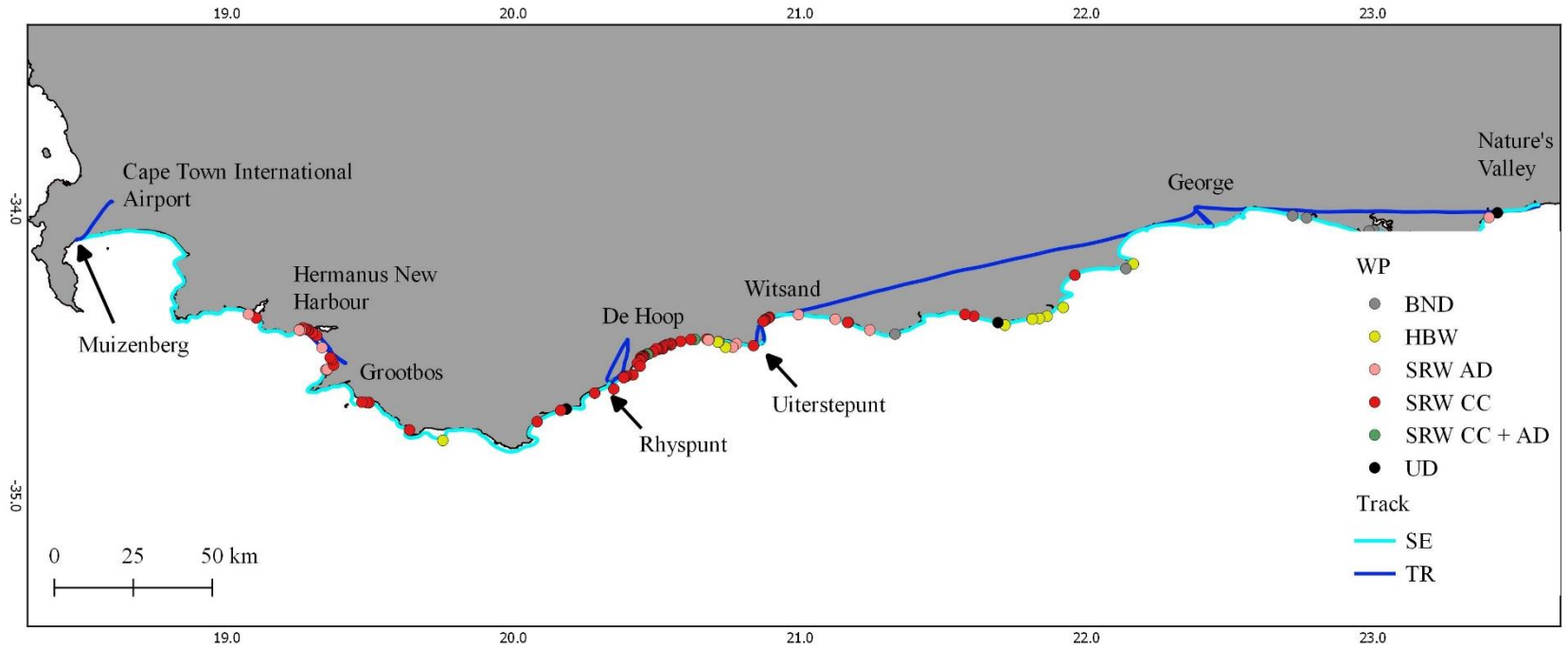

Figure 3. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of bottlenose dolphins (BND), humpback whales (HBW), unaccompanied southern right whales (SRW AD), southern right whale cow and calves (SRW CC), groups including southern right whale cows, calves and unaccompanied adults (SRW CC + AD), and unidentified dolphins (UD) during the 2020 South African southern right whale survey between Nature's Valley and Muizenberg.

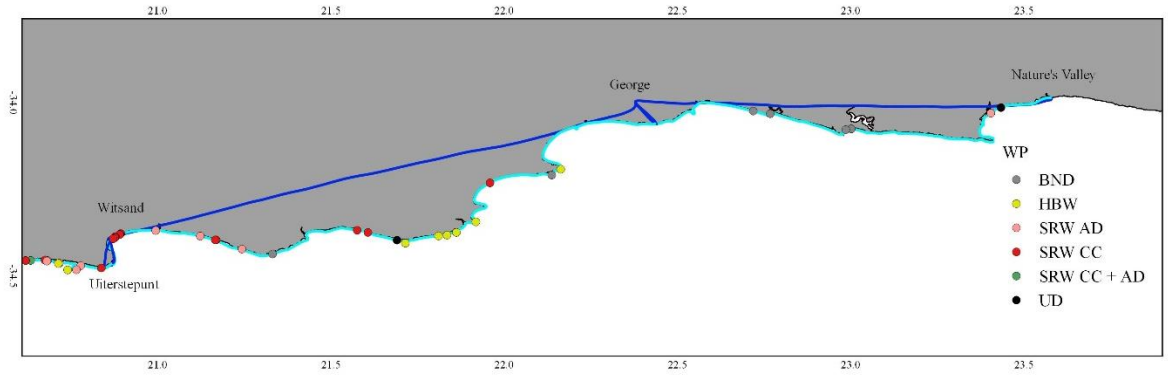

Figure 4. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of bottlenose dolphins (BND), humpback whales (HBW), unaccompanied southern right whales (SRW AD), southern right whale cow and calves (SRW CC), groups including southern right whale cows, calves and unaccompanied adults (SRW CC + AD), and unidentified dolphins (UD) during the 2020 South African southern right whale survey between Nature's Valley and Uiterstepunt.

