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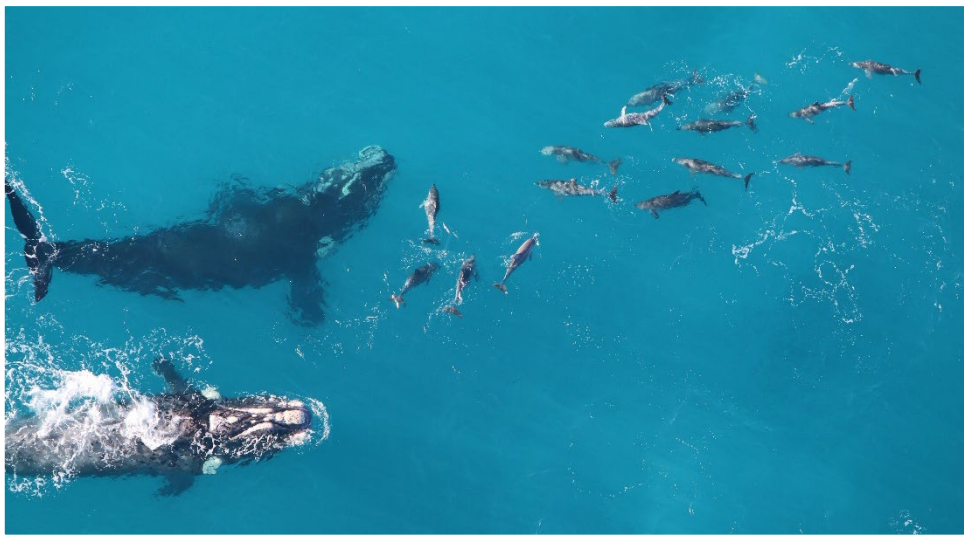
Relative abundance of the ‘western’ population of southern right whales from an aerial survey off southern Australia

Final report on 2021 survey

Joshua Smith, Mike Double
Natalie Kelly, Claire Charlton, John Bannister



Murdoch University

Western Australian Museum

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Australian Antarctic Division

Curtin University

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Please address inquiries to: Joshua Smith, joshua.smith@murdoch.edu.au

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Cover images: Two mother and calf pairs near Doubtful Islands and southern right whales near a group of dolphins in Dolphin Cove © Joshua Smith

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Executive summary

Aerial surveys of southern right whales (*Eubalaena australis*) were undertaken off the southern Australian coast to monitor the recovery of this endangered species following extreme 19th and 20th Century commercial whaling. The aerial survey was undertaken in the coastal waters from Perth (Western Australia) to Ceduna (South Australia) between the 12th and 17th August 2021, to maintain the annual series of surveys and inform the long-term population trend. Despite border restrictions due to COVID-19 during the 2021 survey, the entire survey region between Perth and Ceduna was able to be surveyed using two aerial observer teams (based in Western Australia and South Australia). The long-term trend in abundance for the 'western' population is determined using the maximum whale counts for each leg of the survey flights between Cape Leeuwin and Ceduna, and consisted of a total 643 southern right whales sighted across the survey area (270 cow-calf pairs and 103 unaccompanied whales). Using a simple multiplier, the subsequent population estimate for the Australian 'south-western' population is 2,549 whales, which represents the majority of the Australian population given the very low numbers in the 'south-eastern' subpopulation. The 'south-eastern' population is estimated to comprise 268 (CI: 146–650) breeding females (Stamation et al. 2020).

The population long-term trend data is indicating recent years (from 2007) are showing greater inter-annual variation in whale counts. Anomalous years of pronounced low whale numbers are potentially becoming more frequent, with more dynamic cyclical patterns in whale numbers. However, the non-annual breeding cycle of southern right whales makes it difficult to determine whether the anomalous years represent some form of a cycle that females are conforming to as the population recovers or whether changes to their environment are having an effect on their breeding cycle. To evaluate the recovery of the southern right whale population, it will be critical to collect long-term data on the annual variability in whale numbers related to the non-annual female breeding cycle and identify possible impacts on this by short-term climate dynamics, longer-term climate change and/or anthropogenic threats. Data on inter-annual variation in whale numbers will reliably detect changes in abundance from one year to the next, and over longer time periods. Considerable inter-annual variation in whale numbers does make it difficult to predict patterns in population trends and supports continued annual surveys of the population. Therefore, if continued annually, this study will be better able to identify immediate threats to this population of Endangered whales.

1. Introduction

Southern right whales (*Eubalaena australis*) were hunted almost to extinction (to a few hundred animals) throughout the southern hemisphere during the 19th and 20th centuries, including off Australia. Currently, southern right whales are listed as 'Endangered' under the Australian EPBC Act, following unsustainable whaling. Since the mid-1970s, and following the cessation of whaling on the species, there have been signs of recovery for part of the population that migrates to the southern Australian coast each year. This recovery has been particularly evident for waters off Western Australia (WA) and western South Australia (SA), referred to as the 'western population'.

