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Report of the southern right whale aerial surveys -2019

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INTERNATIONAL
WHALING COMMISSION

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Mammal Research Institute Whale Unit - University of Pretoria

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The survey was carried out under a permit from the Department of Environmental Affairs to approach whales and under specific Marine Protected Area permits from the relevant conservation authorities.

Contents

Abstract

Annual aerial surveys to monitor the South African population of southern right whales (*Eubalaena australis*) have been carried out since 1969. From 1979, these annual surveys incorporated identification using photography of natural markings, resulting in an uninterrupted 40-year survey series of photo-identification history. Over time, these surveys have shown a steady population increase since the protection of the species from commercial whaling. However, recent results of these surveys indicate strong changes in the prevalence of southern right whales on the South African breeding ground, including a marked decline of unaccompanied adults since 2010 and extreme fluctuations in the number of cow-calf pairs since 2015. Additionally, female sighting histories show an overall increase in calving interval from a normal 3-year cycle to 4- and 5-year calving intervals.

The 2019 annual photo-identification aerial survey was flown in early October (30 September to 5 October 2019) 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 between the area of Nature's Valley and Muizenberg. As in previous years, an Airbus EC120B helicopter was used. A total of 14 hours and 17 minutes of flight operations were required to complete the survey, of which 10 hours and 8 minutes were flown as search effort and 4 hours and 9 minutes were flown in transit to and from the survey start and end points. In total, 92 groups comprising 94 cow-calf pairs of southern right whales (188 animals) and 12 unaccompanied adults were observed, leading to a total of 200 southern right whales. This marks the second lowest number of cow-calf pairs along the South African coastline in October since 1995 (after the extreme low numbers of 2016 (55 pairs)) and is a huge decrease from last year's all-time record of 536 cow-calf pairs along the same stretch of coastline. For unaccompanied adults, these numbers reflect the second lowest count since the commencement of the aerial surveys.

Due to financial limitations, only one additional aerial 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 15 August 2019 using an autogyro. Results of this survey indicated the presence of 129 cow-calf pairs and 24 unaccompanied adults in this limited stretch of coastline, suggesting an apparent shift in peak presence from early October (when the annual photo-identification survey is flown) to earlier in the year. Although numbers may not be fully comparable due to different survey methods, this is the 3rd consecutive year in which an apparent shift in peak presence was shown, and warrants further investigation and consideration in future years.

This year, additional photo-identification data was collected in early September in Walker Bay and Saint Sebastian Bay using an Unmanned Aerial Vehicle (UAV), during fieldwork investigating southern right whale body condition. In total, 53 individuals, 45 of which were cows, were photo-identified during this period. Of these, only 7 cows were re-photographed

during the annual aerial survey, suggesting 38 cows and 8 unaccompanied adults were missed or left the South African breeding ground in the 2-week time period between the boat-based survey and the annual aerial survey. If the latter, this would be considered a large movement of female right whales, and may be related to the apparent temporal shift in the peak presence of calves along the South African coast. If cow-calf pairs leave the nursery ground before the calf has reached its critical size, calf survival could be affected. Further investigation should assess this situation, as it will impact population dynamics in the long term. Consideration should therefore be given to conduct additional photo-identification work earlier in the season to assess whether (1) there has indeed been a shift in the peak presence of cow-calf pairs and (2) to provide more detailed information related to the timing and magnitude of movement of cow-calf pairs on the South African coastline.

In total, 93 cow-calf pairs and 7 unaccompanied adults were photo-identified during the annual aerial survey. Photo-identification data analysis showed the presence of 14 duplicates in the dataset, leading to the identification of 86 unique individual southern right whales, including 79 cows. Of these, 52 could be matched to previously known females. The observed calving intervals indicated the majority of cows had a 6-year calving interval (22%), followed by a 5-year interval (20%) and a 3-year interval (16%). Considering a 6-year interval is assumed to be a combination of two normal 3-year calving intervals, this result is slightly different from the recent observed shift from a 3-year to a 4-year calving cycle. Nonetheless, the proportion of females calving at a 5-year interval remains high, and the incessant low numbers of unaccompanied adults remains a concern, especially as they form the basis of the country's whale watching industry (legislation prohibits the approach of cow-calf pairs < 300m). In the absence of unaccompanied adults and law enforcement, accumulative effects of approaching vessels on cow-calf pairs could have energetic consequences for both cow and calf. Without more specific data, the precautionary approach should be adopted, and so 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.

The observed demographic changes 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 coloration, 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).

Despite the observed population increase post-whaling, 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 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 2019 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) in the first two weeks of 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 three 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 port rear 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 port rear seat) limiting the exposure to glare from midday onwards and thus decreasing hovering times.

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, and 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 (see Figure 1). 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 indicating how photographs are obtained

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.

Within Season 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 financial 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 an autogyro (Source: Wikipedia)

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 500 m 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 2019 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), Elwen and Best (2004) and Brandão *et al.* (2011) among others.