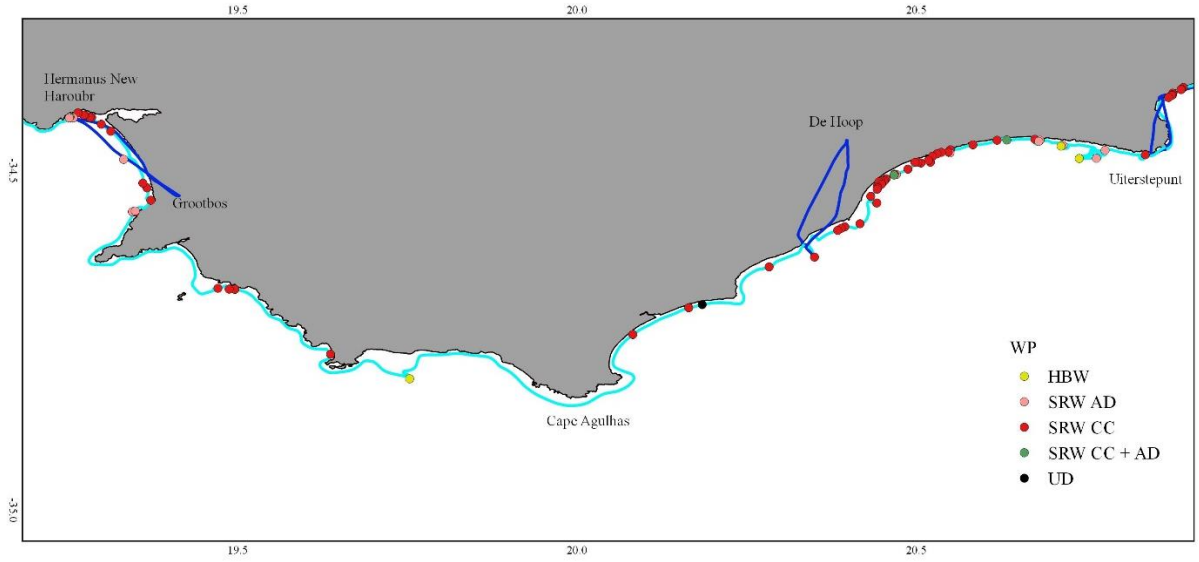

Figure 5. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of humpback whales (HBW), unaccompanied southern right whales (SRW AD), southern right whale cow and calves (SRW CC), groups including southern right whale cows, calves and unaccompanied adults (SRW CC + AD), and unidentified dolphins (UD) during the 2020 South African southern right whale survey between Uiterstepunt and Hermanus New Harbour.

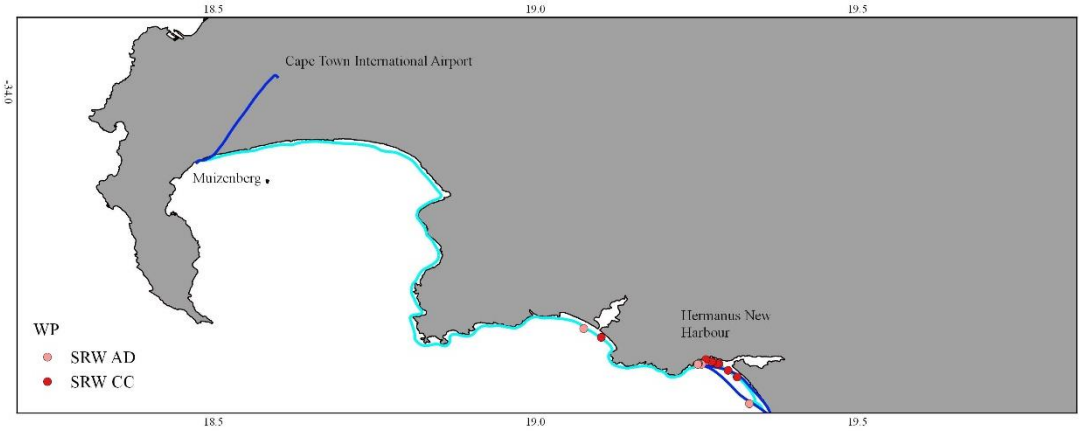

Figure 6. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of unaccompanied southern right whales (SRW AD) and southern right whale cow and calves (SRW CC) during the 2020 South African southern right whale survey between Hermanus New Harbour and Muizenberg.