Since 1976, aerial surveys have been undertaken annually along the south-western coast of Australia to determine numbers and population trend, life history information, and obtain individual identification photographs of whales aggregating close inshore during calving and nursing. Initially, these surveys were undertaken along the WA south coast from Cape Leeuwin east to Twilight Cove and then were extended from 1993 into SA waters to Ceduna, given evidence of whale presence in key aggregations in South Australia and intra- and inter-season coastal movement. The series of surveys from 1993 were designed to provide statistically significant information on population size and trend over a fifteen-year period (to include five three-year breeding cycles; i.e. to 2007 inclusive). An anomalously low count, particularly of breeding females, in 2007 led to subsequent surveys in 2008–2010 and have been continued to date. Collection of these data is a 'high priority' in the Australian EPBC Act Recovery Plan (Conservation Management Plan) to assess the current status of this Threatened Species and assess the effectiveness of federal and state management approaches that aim to facilitate this species' recovery.

In the south-east of the southern Australian coast there has been little sign of recovery in southern right whale numbers (Stamation et al. 2020); a working hypothesis assumes separation between two populations – 'south-western' and 'south-eastern'. Given the relative paucity of animals that visit the remainder of the southern Australian coast, the 'south-western' population is considered to represent the majority of the 'Australian' population. The count data from these aerial surveys provide estimates of population size and trend for the 'western' population, and hence majority of the Australian southern right whales, and the associated photo-identification data provides life history information (e.g. calving intervals) and connectivity between the 'western' and 'eastern' population and life history information (e.g. calving intervals).

2. Methods

Aerial surveys of southern right whales were undertaken following established protocols from previous surveys since 1993, using a high wing, single engine aircraft (Cessna 172 and Cessna 182) crewed by a pilot/observer, photographer/observer and data scribe along the southern coast of Australia between Perth (Western Australia) and Ceduna (South Australia) (Fig. 1). For the 2021 aerial survey, COVID-19 border and quarantine restrictions between Western Australia and South Australia resulted in two teams (Murdoch and Curtin University) undertaking the aerial surveys to cover the full survey area. The Murdoch Uni. team undertook the aerial survey between Perth (W.A.) and Head of the Bight (HOB) (S.A.) and the Curtin Uni. team undertook the aerial survey between Head of the Bight to Ceduna (S.A.). The survey was undertaken during August when peak whale abundance is expected along the southern coastline given the known calving period. Flights are only conducted on days when wind speeds are less than 15 knots within *ca* one nautical mile of the coast, given the highly coastal distribution of southern right whales. Flights were undertaken at a survey altitude of 304 m. and photographs of the individual markings of the whales were taken at 152 m.

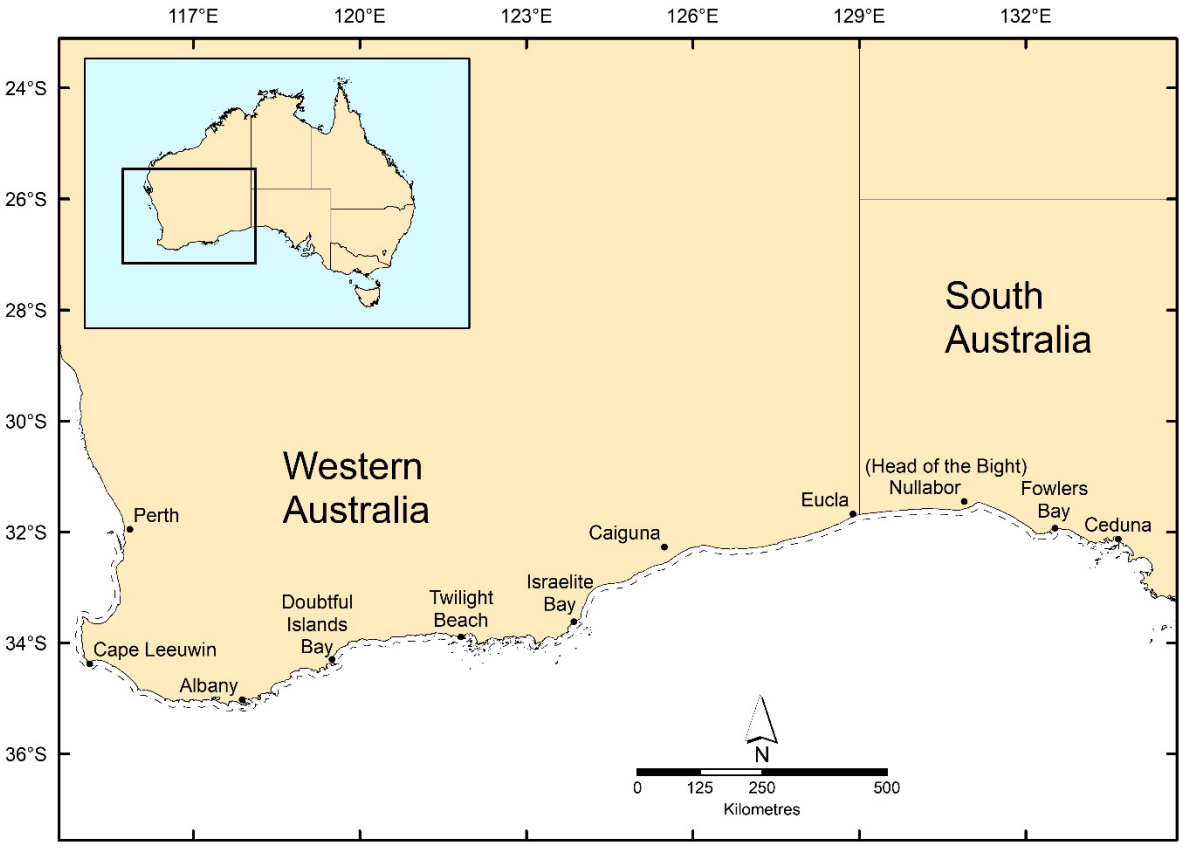

Figure 1. Approximate survey area for southern right whales off the southern coast of Australia in 2021, Perth to Ceduna. Dashed line represents the approximate offshore survey area boundary.