Results

Annual photo-identification aerial survey

The 2019 annual photo-identification survey was flown along the coast from 30 September to 5 October 2019 in a general westwards direction between Nature's Valley and Muizenberg. Only the first stretch of coastline between Puntije and Nature's Valley was flown in an eastward direction for practical considerations. The helicopter and survey team were positioned at Witsand on 30 September. The region between the eastern border of Saint Sebastian Bay (Puntije) to Nature's Valley was surveyed on 1 October. Saint Sebastian Bay and part of De Hoop Nature

Reserve (Puntjie to Koppie Alleen) was surveyed on 2 October. The main part of the De Hoop coastline (Koppie Alleen to Ryspunt) was surveyed on 3 October, and the remaining coast to Muizenberg was surveyed on 5 October.

A total of 14 hours and 17 minutes of flight operations were required to complete the survey, of which 10 hours and 08 minutes were search effort and 04 hours and 09 minutes 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.

Flight	Date	Flight Start	Flight End	Total Time	Survey start	Survey end	Search Time	Transit Time	CC SRW	Un Ad SRW
1	30 September 2019	Cape Town International Airport	Witsand	1:14	Transit			1:14		
2	1 October 2019	Witsand	George	1:54	Puntije	George Coast	1:40	0:13	3	1
3	1 October 2019	George	Witsand	2:28	George Coast	Nature's Valley	1:01	1:27	0	0
4	2 October 2019	Witsand	Witsand	1:03	Puntjie	Uiterstepunt	0:50	0:12	12	1
5	2 October 2019	Witsand	De Hoop	1:19	Uiterstepunt	Koppie Alleen	1:05	0:13	12	1
6	3 October 2019	De Hoop	De Hoop	1:30	Koppie Alleen	Ryspunt	1:17	0:13	28	2
7	5 October 2019	De Hoop	Grootbos	2:01	Ryspunt	De Kelders	1:41	0:20	16	0
8	5 October 2019	Grootbos	Hangklip Hotel	2:01	De Kelders	Hangklip	1:56	0:04	23	7
9	5 October 2019	Hangklip Hotel	Cape Town International Airport	0:45	Hangklip	Muizenberg	0:35	0:10	0	0
Total				**14:17**			**10:08**	**4:09**	**94**	**12**

Table 1. Flight schedule of the 2018 annual southern right whale aerial survey flown between Nature's Valley and Muizenberg.