Table 2 shows the cetacean groups encountered in adequate or above adequate sighting conditions across the entire survey region (Nature's Valley to Muizenberg). In total 67 cow and calf pairs of southern right whales (134 animals) in as many groups, as well as 22 groups of 31 unaccompanied adult southern right whales, were encountered during the survey. Over 4,000 photographs of southern right whales were taken during the survey including between-group spacer images. Furthermore,7 groups of 11 adult humpback whales (*Megaptera novaeangliae*) were encountered (Figure 3, 4, 5 and Table 2). Additionally, six groups of some 313 bottlenose dolphins (probably *Tursiops aduncus*) and 3 groups of some 23 unidentified dolphins were encountered (Figure 3, 4, 5 and Table 2).

Table 2. Numbers of groups and individual cetaceans encountered during the 2020 South African southern right whale survey between Nature's Valley and Muizenberg.

	Southern right whales	Southern right whales	Humpback whales	Humpback whales	Bottlenose dolphins	Unidentified dolphins
	Cow-calf pairs	Unacc. Adults	Cow-calf pairs	Unacc. Adults		
Groups	67	22	0	7	6	3
Individuals	67	31	0	11	313	23

Field counts of cow-calf pairs and unaccompanied adult southern right whales encountered on the 2020 annual aerial survey are shown in figure 7 in relation to the field counts since 1979.

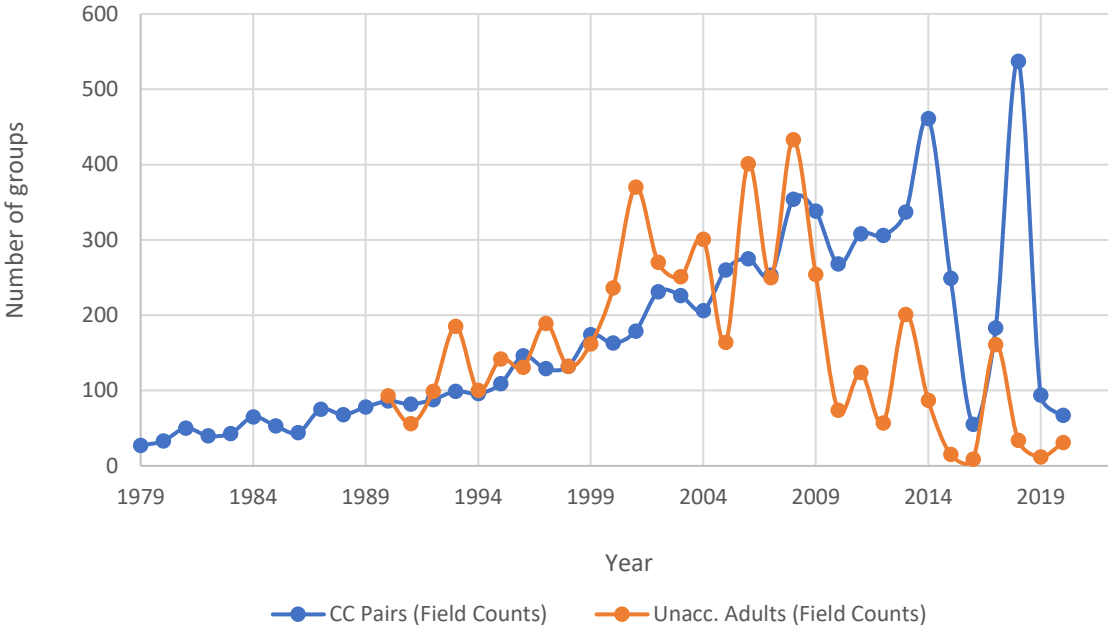

Figure 7. Numbers of cow and calf pairs and unaccompanied adults counted on the South African southern right whale survey each year since 1979.

Aerial count survey

Due to COVID-19 restrictions, only one aerial survey could be conducted between the Hermanus New harbour and Witsand in addition to the annual photo-identification aerial survey, for the sole purpose to count cow-calf pairs. This survey was flown on 21st August 2020 and revealed the presence of 71 cow-calf pairs and 11 unaccompanied adults on this stretch of coastline (Figure 8). Although numbers may not be fully comparable with numbers recorded on the annual aerial survey due to the different methodologies used, these results are in line with previous data, which suggest an apparent peak presence of cow-calf pairs in late August/early September, as opposed to the generally believed peak presence of cow-calf pairs in October, when the annual photo-identification aerial survey is conducted. On the count survey, as well as on the annual photo-identification survey, the largest concentration of cow-calf pairs was observed in the De Hoop Nature Reserve.

Table 3. Number of cow-calf pairs counted during the aerial count survey flown between Hermanus New Harbour and Witsand (21/08/2020). The number of cow-calf pairs counted along this stretch of coastline during the annual photo-identification aerial survey (28 and 29/09/2020) is given in italics for comparative purposes.