During the survey, direct counts were obtained of animals observed within the search area. Most animals, particularly cows accompanied by calves, are easily observed in the relatively clear waters on the south coast and no corrections are made for the detection probability of a sighting (g(0)), which is assumed to be 1. When whales are sighted, a GPS position is recorded, a direct count of the number of whales is made, and individuals are circled for photography with an emphasis on cows with calves. For individual identification, clear aerial photographic images of the head callosity pattern and/or other identifying characteristics are required. Photo-identification images were obtained with a Canon EOS 70D and were geotagged using a Canon GP-E2 GPS receiver.

Each annual survey involves multiple ‘legs’ along the coast that can occur on the same day or spread across several days, depending on the weather. Each ‘leg’ is generally covered twice, once ‘outwards’ from Cape Leeuwin to Ceduna and once ‘inwards’ on the return flights. The maximum count on either the ‘outward’ or ‘inward’ flight on each ‘leg’ are then used to obtain estimates of both population trend and current population size, which is consistent and comparable to previous years since 1993. Given the relative paucity of animals that visit the remainder of the southern Australian coast, the ‘south-western’ population recorded between Cape Leeuwin and Ceduna is considered to represent the majority of the ‘Australian’ population.

A population trend analysis is undertaken using an exponential regression (i.e. a linear regression of the natural log of the count on year) of the maximum count data for ‘all animals’ and ‘cow/calf’ pairs (Table 2) from aerial surveys flown between Cape Leeuwin (WA) and Ceduna (SA) since 1993. It excludes data for two years (1996 and 1997), due to potential bias in the data as a result of possible undercounting of whales during those years (Bannister 1998, 2002) due to adverse weather and sighting conditions.

The total population size estimate for the ‘western’ population is currently obtained using a simple model adopted at the 2011 International Right Whale Workshop (IWC, 2013) based on the numbers of cow/calf pairs (i.e. mature females) sighted, multiplied by a single applied conversion factor. The conversion factor is based largely on evidence from increasing populations off Argentina and South Africa, whereby the cow/calf count over three years (to allow for a 3-year calving interval) is multiplied by a factor of 3.94. Given the multiplication factor is based on a 3-year average of counts, it can be influenced by consecutive annual low/high whale counts.

Photographs of individuals identified from their head callosity pattern are manually reviewed for quality and images where the callosity patterns are unobstructed from water-wash over the head and where the callosity patterns are clearly discernible are submitted to the Australasian Right Whale Photo-Identification Catalogue (ARWPIC). This is an online platform supported by the Australian Antarctic Division and developed to manage and share images and sighting information of Australia’s southern right whales.

3. Results

3.1 Aerial survey

An aerial survey of the 'western' population of Australian southern right whales was undertaken between Perth (WA) and Ceduna (SA) over six days in total, from the 12th to 17th August 2021 for a combined 37.9 flying hours (35.2 hrs W.A. and 2.7 hrs S.A.). On the 14th August, the Curtin University team conducted the aerial survey leg between the Head of the Bight (Nullabor) to Ceduna, although the return trip was not undertaken. During the entire survey, a total 1084 sightings of southern right whales were recorded consisting of 456 calves of the year, which incorporates double counts of individual whales given the majority of the survey area was surveyed twice (Albany - HOB, return HOB - Albany). There were an additional twelve groups of humpback whales, totalling 15 individuals and consisting a mother with newly born calf (Appendix A and B). The maximum whale counts of each leg ('outwards' or 'inwards') between Cape Leeuwin and Ceduna are used to determine population size and trend for the 'western' population, and consisted of a total 643 southern right whales sighted across the survey area, of which there were 270 cow-calf pairs and 103 unaccompanied whales (Appendix C).

Sightings of southern right whales during the 2021 aerial survey were consistent with the distribution and areas sighted of whales in previous years, for both cow/calf pairs and unaccompanied animals (Fig. 2). Specifically, there were higher numbers of population classes in four main areas; Albany east to Doubtful Island Bay, Israelite Bay to Point Culver, Twilight Cove and at the HOB in South Australia (Fig. 2). From 7535 images obtained on the 2021 flight, preliminary analysis has identified 356 images of individual whales selected to conduct computer-assisted 'matching' with those images already available in the ARWPIC catalogue.

3.2 Population size

There were an overall greater number of whales sighted in 2021 compared to the previous year, highlighting the irregular and evidently lower number of whales sighted on the Australian coast in 2020 (Appendix C). The total number of whales (N = 643) was largely due to the comparatively higher numbers of cow calf pairs sighted (N = 270), similar to previous years in 2017 and 2018. It was evident there was a low number of unaccompanied whales sighted in 2021, similar to 2020, which had an effect on the overall number of sightings. This was the lowest number of unaccompanied animals sighted since 2003 (excluding 2020) and is similar to numbers observed in 1994 (Appendix C). It is evident there is significant inter-annual variation in the numbers of whales sighted as a result of the non-annual breeding female cycle of typically 3 year cycles (Fig. 3a). Recent years (from 2007) are showing greater inter-annual variation in whale counts and anomalous years of pronounced low whale numbers are becoming more frequent (Fig. 3).