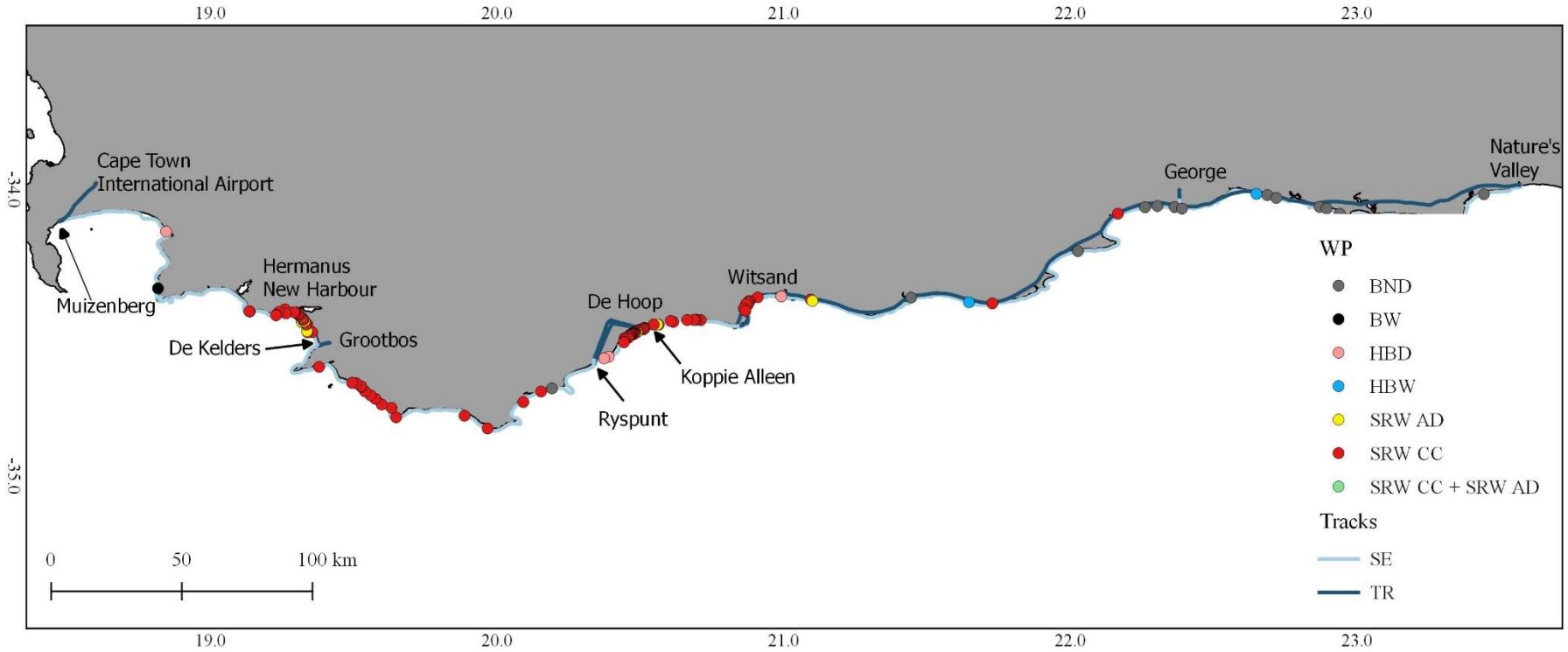

Figure 3. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of bottlenose dolphins (BND), Bryde's whales (BW), humpback dolphins (HBD), humpback whales (HBW), unaccompanied southern right whales (SRW AD), southern right whale cow and calves (SRW CC), and groups including southern right whale cows, calves and unaccompanied adults (SRW CC - AD) during the 2019 South African southern right whale survey between Nature's Valley and Muizenberg.

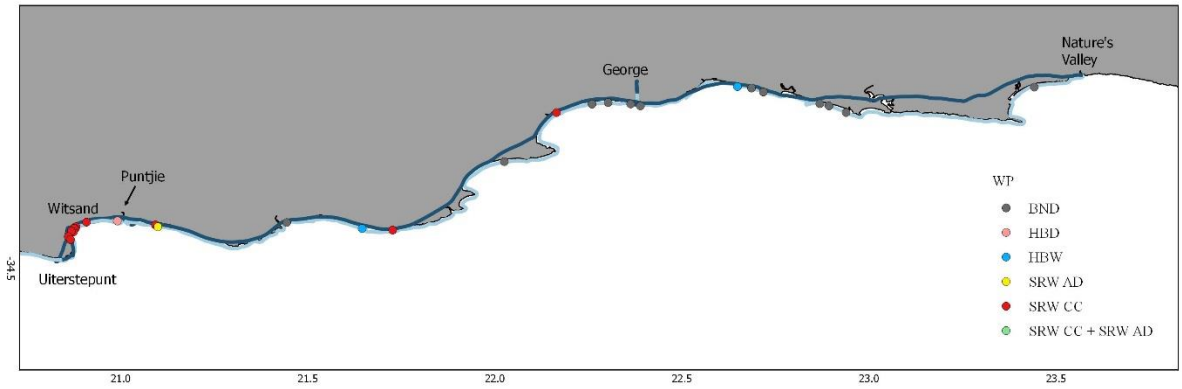

Figure 4. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of bottlenose dolphins (BND), humpback dolphins (HBD), humpback whales (HBW), unaccompanied southern right whales (SRW AD) and southern right whale cow and calves (SRW CC), and a group including southern right whale cows, calves and unaccompanied adults (SRW CC - AD) during the 2019 South African southern right whale survey between Nature's Valley and Uiterstepunt.

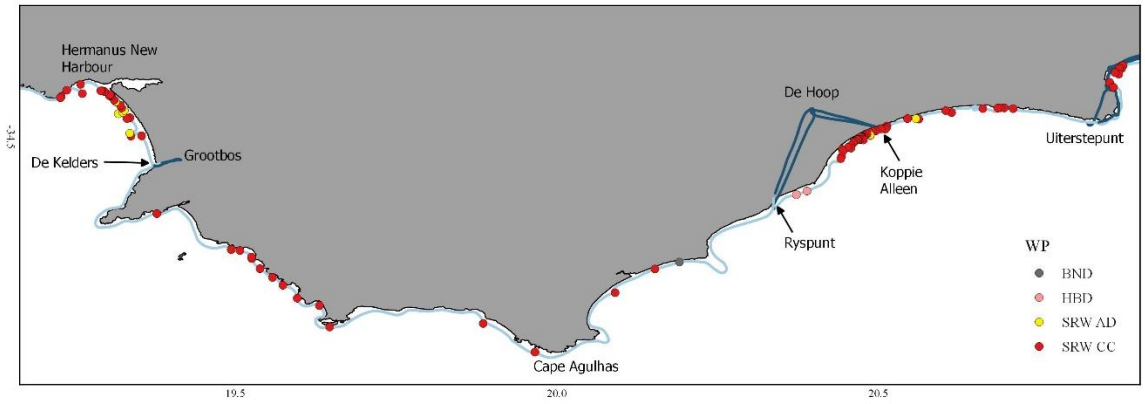

Figure 5. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of bottlenose dolphins (BND), humpback dolphins (HBD), unaccompanied southern right whales (SRW AD) and southern right whale cow and calves (SRW CC) during the 2019 South African southern right whale survey between Uiterstepunt and Hermanus New Harbour.