Date	Number of cow-calf pairs counted	Flight (search) times	Duration
21/08/2020	71	10:35–13:28	2h53min
28 and 29/09/2020	*54*	*NA*	*NA*

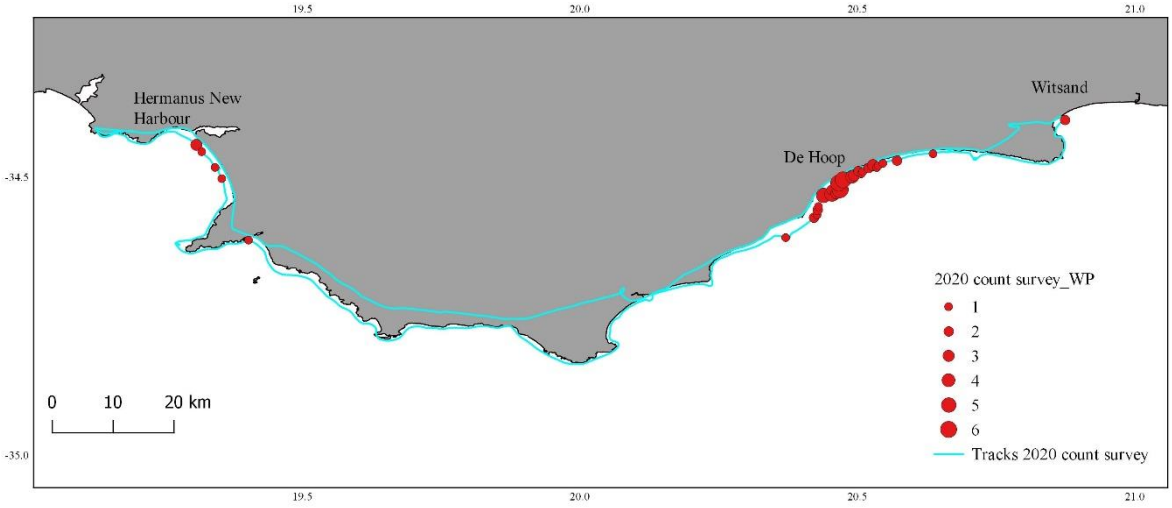

Figure 8. Map indicating the encounters of southern right whale cow-calf pairs along the stretch of coastline between Hermanus New Harbour and Witsand on 21 August 2020

Photo-identification analysis

In total, 67 cow-calf pairs and 19 unaccompanied adults were photo-identified during the survey. Subsequent data analysis indicated the presence of 4 duplicates in the dataset, leading to the identification of 82 unique individual southern right whales, including 64 cows. Of these latter, 30 could be matched to previously known females whereas the other 34 were assigned as newly identified cows (Table 4).

Table 4. The number of southern right whale cow-calf pairs counted, number of unique females identified (i.e. duplicates excluded) and the number of identified females matched with previously known individuals, during the 2020 annual aerial survey

	2020
Number of females with calves counted	67
Number of unique females with calves identified	64
Number of females with calves matched to previous known females	30

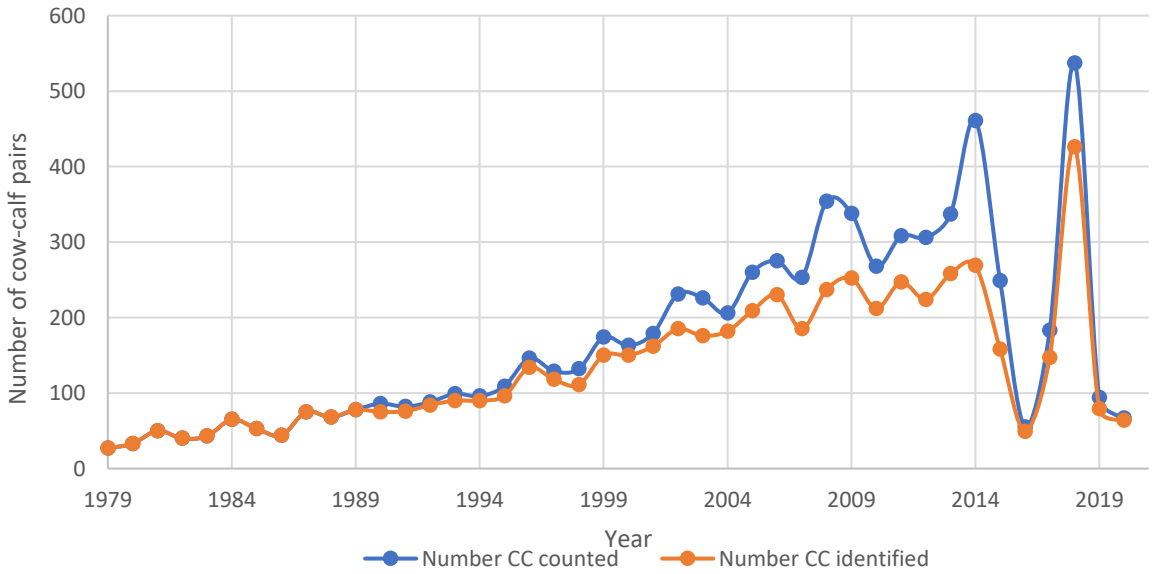

Figure 9. The number of females with calves counted and identified during the annual aerial surveys since 1979. The difference between both graphs indicates the number of within year duplicates (individuals photographed more than once during an aerial survey).