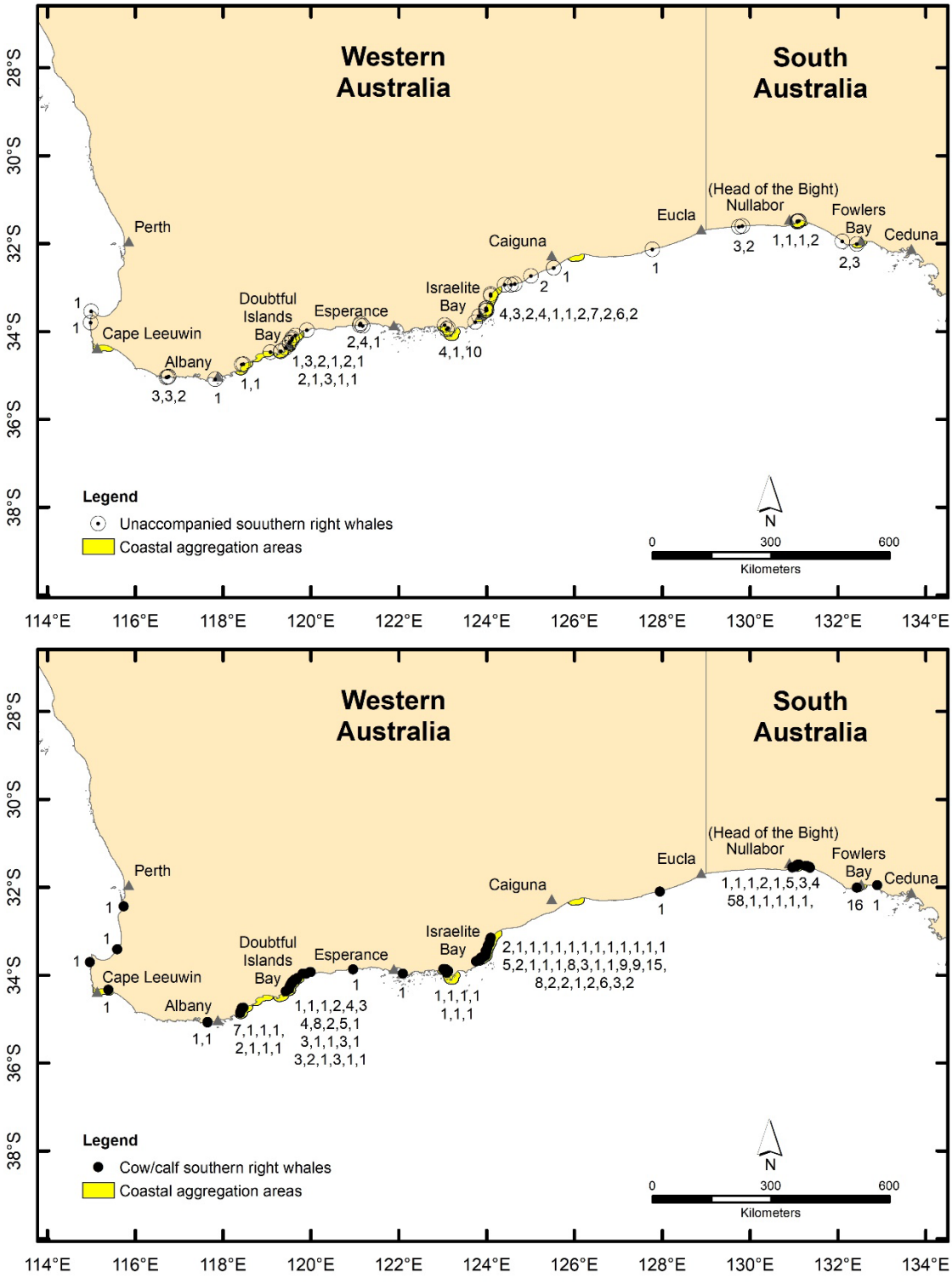

Figure 2 Survey area covered during the aerial survey undertaken in August 2021 for southern right whales. Map shows approximate positions of right whale sightings and their associated group sizes for **a)** cow / calf pairs and **b)** unaccompanied animals

Figure 3. Graph of the relative abundance of the 'western' population of southern right whales for (a) all animals, unaccompanied animals and cow/calf pairs, between 1993 and 2021 and (b) unaccompanied animals and cow/calf pairs between 2007 and 2021

Current population sizes of southern right whales are estimated using the cow/calf count over three years (to allow for the 3-year periodicity in calving), multiplied by a factor of 3.94. For the Australian 'western' population, this results in a current population size (i.e. for the three-year rolling average period, 2019 to 2021) of 2,549 whales, which is similar to the 2018–2020 estimate of 2,585 whales. The implications for future population estimates over the next two years is that they will still be influenced by the low whale count in 2020, as demonstrated in previous years of low whale counts (e.g. 2015, Table 2). Figure 4 shows the increasing trend in the size of the 'western' population and also demonstrates the influence that increased inter-annual variation in whale counts has on the population estimates.