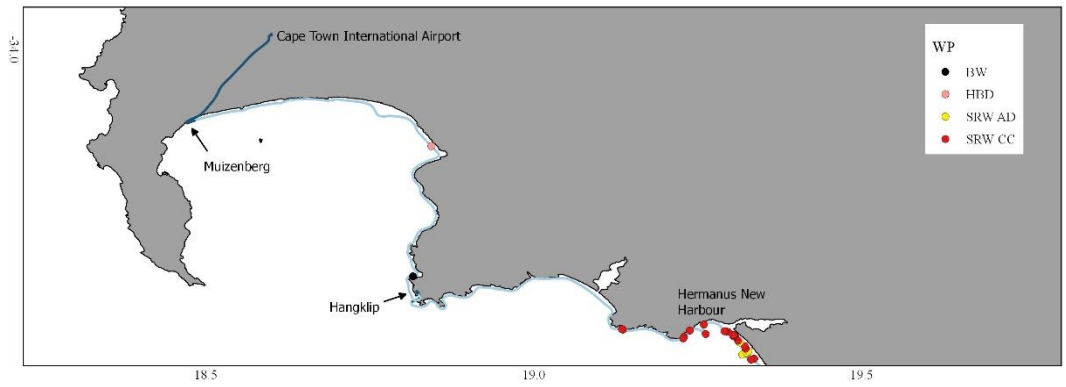

Figure 6. Flight path with search effort (light blue line) and transit (dark blue line), as well as encounters of Bryde's whales (BW), humpback dolphins (HBD), unaccompanied southern right whales (SRW AD), and southern right whale cow and calves (SRW CC) during the 2019 South African southern right whale 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, 92 groups of 94 cow and calf pairs of southern right whales (188 animals) and 12 unaccompanied adult southern right whales in as many groups were encountered during the survey. Over 5,300 photographs of southern right whales were taken during the survey including between-group spacer images. Only 2 groups of 3 adult humpback whales (*Megaptera novaeangliae*) and one cow-calf pair were encountered (Figure 3, 4 and Table 2). One single Bryde's whale (*Balaenoptera brydei/edeni*) was encountered (Figure 3, 6 and Table 2), as well as four groups of humpback dolphins (*Sousa plumbea*) and 15 groups of bottlenose dolphins (probably *Tursiops aduncus*) (Figure 3, 4, 5 and Table 2).

Table 2. Numbers of groups and individual cetaceans encountered during the 2019 South African southern right whale survey between Nature's Valley and Muizenberg.

	Southern right whales	Southern right whales	Humpback whales	Humpback whales	Bryde's whales	Bryde's whales	Bottlenose dolphins	Humpback dolphins
	Cow-calf pairs	Unacc. Adults	Cow-calf pairs	Unacc. Adults	Cow -calf pairs	Unacc. Adults		
Groups	92	12	1	1	1	1	15	4
Individuals	94	12	2	3	1	1	150	12

Field counts of cow-calf pairs and unaccompanied adult southern right whales encountered on the 2019 annual aerial survey is shown in figure 7 in relation to the field counts since 1979.

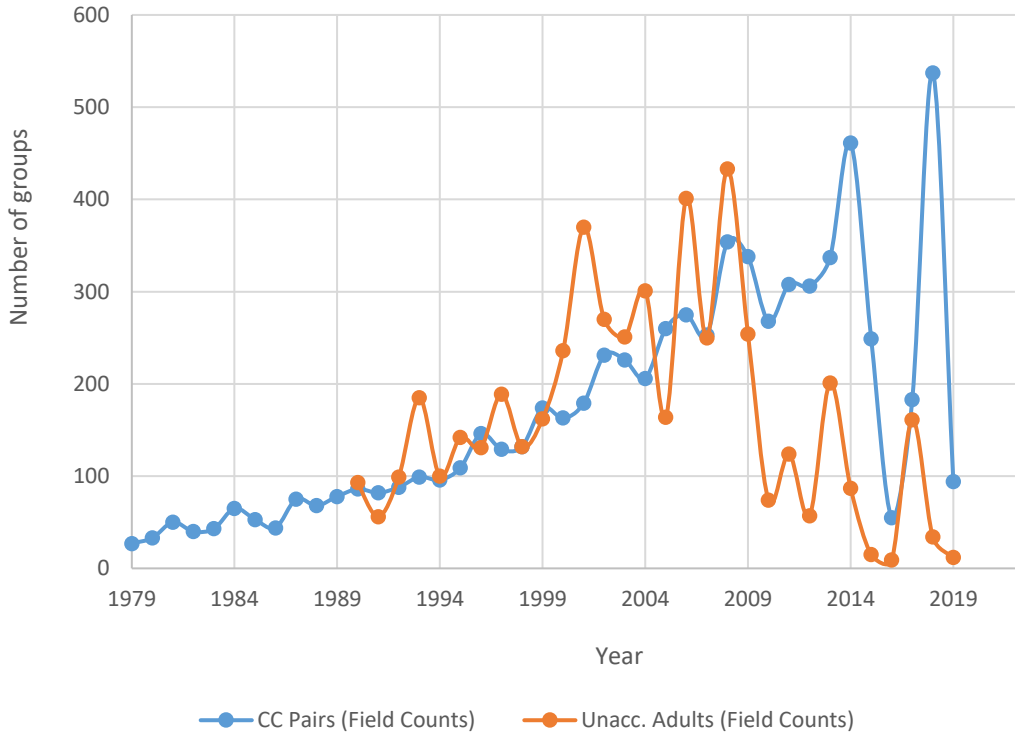

Figure 7. Numbers of cow and calf pairs and unaccompanied adults counted on the South African southern right whale survey each year since 1979.