Photo-identification matching gave results on 28 new inter-calving intervals (i.e. 2 females were previously identified as unaccompanied adults). The majority of cows had a normal 3-year (68%), 6-year (11%) or 9-year (7%) calving interval. Considering a 6- and 9-year interval is assumed to be a combination of two and three normal 3-year calving intervals respectively, this result is remarkably different from the recently observed shift to a 4- and 5-year calving cycle, and ties in with the increased observation of 3-year and 6-year calving intervals in 2019 (Figure 10).

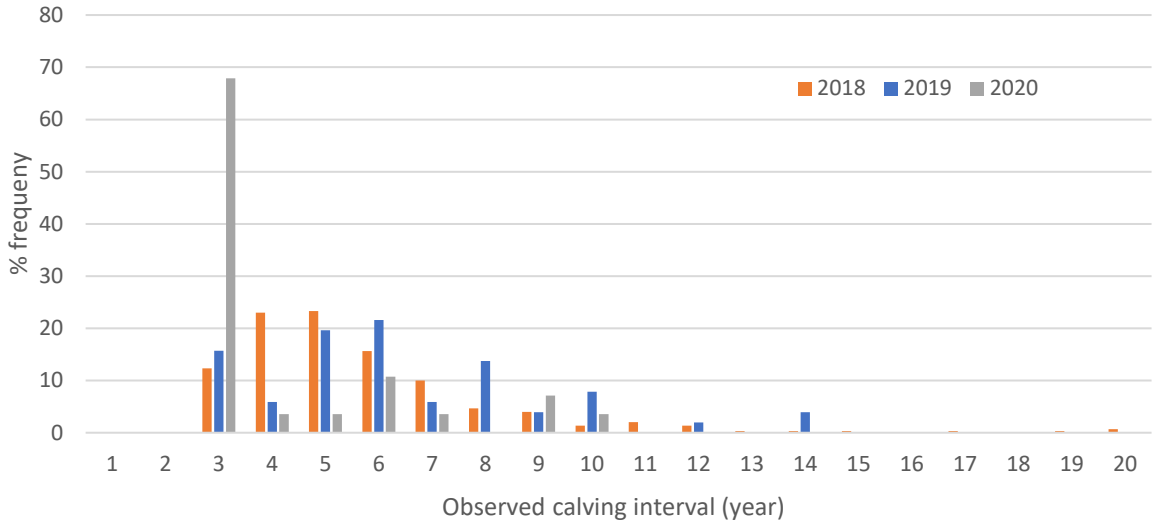

Figure 10. Last calving interval of females identified with a calf during the annual aerial surveys of 2018, 2019 and 2020

Furthermore, it was notable that 53% of the identified cows were unknown to the catalogue, and therefore presumably first time mothers, whereas proportions in previous years ranged between 30%-40%. In fact, 84% of all cows identified in the 2020 survey were relatively "young", having been added to the catalogue post-2010 and therefore presumably under the age of 20. Only 4 cows photographed in 2020 were known to the catalogue since prior the year 2000.

Discussion

The 2020 annual aerial survey resulted in the second-lowest count of cow-calf pairs along the southern Cape coast since 1989 (Figure 9). These numbers remain extremely low considering a modelled population increase rate of 6.5% per annum (Brandão et al., 2018). With the third-lowest count on record, also the number of unaccompanied adults remains extremely low (Figure 7). As in previous years, these low numbers are not believed to result from any changes to the standardised survey methodology or differences in sightings conditions overt the survey series.

Shift in peak presence

Best (1994) determined that the calving season in South Africa occurs over 118 days around mid-August, with 95.5% of calves being born in this time period. Additionally, Best and Rüther (1992) suggested a residency time of cow-calf pairs of at least 2.5 – 3 months on the South African breeding ground to ensure the calf reaches a "critical size" of about 8m, before commencing their migration to the feeding grounds. This would lead to a peak in cow-calf pair presence along the South African coast around early to mid-October, when the aerial survey is flown.

Although only one count aerial survey could be concluded this year due to COVID-19 restrictions, this year's data corroborated the data collected in 2017, 2018 and 2019 (see Vermeulen et al. 2018, 2019, 2020), showing a greater number of cow-calf pairs along the southern Cape coast in August compared to late September/October. As there is no (scientific nor anecdotal) data suggesting an earlier birthing

season, these data point towards a reduced residency time of cow-calf pairs on the South African breeding ground. The general west-ward movement (believed to occur immediately prior to the southward movement) of cow-calf pairs between August and late September this year (compare Figures 5 and 8), as seen in previous years (see Vermeulen et al. 2018, 2019, 2020), further strengthens this hypothesis. Whether or not this reduced residency time affects calf survival, and therefore population dynamics, remains to be determined.