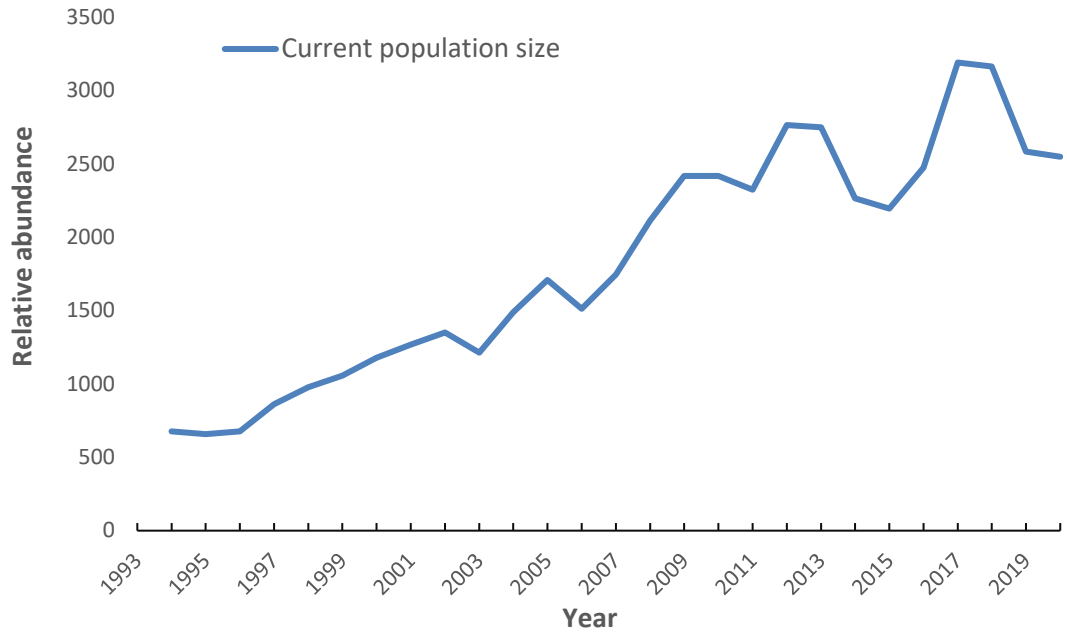

Figure 4 Current population size and population trend for the 'western' population of southern right whales

3.3 Trend analysis

An exponential regression analysis of the count data for 'all animals' between 1993 and 2021 (excluding 1996/97) provides an exponential rate of increase of 0.042 (95% CI 0.028, 0.056), which is equivalent to an annual increase of 4.3% (95% CI 2.83, 5.80) (Table 1, Appendix D). The estimated exponential rate of increase based on counts of only cow/calf pairs was 0.0526 (95% CI 0.035, 0.069) or an annual increase of 5.4% (95% CI 3.6, 7.2) (Table 2, Appendix E). The trend in the rate of population increase from the 2021 aerial survey is comparable to the trend data in 2020 (Table 1 and 2).

It is evident that there is considerable inter-annual variation in unaccompanied animals and cow/calf pairs. The variation in cow/calf pairs is related to their breeding cycle (typically a 3-year cycle) and environmental factors might possibly influence that (Fig. 3), whereas the factors that influence variation in whale numbers on the southern Australian coast for unaccompanied animals is less clear. Using the same regression analysis approach for a subset of the data between the years 2000 to 2020, there is evidence of a less significant increase in population abundance over time (Table 2). When more recent data between the years 2007 to 2020 is examined, this relationship is not statistically significant (Table 2).

Table 1. Best fit regressions for maximum counts of whales in each leg of the southern right whale aerial survey for years between 1993–2021 (excl. 1996 & 97)

Period	**1993 - 2021**		**1993 - 2021**	
Class	All animals	Cow/calf pairs	All animals	Cow/calf pairs
Exponential increase	0.0421	0.0526	0.0440	0.0531
SE	0.0069	0.0084	0.0073	0.0090
95% CI (Lower – Upper)	0.028 – 0.056	0.035 – 0.069	0.029 – 0.059	0.034 – 0.072
p-value	< 0.001	< 0.001	< 0.001	< 0.001
R^2	0.60	0.61	0.60	0.59
Percentage annual increase	**4.3**	**5.4**	**4.5**	**5.5**
SE	0.69	0.84	0.74	0.90
95% CI (Lower – Upper)	2.83 – 5.80	3.60 – 7.23	2.93 – 6.09	3.51 – 7.43

Table 2. Best fit regressions for maximum counts of whales in each leg of the southern right whale aerial survey for years between 2000–2021 and 2007–2021 (excl. 1996 & 97)

Period	**2000 - 2021**		**2007 - 2021**	
Class	All animals	Cow/calf pairs	All animals	Cow/calf pairs
Exponential increase	0.0323	0.0454	0.0078	0.0381
SE	0.0101	0.0127	0.0180	0.0260
95% CI (Lower – Upper)	0.011 – 0.053	0.019 – 0.072	-0.031 – 0.047	-0.018 – 0.094
p-value	< 0.01	< 0.01	0.673	0.168
R^2	0.34	0.39	0.01	0.14
Percentage annual increase	**3.3**	**4.6**	**0.8**	**3.7**
SE	1.01	1.28	1.82	2.64
95% CI (Lower – Upper)	1.13 – 5.48	1.90 – 7.45	-3.07 – 4.79	-1.80 – 9.89