Within season aerial count survey

Due to financial limitations, only one aerial survey was 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 15 August 2019 and revealed the presence of 129 cow-calf pairs on this stretch of coastline (Figure 8). Although numbers may not be fully comparable due to the different methodologies used, these results are in line with 2017 and 2018 data, which suggest an apparent peak in the 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 (15/08/2019). The number of cow-calf pairs counted along this stretch of coastline during the annual photo-identification aerial survey (3/10/2019) is given in italics for comparative purposes.

Date	Number of cow-calf pairs counted	Flight (search) times	Duration
15/08/2019	129	9:28–11:46	2h18min
3/10/2019	*77*	*NA*	*NA*

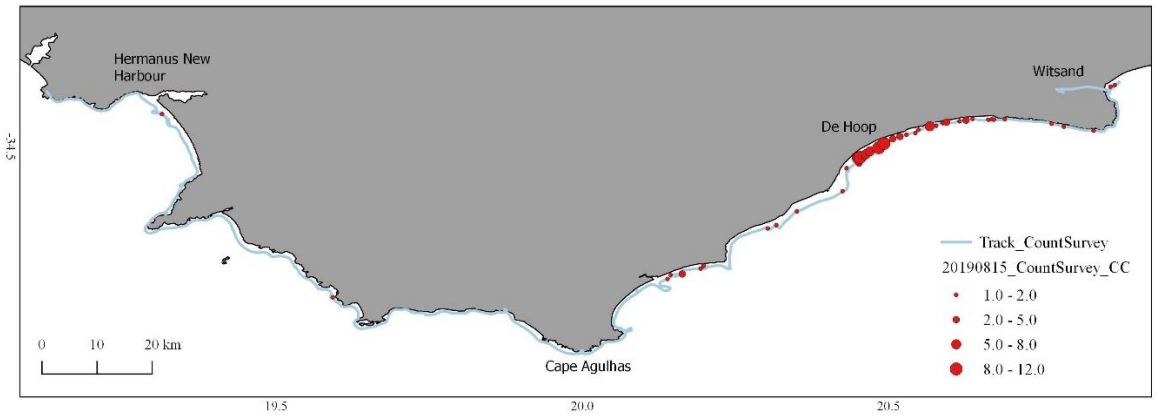

Figure 8. Map indicating the encounters of southern right whale cow-calf pairs along the stretch of coastline between Hermanus New Harbour and Witsand on 15 August 2019.

Photo-identification analysis

In total, 93 cow-calf pairs and 7 unaccompanied adults were photographed during the aerial survey. Of these, a total of 86 unique individual southern right whales could be identified (14 duplicates), including 79 females with calves. Of these identified individuals, 54 were matched to previously known individuals (of which 52 adult females and 2 previously known unaccompanied adults) whereas the other 32 were assigned as newly identified individuals. Since last year's annual aerial survey report, the photo-identification data from the 2018 annual aerial survey has been analysed. Table 4 provides a summary of both years.

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 annual aerial surveys of 2018 and 2019

	2018	2019
Number of females with calves counted	537	94
Number of females with calves identified	426	79
Number of females with calves matched to previous known females	291	52

Figure 9 shows 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).