Observed calving intervals

For the first time in a decade, the majority of observed calving intervals reflected normal 3-year cycles. These data are very different from the increased proportion of 4- and 5-year calving intervals observed since 2010 (Vermeulen et al., 2018, 2019; Brandão et al., 2018), but seem to follow data from 2019 when a slight surge of 3- and 6- year calving intervals could be observed again (see Figure 10). Such data raise questions on the possible reversal of increased calving intervals back to normal levels.

However, it should be considered that this apparent re-surge of normal calving intervals could be a by-product of the reduced residency time of some cow-calf pairs (i.e. only those cows in a good enough condition to reside sufficient time along the South African coast to be captured on the photo-identification survey, might also have a good enough body condition to breed at normal intervals). Furthermore, the seemingly "young" (i.e. starting to reproduce post-2010) age of the cows photo-identified in 2020 could also be relevant to this point.

Therefore, additional photo-identification work earlier in the season is highly recommended to (re)assess i.a.

- Birthing season
- Residency time of cow-calf pairs
- The portion of the female population captured on the annual photo-identification survey

If females indeed resumed the ability to reproduce in normal 3-year cycles, the cohorts may stabilise again and a 3-year "bumper cohort", which was visible in the dataset between 1979 and 2009, may re-appear. In such case, considering the "super cohort" (including roughly 40% of the parous females) observed in 2018 (Vermeulen et al., 2019), a record year could be expected in 2021.

Foraging ecology

In general, as capital breeders, successful calving and migration in southern right whales rely on having an adequate body condition, and thus energy reserves, which is directly influenced by their feeding success (Leaper et al. 2006). Direct links between a decreased calving success and decreased krill densities at feeding grounds due to climate anomalies have been found for the breeding areas of Argentina (Leaper et al., 2006) and Brazil (Seyboth et al., 2016). Preliminary results have also been found for the South African population, with strong correlations occurring between the annual number of calves observed along the South African coast and ENSO (El Niño–Southern Oscillation), the Antarctic Oscillation and biological productivity in two historical feeding grounds (van den Berg et al., 2019).

Additionally, new data reveal that the South African population has drastically altered their feeding strategies (i.e. locations of feeding grounds and/or preferred prey type) in the past two decades (van den Berg et al. in press). Considering the vast oceanic range of southern right whale feeding grounds, the findings point toward large-scale ecosystem changes in the Southern Ocean. This is perhaps not surprising, given the unprecedented impacts of recent climate change on Southern Ocean physical features, which in turn have driven regional changes on all levels of Antarctic marine food webs (see Rogers et al., 2020 and references therein). The change in feeding strategy of South Africa's population of southern right whales could represent an attempt to cope with the impacts of climate change in the Southern Ocean. However, the change has been concurrent with a decline in reproductive success, suggesting that the shift could also be a suboptimal foraging strategy. In this regard, we are further investigating the whales' nutritional condition using overhead drone images and analysis of blubber stress hormone levels. These results should be available mid-2021.

Unlike the fluctuating numbers of cow-calf pairs, numbers of unaccompanied whales remain extremely low since 2010, indicating that this component of the population continues to alter their migration patterns, reasons for which still need to be determined. Consideration should be given to the motivation to invest the energetic cost to complete the annual migration up to the South African coast when feeding conditions are not optimal in higher latitudes. For cow-calf pairs, the motivation for migration would clearly be a matter of an increased calf survival (Norris, 1967; Brodie, 1975; Corkeron and Connor, 1999). For unaccompanied adults, one would expect this to be related to mating. However, Best et al. (2003) indicated that very little true conception occurs in the Surface Active Groups (mating groups) observed along the South African coast. Therefore, the motivation for unaccompanied adults to migrate to the South African breeding ground may be minimal (the area(s) where conception occurs remains to be determined). It is believed that apparent altered migration of non-calving southern right whales could be due to an insufficient amount of energy linked to a decreased prey abundance (e.g. Trathan et al. 2006, Murphy et al. 2007), or due to a spatial (e.g. Loeb et al., 2009) and/or temporal (e.g. Del Castillo et al., 2019) displacement of prey due to climate variability. These data and hypotheses urgently call for an assessment of the (seemingly altered) migratory routes via satellite tags.

Recommendations

The continuation of the survey series and an assessment of the resulting demographic parameters is of crucial importance to monitor and investigate the observed changes in coastal presence of southern right whales on their breeding ground off South Africa, and its effects on population dynamics. This will entail not only a continuation of the annual photo-identification aerial surveys, but also the continuation of the additional count surveys to monitor the timing of peak calving along the South African coast and additional photo-identification effort prior to the annual aerial survey, especially around the main concentration areas of cow-calf pairs (especially De Hoop Nature Reserve).