4. Conclusions

There were an overall greater number of whales sighted in 2021 (N = 643) compared to the previous year (N= 384), highlighting the irregular and evidently lower number of whales sighted on the Australian coast in 2020. However, there were differences in the patterns of unaccompanied animals and cow calf pairs sighted. The overall number of whales was largely influenced by the comparatively higher numbers of cow calf pairs sighted, whereas it was evident there was a low number of unaccompanied whales sighted in 2021, similar to 2020. Although the cow calf pairs counts were high compared to previous years, they were not higher than previous peaks in cow-calf numbers in 2017 and 2018. The 2021 survey recorded the lowest number of unaccompanied animals sighted since 2003 (excluding 2020) and is similar to numbers observed in 1994 (Appendix C). For the Australian 'south-western' population, the estimated current population size (i.e. for the three-year rolling average period, 2019 to 2021) based on cow-calf pairs is 2,549 whales, which is similar to the 2020 estimate of 2,585 whales. There is an increasing trend in the size of the 'south-western' population, although it is also evident that the increased inter-annual variation in whale counts is also influencing the population estimates. The implications for future population estimates over the next two years is that they will still be influenced by the low whale count in 2020, as demonstrated in previous years of low whale counts (e.g. 2015, Table 2). This results in a population estimate that is biased downwards (i.e. negatively biased) due to the low whale count as part of the three-year average and not necessarily due to real declines in population numbers.

The range in population estimates in recent years (from 2007) have become more pronounced as the inter-annual variation in whale counts increases. The population long-term trend data is indicating recent years are showing greater inter-annual variation in whale counts and anomalous years of pronounced low whale numbers are becoming more frequent. It is possible the typical 3-year breeding cycle of females may be becoming more unpredictable, possibly as a result of environmental effects such as changes in sea surface temperatures related to El Nino events having an effect on pregnancy rates (Leaper et al 2006). Fluctuations in breeding cycles were reported for breeding females at Head of Bight using long term life history data, and the mean observed calving interval increased from 3 years to four years between 2015 and 2021 (Charlton et al. 2021 & 2022). However, the non-annual breeding cycle of southern right whales makes it difficult to determine whether the anomalous years represent some form of a cycle that females are conforming to as the population recovers or whether changes to their environment are having an effect on their breeding cycle.

To evaluate the recovery of the southern right whale population, it will be critical to understand annual variability in whale numbers related to the non-annual female breeding cycle and identify possible impacts on this by short-term climate dynamics, longer-term climate change and/or anthropogenic threats. A series of lower than expected counts in the long-term data may provide evidence of a slowing population growth rate, although continued annual population surveys will be the only way to determine this. Considerable inter-annual variation in whale numbers makes it difficult to detect consistent and reliable changes in abundance from one year to the next, and over longer time periods. This severely inhibits our ability to identify immediate threats to the population and strongly supports continued annual

surveys of the population. To inform national and international species recovery assessments using life history data, efficient processing of photo identification data is crucial and improved machine learning artificial intelligence software and resources for data curation is needed to tackle the issue of data curation for large datasets such as these.

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Appendix A

A mother and (relatively) newborn calf photographed near Gracetown (Margaret River) in South-West Western Australia on 17th August, 2021.

Appendix B

Flight	Date	Leg	Whale sightings								Weather[1]	Flying hrs
			Right whales				Other large whales[2]					
			A[3]	C	Y	T	A	C	Y	T		
Outward legs Albany to Ceduna	12-08-21	1. Albany-Esperance	86	70	0	156	1	0	0	1	280/13	5.1
	13-08-21	2. Esperance-Caiguna	129	90	0	219	0	0	0	0	350/12	5.7
	14-08-21	3. Caiguna-Nullarbor * (excl. Head of Bight)	16	6	0	22	1	0	0	1	00/10-12	6.0
	14-08-21	4. Nullarbor-Ceduna * (incl Head of Bight)	108	92	0	200	0	0	0	0	ENE/8-10	2.7
Total Outward		**1-3 Albany-Ceduna**	**339**	**258**	**0**	**597**	**2**	**0**	**0**	**2**		**19.5**
Inward legs Ceduna to Albany	N/A	Ceduna-Nullarbor (incl. Head of Bight)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	14-08-21	5. Nullarbor-Caiguna (excl. Head of Bight)	5	2	0	7	0	0	0	0	00/10	2.4
	15-08-21	6. Caiguna-Esperance *	156	104	0	260	2	0	0	2	Calm	5.1
	16-08-21	7. Esperance-Albany *	93	68	1	162	0	0	0	0	360/8	5.0
Total Inward		**3-5 Ceduna-Albany**	**254**	**174**	**1**	**429**	**2**	**0**	**0**	**2**		**12.5**
Additional leg	17-08-21	8. Albany-Perth	17	6	0	23	10	1	0	11	300/18	5.4
Total	**6 days**	**8 legs**	**610**	**438**	**1**	**1049**	**14**	**1**	**0**	**15**		**37.9**