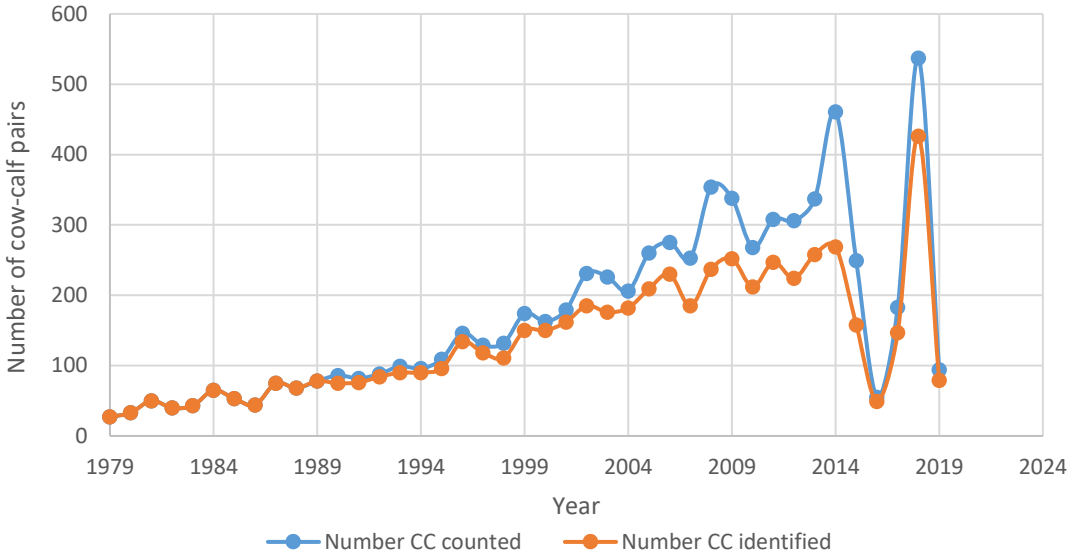

Figure 9. The number of cow-calf pairs counted and identified during the annual aerial surveys since 1979.

Subsequent to the matching process, the calving interval could be assessed for all 52 previously known females identified during the 2019 survey. Most of these females had a 6-year (21.6%) and a 5-year calving interval (19.6%), while 15.7% had a 3-year calving interval. This is slightly different from the 2018 data, which showed a large number of females calving at a 4- and 5-year calving interval (23% and 23.3% respectively) (Figure 10).

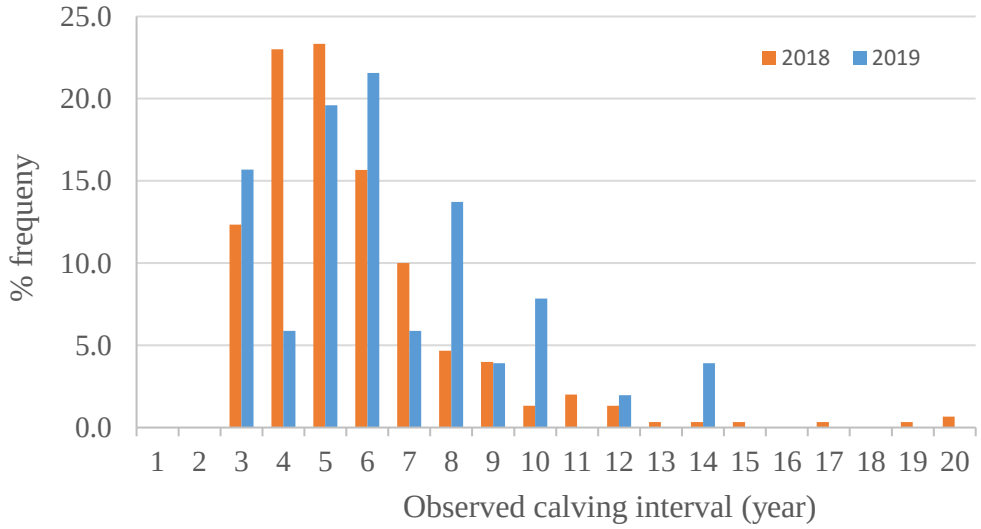

Figure 10. Last calving interval of females identified with a calf during the annual aerial surveys of 2018 and 2019

Discussion

The 2019 annual photo-identification aerial survey resulted in the second lowest count of cow-calf pairs along the southern Cape coast since 1995 (Figure 9). Although numbers were expected to be lower than the all-time peak of cow-calf pairs observed in 2018, the observed number was even lower than expected considering the recent estimated population growth rate of 6.5% (Brandão *et al.*, 2018). Also the number of unaccompanied adults continues to remain extremely low. In fact, this year's count reflects the second lowest count of unaccompanied adults ever recorded (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.

Possible shift in peak presence

Despite only one count aerial survey being conducted prior to the annual photo-identification aerial survey this year, the presence of nearly 70% more cow-calf pairs in August compared to October in the main distribution area of the southern Cape coast breeding ground suggests a shift in peak presence. These data corroborate the data collected in 2017 and 2018, which also showed an increased presence of cow-calf pairs along the coastline between Hermanus and Witsand in late August-early September as opposed to October (Figure 11).