Additionally, a continued in-depth assessment on the foraging ecology and body condition of this population is warranted. In addition to the analyses of currently available data, it is strongly recommended that satellite tagging of individuals during their winter migrations (which was planned

for 2020 but halted by COVID-19 restrictions), as well as further stable isotope analyses, be carried out to provide more evidence of (possibly changed) residence time in the South African breeding ground, identify (possibly altered) migration routes and determine current feeding distributions (see Mate *et al.*, 2011).

Additionally, the continued low numbers of unaccompanied adults along the South African coast has serious consequences for cow-calf pairs in relation to the country´s whale-watching industry. Legislation around this industry prohibits the approach of cow-calf pairs at a distance < 300m, allowing only the approach of unaccompanied adults under special permits. However, in the absence of unaccompanied adults and of law enforcement, cow-calf pairs are being approached nonetheless. Without more specific data and in the precautionary approach, it is strongly recommended that the South African permitting authority and the South African Boat based Whale-watching Association engage with researchers in order to properly manage the activities with this valuable natural resource, especially considering the likely low energetic reserves of the nursing cows.

Acknowledgements

The annual aerial photo-identification survey was conducted under charter from Silvercross Helicopters and under the auspices of ExxonMobil and Total, for which we are very grateful. The De Hoop Collection is thanked for providing accommodation during the survey. We are grateful to the Overberg Test Range Air Traffic Control for weather reports and accommodating us in their airspace amid their own operations. Numerous people are thanked for kindly providing weather and sighting condition information along the coast.

The aerial count survey was conducted under charter of Jean Tresfon, whom we wish to thank for his continuous support. All surveys were carried out under a permit from the Department of Environment, Forestry and Fisheries to approach whales and under specific Marine Protected Area permits from the relevant conservation authorities.

Literature cited

Best, P.B. (1981). The status of right whales (*Eubalaena glacialis*) off South Africa, 1969-1979. Invest. Rep. Sea Fish. Inst. S. Afr. 123: 1-44.

Best, P.B. (1990). Natural markings and their use in determining calving intervals in right whales off South Africa. S. Afr. J. Zool. 25: 114-123.

Best, P.B. (1994). Seasonality of reproduction and the length of gestation in southern right whales *Eubalaena australis*. J. Zool. 232: 175-189.

Best, P.B. (2011). Review of aerial photo-identification surveys for right whales off South Africa, 1979-2010 Document SC/S11/RW 18 submitted to the Special Meeting of the Scientific Committee of the International Whaling Commission, Buenos Aires, 2011.

Best, P.B., Brandão, A. and Butterworth, D.S. (2001). Demographic parameters of southern right whales off South Africa. J. Cet. Res. Mgmt (Special Issue 2): 161-169.

Best, P.B., Brandão, A. and Butterworth, D.S. (2005). Updated estimates of demographic parameters of southern right whales off South Africa. Document SC/57/BRG2 submitted to the Scientific Committee of the International Whaling Commission.

Best, P.B. and Rüther, H. (1992). Aerial photogrammetry of southern right whales, *Eubalaena australis*. J. Zool. 228: 595-614.

Best, P.B., Schaeff, C.M., Reeb, D. and Palsbøll, P.J. (2003). Composition and possible function of social groupings of southern right whales in South African waters. Behaviour 140: 1469-1494.

Brandão, A., Vermeulen, E., Ross-Gillespies A., Findlay, K. and Butterworth, D.S. (2018). Updated application of a photo-identification based assessment model to southern right whales in South African waters, focussing on inferences to be drawn from a series of appreciably lower counts of calving females over 2015 to 2017. Report presented at the 67Bth IWC scientific committee (Southern Hemisphere subcommittee, Bled Slovenia.

Brodie, P., F. (1975). Cecacean energetics, an overview of intraspecific size variation. Ecology. 56: 152-161. Doi: 10.2307/1935307

Del Castillo, C. E., Signorini, S. R., Karaköylü, E. M., Rivero-Calle, S. (2019). Is the Southern Ocean getting greener? Geoph. Res. Let. 46: 6034–6040. https://doi.org/10.1029/2019GL083163

Corkeron P.J. and Connor R.C. (1999). Why do baleen whales migrate? Mar. Mamm. Sci. 15:1228–1245. doi:10.1111/j.1748-7692.1999.tb00887.x

Elwen, S.H. and Best, P.B. (2004). Female southern right whales *Eubalaena australis*: are there reproductive benefits associated with their coastal distribution off South Africa? Mar. Ecol. Prog. Ser. 269: 289-295.

Findlay, K., Thornton, M., Wilkinson, C., Vermeulen, E. and Hoerbst, S. (2017). Report on the 2016 Mammal Research Institute Whale Unit Southern Right Whale Survey, Nature's Valley to Lamberts Bay, South Africa. Report presented to the 67th IWC scientific committee (Southern Hemisphere Subcommittee), Bled, Slovenia

International Whaling Commission (IWC) (2013). Report of the IWC workshop on the assessment of southern right whales. J. Cetacean Res. Manage. 14 (Suppl.): 439-462.