[1] direction of wind/wind speed (knots)
[2] all humpback whales; no other large whales recorded
[3] A = adult, C = calf, Y = 'yearling', T = total
* survey legs with maximum numbers of whales used for mapping and calculating trend (i.e. in Table 2)

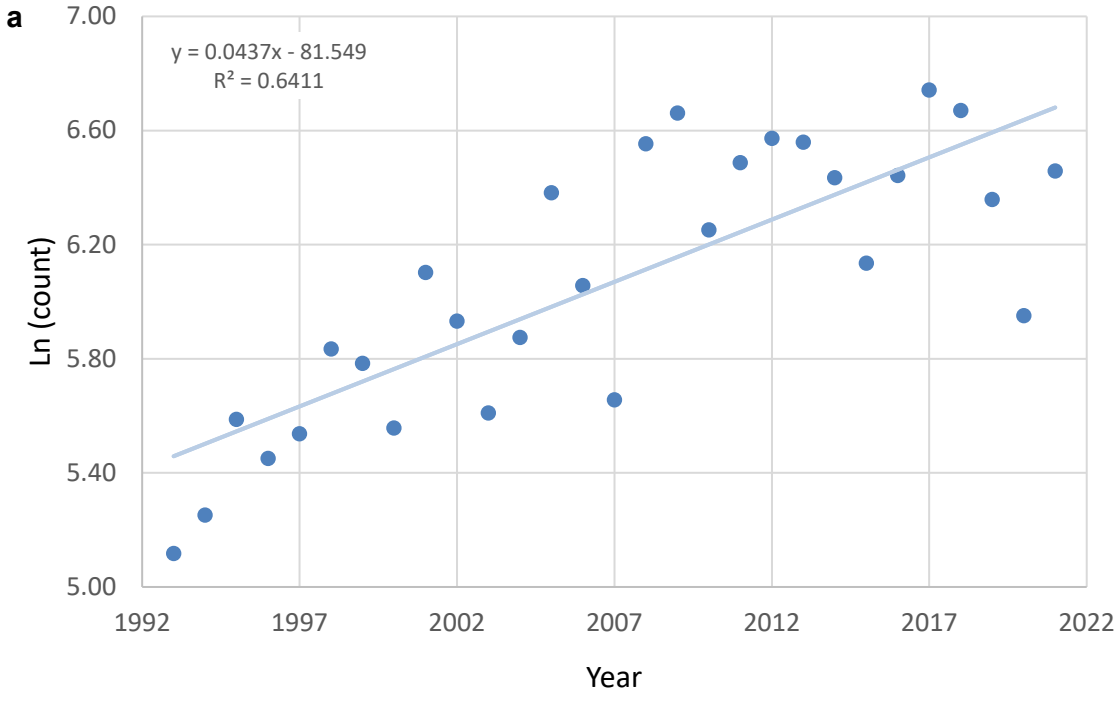
Appendix C

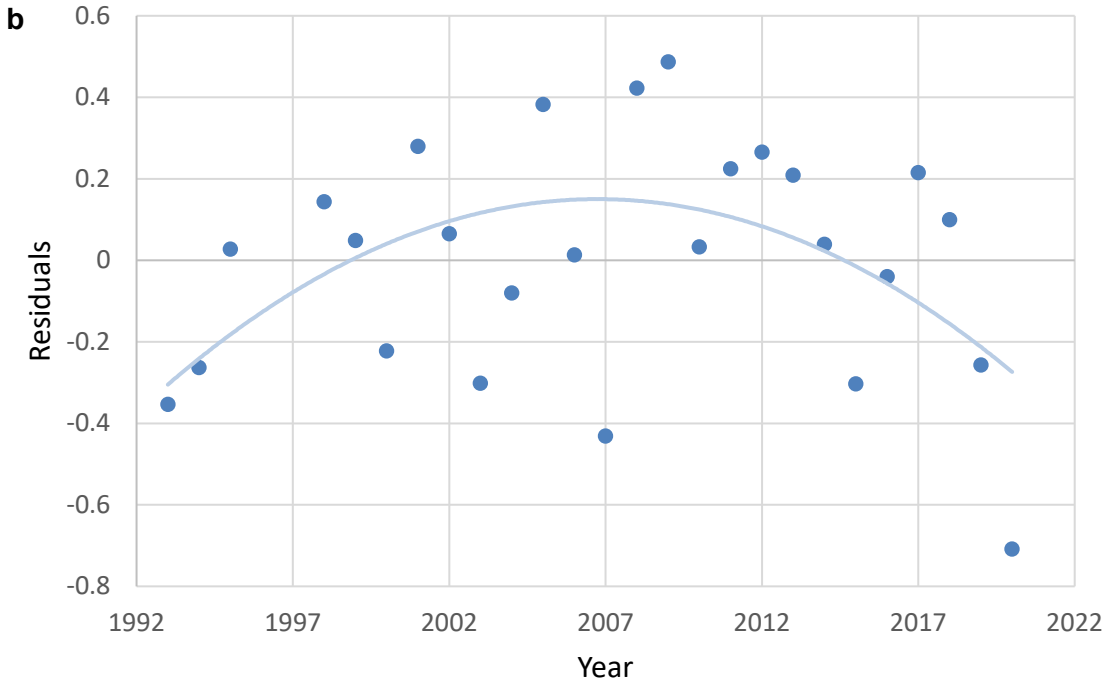
Total comparable maximum counts of southern right whales from annual aerial surveys since 1993 between Cape Leeuwin (W.A.) to Ceduna (S.A.).