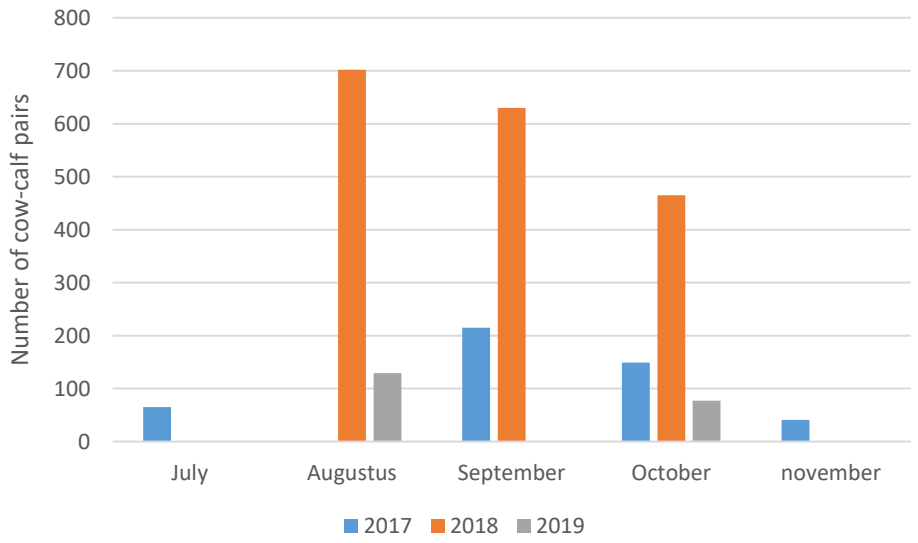

Figure 11. Number of cow-calf pairs observed during the count surveys (July, August, September and November) and annual aerial surveys (October) of 2017, 2018 and 2019 between Hermanus New Harbour and Witsand.

In addition to the aerial surveys, boat-based surveys were carried out between 3 and 15 September 2019, during which southern right whales were photo-identified using an UAV as part of a research project on body-condition. In total, 53 adult right whales were photo-identified with this method (Walker Bay: 6 cows and 6 UA; Saint Sebastian Bay; 39 cows and 2 UA). Of these, only 7 cows were re-photographed on the aerial survey, suggesting that 8 unaccompanied adults and 38

cow-calf pairs were missed during the aerial survey, or left the southern Cape coast breeding ground in the two-week time period between the boat-based surveys and the annual aerial survey. If the latter, the movement of over 1/3rd of cow-calf pairs away from the South African breeding ground in a two-week time period prior to the assumed peak in cow-calf pair presence seems substantial and warrants deeper investigation.

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. Consideration was therefore given to conduct the annual aerial survey in October being the time of peak calf presence, as most calves would have been born, yet most would not have reached the "critical size" (about 8 m, obtained approximately 2.5 to 3 months after birth) to leave on their annual migration (Best and Rüther, 1992). The apparent temporal shift in peak presence of calves from October to August, observed by the aerial count surveys, could therefore be related to earlier calving (and earlier mating, considering a 12 month gestation period), and/or to cow-calf pairs leaving the South African coast more quickly, possibly before the calf reaches its "critical size". The paucity of calf sightings earlier in the year than normal (e.g., general report of whale-watching companies to spot the first calf of 2019 only in early August; E. Vermeulen, pers. comm.), the general west-ward movement from cow-calf pairs between August and October (compare figures 5 and 8), and the apparent movement of a substantial number of identified females away from the breeding ground prior to the annual aerial survey, supports the latter hypothesis of females leaving the breeding ground sooner. However, so far, no strong conclusion can be drawn and further investigation seems crucial due to the potential consequences for the probability of calf survival and therefore population dynamics.

Shift in calving interval

Southern right whale cows generally exhibit a strong 3-year calving interval (one year each of gestation, nursing and rest). However, photo-identification analysis indicates the decreased occurrence of the normal 3-year calving interval post-2009 with a general increase of the calving interval to 4- and even 5-years (peaking in 2015 and 2017 respectively; Figure 12; Vermeulen *et al.*, 2018; Brandão *et al.*, 2018). Also, it seems noteworthy that the proportion of females captured in a 3-, 4- or 5-year interval seems to decrease over time (Figure 12), with an increased presence of even longer calving intervals, while the proportion of 2-year intervals remains largely the same over time (average = 1.4% of the re-identified females; MRIWU unpublished data). However, as calving intervals >6 years are difficult to interpret, they are not discussed.

Such an increase in calving interval inevitably leads to a reorganisation of the female calving cohorts. For example, the observed peak in calving in 2018 is believed to be the result of a combination of various calving cohorts, half of which were females that calved in a 4- or 5-year interval (i.e. previous calving in 2013 and 2014). If such a "super cohort" including roughly 40% of the parous females holds, then the 3-year "bumper cohort", which was visible in the dataset between 1979 and 2009, may become apparent again.