Leaper, R., Cooke, J., Trathan, P., Reid, K., Rowntree, V. and Payne, R. (2006). Global climate drives southern right whale (*Eubalaena australis*) population dynamics. Biol. Lett. 2: 289-292.

Loeb, V. J., Hofmann, E. E., Klinck, J. M., Holm-Hansen, O., & White, W. B. (2009). ENSO and variability of the Antarctic Peninsula pelagic marine ecosystem. Ant. Sci. 21: 135-148.

Mate, B.R., Best, P.B., Lagerquist, B.A. and Winsor, M.H. (2011). Coastal, offshore, and migratory movements of South African right whales revealed by satellite telemetry. Mar Mamm. Sci. 27: 455–476

Murphy, E. J., Watkins, J. L., Trathan, P. N., Reid, K., Meredith, M. P., Thorpe, S. E., ... Forcada, J. (2007). Spatial and temporal operation of the Scotia Sea ecosystem: a review of large-scale links in a krill centred food web. Philosophical Transactions of the Royal Society B: Biol. Sci. 362: 113-148.

Norris, K.S. (1967). Some observations on the migration and orientation of marine mammals. In: Storm R.M, editor. Animal orientation and migration. Oregon State University Press; Corvallis, OR: 1967. pp. 101–125.

Payne, R., Brazier, O., Dorsey, E.M., Perkins, J.S., Rowntree, V.J. and Titus, A. (1983). External features in southern right whales (*Eubalaena australis*) and their use in identifying individuals. Pp 371-445 in (Payne, R., ed.) *Communication and behavior of whales*. AAAS Selected Symposia Series 76, Boulder, Colorado, Westview Press.

Rogers, A. D., Frinault, B. A. V., Barnes, D. K. A., Bindoff, N. L., Downie, R., Ducklow, H. W., Friedlaender, A. S., Hart, T., Hill, S. L., Hofmann, E. E., Linse, K., McMahon, C. R., Murphy, E. J., Pakhomov, E. A., Reygondeau, G., Staniland, I. J., Wolf-Gladrow, D. A., & Wright, R. M. (2020). Antarctic Futures: An Assessment of Climate-Driven Changes in Ecosystem Structure, Function, and Service Provisioning in the Southern Ocean. Annual Review of Marine Science, 12, 87–120. https://doi.org/10.1146/annurev-marine-010419-011028

Seyboth, E., Groch, K.R., Dalla Rosa, L., Reid, K., Flores, P.A.C., Secchi, E.R. (2016). Southern Right Whale (*Eubalaena australis*) Reproductive Success is Influenced by Krill (*Euphausia superba*) Density and Climate. Scientific Reports, 6.

Trathan, P. N., Green, C., Tanton, J., Peat, H., Poncet, J., & Morton, A. (2006). Foraging dynamics of macaroni penguins *Eudyptes chrysolophus* at South Georgia during brood-guard. Mar. Ecol. Progr. Ser. 323: 239-251.

van den Berg, G.L., Vermeulen, E., Hui, Cang., Findlay, K., Von der Heyden, S., Midgley, G. (2019). Linking climate and ocean productivity to the prevalence of southern right whales (*Eubalaena australis*) in South African waters. Report presented to the 68Ath IWC scientific committee (Southern Hemisphere Subcommittee), Nairobi, Kenya

van den Berg, G.L., Vermeulen, E., Valenzuela, L.O., Bérubé, M., Ganswindt, A., Gröcke, D.R., Hall, G., Hulva, P., Neveceralova, P., Palsbøll, P.J., Carroll, E.L. (in press). Decadal shift in foraging strategy of a highly migratory marine capital breeder. Global Change Biology

Vermeulen, E., Wilkinson, C., Thornton, M., Peters, I.T., Findlay, K. 2018. Report on the 2017 Mammal Research Institute Whale Unit Southern Right Whale Survey, Nature's Valley to Lamberts Bay, South Africa. Report presented to the 67Bth IWC scientific committee (Southern Hemisphere Subcommittee), Bled, Slovenia. Doi: 10.13140/RG.2.2.33382.45125

Vermeulen, E., Wilkinson, C., Thornton, M. (2019). Report of the 2018 South African southern right whale aerial surveys. Report presented to the 68Ath IWC scientific committee (Southern Hemisphere Subcommittee), Nairobi, Kenya. Doi: 10.13140/RG.2.2.35060.17284

Vermeulen, E., Van den Berg, G.L., Wilkinson, C. (2020). Report of the 2019 South African southern right whale aerial surveys. Report presented to the 68B IWC scientific committee (Southern Hemisphere Subcommittee), Cambridge, UK. Doi: DOI: 10.13140/RG.2.2.29556.37766