Year	All animals	Unaccompanied animals	Cow/calf pairs
1993	167	47	60
1994	191	95	48
1995	267	139	64
1996	233	123	55
1997	254	148	53
1998	342	120	111
1999	325	157	84
2000	259	113	73
2001	447	163	142
2002	377	163	107
2003	273	85	94
2004	356	142	107
2005	591	237	177
2006	427	127	150
2007	286	172	57
2008	702	230	236
2009	782	294	244
2010	519	251	134
2011	657	185	236
2012	715	275	220
2013	706	214	246
2014	623	159	232
2015	462	268	97
2016	628	172	228
2017	847	241	303
2018	789	231	279
2019	577	135	221
2020	384	72	156
2021	638	98	270

Appendix D

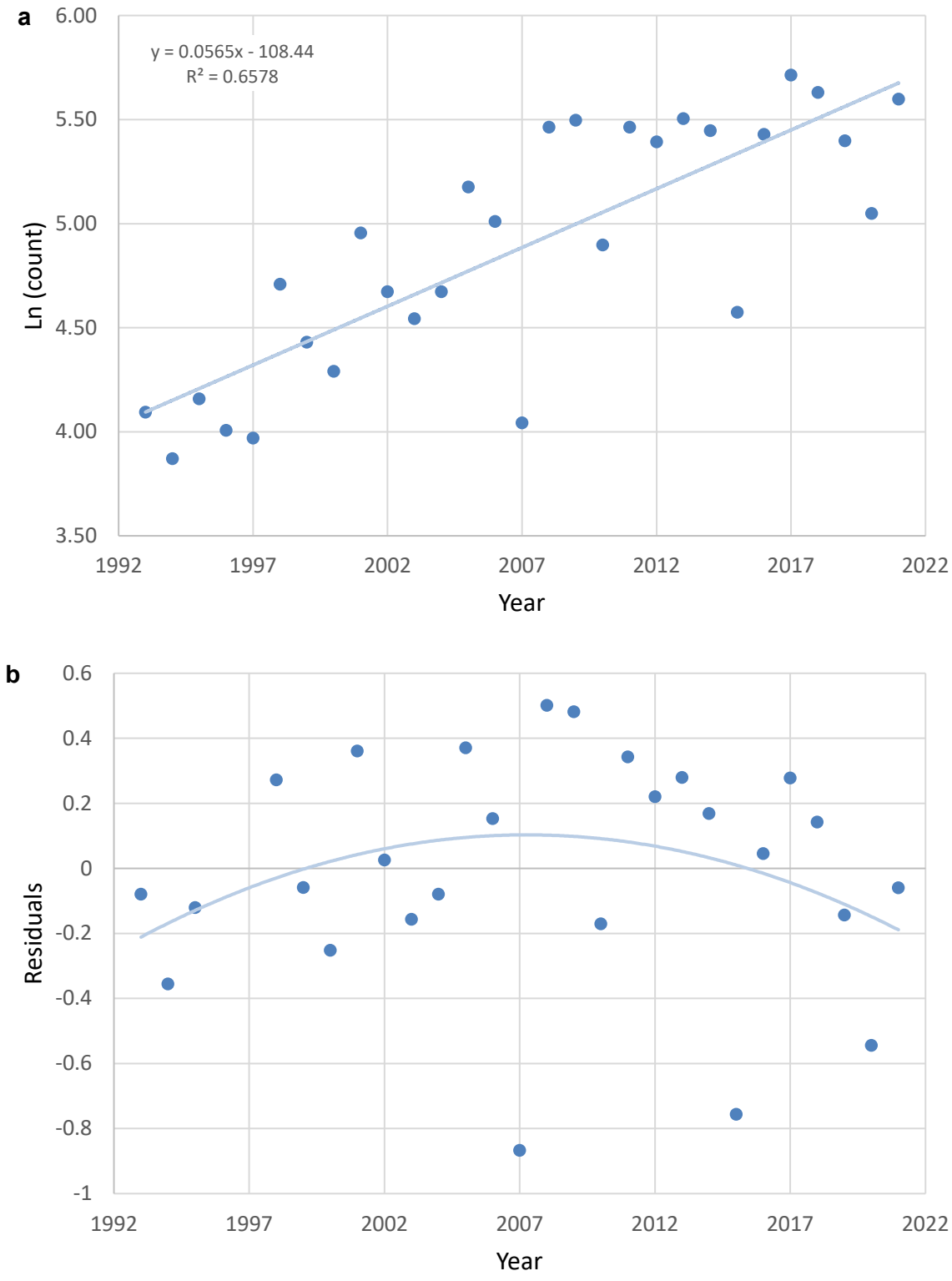
Plots of the fitted (a) linear regression and (b) residuals for the maximum counts of whales in each leg for 1993–2021 (excluding 1996 / 1997) for *All animals*.





Appendix E

Plots of the fitted (a) linear regression and (b) residuals for the maximum counts of whales in each leg for 1993–2021 (excluding 1996 / 1997) for *Cow / calf pairs*.



CONTACT

Name: Joshua Smith

Email: Joshua.smith@murdoch.edu.au

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