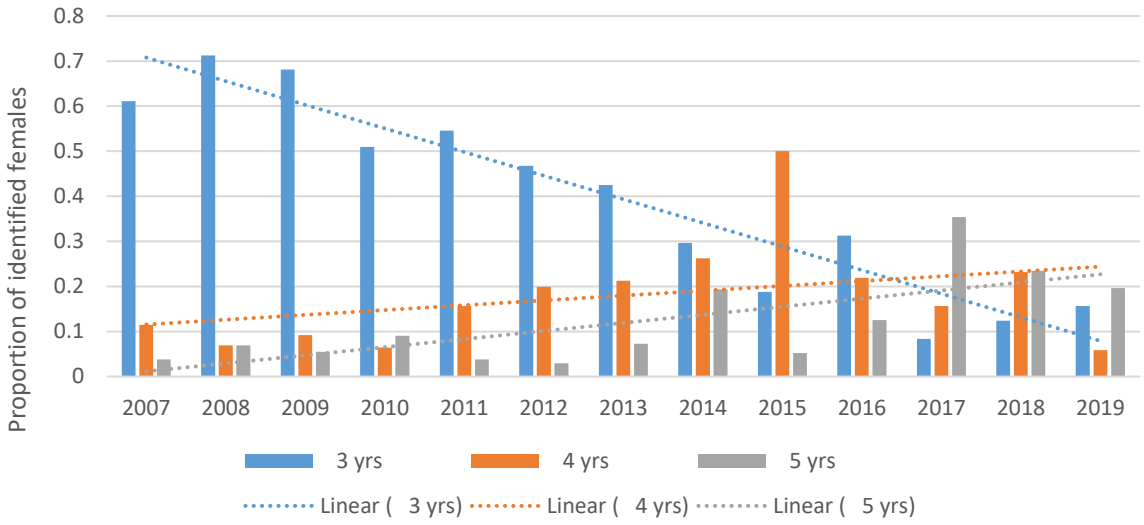

Figure 12. Observed calving interval of South African parous female southern right whales, derived from photo-identification analyses between 2007 and 2019.

Calving intervals of 4 and 5 years are interpreted as resulting from calving failure (Knowlton *et al.*, 1994). More specifically, 4-year calving intervals are believed to result from a failure to initiate gestation (i.e. the female spends an extra year resting) or foetal loss early in gestation after which the female switches to resting until the next mating season (Knowlton *et al.*, 1994). Five-year calving intervals are generally believed to be the result of foetal loss late in gestation or the loss of a newborn calf which frequently remains unobserved (i.e. a 3-year calving interval plus a 2-year interval) (Knowlton *et al.*, 1994). Such an increase in calving intervals has shown to lead to decreased population growth rates at other breeding grounds (e.g. Maron *et al.*, 2015). Within the South African population, such a slight, yet continuous decrease in population growth rate is already visible (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)).

Links between climate, prey availability and reproductive output

In general, the reproductive success of southern right whales is dependent on their body condition and therefore foraging 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). Similar results have been found for the South African population, with strong correlations between ENSO (El Niño–Southern Oscillation), sea ice extent and ocean productivity in two proposed feeding grounds, and the number of calves observed along the South African coast each year (Van den Berg *et al.*, 2019). In view of this, currently research is being conducted to assess the body condition of South Africa's southern right whales, as well as to identify the contemporary feeding grounds through stable isotope analysis of skin and baleen samples. The latter will lead to a further in-depth assessment of the possible effects of environmental variability on the productivity of these feeding grounds. It is aimed to have results available by mid-2020.

Unlike the fluctuating numbers of cow-calf pairs, numbers of unaccompanied whales remain extremely low since 2010, indicating that this component of the population does not complete their migration to the South African breeding ground, 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. According to Best (2007), mating activities observed around South Africa are more likely to involve younger females practicing mating activities. If this is the case, 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). Therefore, the lack of migration to the South African coast could be due to an insufficient amount of energy due 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. For example, Del Castillo *et al.* (2019) recently published the results of an analysis of 21 years of ocean colour data for the Southern Ocean, in which they indicate an expansion of the productive months into winter. In fact, for certain areas in the southern Atlantic Ocean, productivity peaked in winter, and not in spring. Such results clearly indicate the urgent need for an in-depth assessment of the feeding ecology of South Africa's southern right whales, and most importantly the assessment of their 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), to assess within-season movement patterns.

Considering the observed decreased calving success of the South African population of southern right whales and the strong link between foraging success and reproduction, a further in-depth assessment on the foraging ecology of this population is warranted. This includes an investigation on a possible decrease and/or spatial or temporal shift in their prey availability at higher latitudes due to environmental variability. Along these lines, it is vital to continue the assessments of their body condition, while comparing these data to other southern right whale breeding populations. In

addition to the analyses of currently available data, it is strongly recommended that satellite tagging of individuals during their winter migrations, 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.

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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. 2007. Whales and dolphins of the southern African subregion. Cambridge University Press. 29-35 pp.

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

Crespo, E. A., Pedraza, S. N., Dans, S. L., Coscarella, M. A., Svendsen, G. M. and Degrati, M. 2014. Number of southern right whales *Eubalaena australis* and population trend in the neighbourhood of Península Valdés during the period 1999-2013 by means of aerial and boat surveys. Report presented to the IWC Southern Right Whale Assessment Workshop SC/65b/BRG07.

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.

Knowlton, A.R., Kraus, S.D. and Kenney, R.D. 1994. Reproduction in North Atlantic right whales (*Eubalaena glacialis*). Can. J. Zool. 72:1297–1305.

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.

Maron, C.F., Rowntree, V.J., Sironi, M., Uhart, M., Payne, R.S., Adler, F.R. and Seger, J. 2015. Estimating population consequences of increased calf mortality in the southern right whales off Argentina. Document SC/66a/BRG/1 submitted to the Scientific Committee of the International Whaling Commission.

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.

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., 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